

# HWA CHONG INSTITUTION



## C1 PROMOTIONAL EXAMINATION

### H2 CHEMISTRY 9647

#### Paper 1: Multiple Choice

7 October 2009

45 minutes

### READ THESE INSTRUCTIONS FIRST

Complete the information on the optical mark sheet (OMS) as shown below.

1. Enter your NAME ( as in NRIC ). \_\_\_\_\_

Write your **name**

2. Enter the SUBJECT TITLE. \_\_\_\_\_

3. Enter the PAPER NUMBER. \_\_\_\_\_

4. Enter your CT GROUP. \_\_\_\_\_

Write your **CT group**

5. Date. \_\_\_\_\_

6. Enter your NRIC NUMBER or  
FIN NUMBER.

7. Now SHADE the corresponding  
lozenge in the grid for  
EACH DIGIT or LETTER

NRIC / FIN											
S	0	0	0	0	0	0	0	0	A	K	U
F	1	1	1	1	1	1	1	1	B	L	V
G	2	2	2	2	2	2	2	2	C	M	W
T	3	3	3	3	3	3	3	3	D	N	X
	4	4	4	4	4	4	4	4	E	O	Y
	5	5	5	5	5	5	5	5	F	P	Z
	6	6	6	6	6	6	6	6	G	Q	
	7	7	7	7	7	7	7	7	H	R	
	8	8	8	8	8	8	8	8	I	S	
	9	9	9	9	9	9	9	9	J	T	

Write and **shade**  
your **NRIC**  
or **FIN** number.

There are **30** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** or **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

After the examination, you are required to submit only the OMS.

Each correct answer will score one mark. Marks will not be deducted for wrong answers.

You should have a *Data Booklet*.

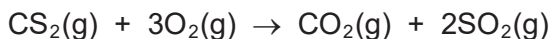
You may use a calculator.

Any rough working should be done in this booklet.

## Section A

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

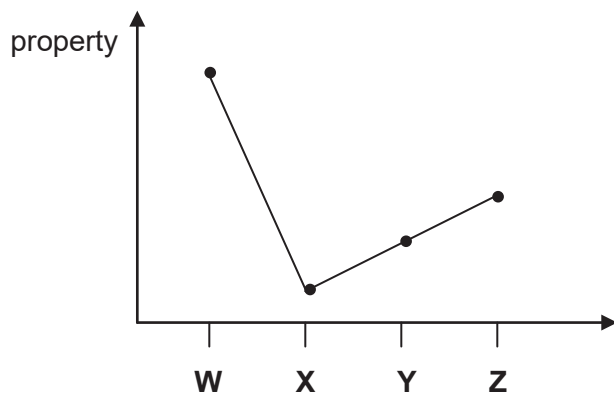
- 1 Carbon disulfide,  $\text{CS}_2$ , is a volatile flammable liquid used in the manufacture of cellophane. On combustion,  $\text{CS}_2$  is oxidised as follows:



A  $20 \text{ cm}^3$  sample of carbon disulfide vapour is ignited with  $100 \text{ cm}^3$  of oxygen. The resultant gas mixture is treated with excess aqueous alkali.

What percentage (by volume) of the gas mixture is absorbed by the alkali?

- A** 40%                      **B** 60%                      **C** 80%                      **D** 100%
- 2 The metallic ion  $\text{X}^{n+}$  is oxidised to  $\text{XO}_3^-$  by  $\text{MnO}_4^-$  ion in an acidic solution. If  $1.93 \times 10^{-3}$  moles of  $\text{X}^{n+}$  require  $1.16 \times 10^{-3}$  moles of  $\text{MnO}_4^-$  for oxidation, what is the value of  $n$ ?
- A** 1                      **B** 2                      **C** 3                      **D** 4
- 3 Which of the following species has **neither** a half-filled **nor** a fully-filled p subshell?
- A** Be                      **B** P                      **C**  $\text{S}^{2-}$                       **D**  $\text{Ca}^{2+}$
- 4 Which of the following combinations of property and identities of **W** to **Z** gives the shape of the graph shown below?



	<u>property</u>	<u>W</u>	<u>X</u>	<u>Y</u>	<u>Z</u>
<b>A</b>	boiling point	HF	HCl	HBr	HI
<b>B</b>	melting point	Na	Mg	Al	Si
<b>C</b>	ionic radius	$\text{F}^-$	$\text{Na}^+$	$\text{Mg}^{2+}$	$\text{Al}^{3+}$
<b>D</b>	first ionisation energy	Al	Si	P	S

- 5 Which of the following statements about the properties associated with ionic and covalent compounds is correct?
- A The only covalent compounds with high melting points are those in which hydrogen bonding occurs.
  - B Any compound that contains both hydrogen and oxygen atoms in its molecule can form hydrogen bonds.
  - C Ionic bonds and covalent bonds cannot both occur in the same compound.
  - D Ionic compounds differ from metals in that ionic compounds do not conduct electricity in the solid state.

- 6 In microwave ovens, the wave energy produced is absorbed by certain polar molecules.

Which of the following would **not** absorb microwave energy?

- A  $\text{CCl}_4$                       B  $\text{CH}_2\text{F}_2$                       C  $\text{PCl}_3$                       D  $\text{CH}_3\text{CH}_2\text{OH}$

- 7 An ideal gas obeys the general gas equation  $pV = nRT$ .

Which of the following statements is correct?

- A The density of an ideal gas is directly proportional to its temperature at constant pressure.
- B The volume of a given mass of an ideal gas is doubled if its temperature is raised from  $20^\circ\text{C}$  to  $40^\circ\text{C}$  at constant pressure.
- C The relative molecular mass of an ideal gas can be estimated by  $M_r = \frac{mRT}{pV}$  where  $m$  is the mass of the gas.
- D For a given mass of an ideal gas, the pressure is directly proportional to its volume at constant temperature.

- 8 For which one of the following equations does the enthalpy change represent the average bond enthalpy of the  $\text{P}-\text{Cl}$  bond in  $\text{PCl}_5$ ?

- A  $\text{PCl}_5(\text{s}) \rightarrow \text{P}(\text{s}) + 5\text{Cl}(\text{g})$                       B  $\text{PCl}_5(\text{g}) \rightarrow \text{PCl}_4(\text{g}) + \text{Cl}(\text{g})$
- C  $\frac{1}{5}\text{PCl}_5(\text{g}) \rightarrow \frac{1}{5}\text{P}(\text{g}) + \text{Cl}(\text{g})$                       D  $\frac{1}{5}\text{PCl}_5(\text{s}) \rightarrow \frac{1}{5}\text{P}(\text{g}) + \text{Cl}(\text{g})$

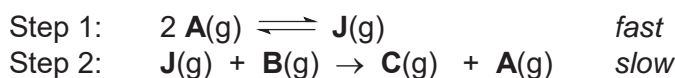
- 9 For which of the following processes is the entropy change positive?

- A Dimerisation of ethanoic acid
- B Mixing  $\text{AgNO}_3(\text{aq})$  and  $\text{NaCl}(\text{aq})$
- C Sublimation of iodine
- D Compression of gas volume at constant pressure

- 10** Consider the reaction between gaseous compounds **A** and **B** to form **C**:



The mechanism for the reaction was found to be as follow:



Which of the following is the correct rate equation?

- A** Rate =  $k[A]^2$                       **B** Rate =  $k[A]^2[B]$   
**C** Rate =  $k[A][B]$                       **D** Rate =  $k[J][B]$

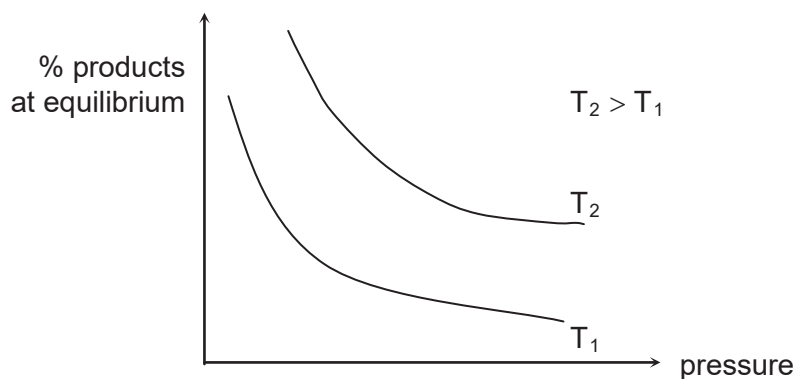
- 11** The decomposition of hydrogen peroxide is a first order reaction with respect to hydrogen peroxide. The rate equation is

$$\text{rate} = k[\text{H}_2\text{O}_2] \quad \text{where } k = 0.0495 \text{ min}^{-1}$$

Which of the following statements is **not** correct?

- A** The half life of decomposition of hydrogen peroxide is 14 min.
- B** Graph of rate against concentration of hydrogen peroxide is linear.
- C** Doubling the concentration of hydrogen peroxide will double the rate of decomposition.
- D** Doubling the concentration of hydrogen peroxide will reduce the half life by a factor of 2.

- 12** The graphs below show the variation of the percentage of gaseous products present at equilibrium with temperature and pressure.

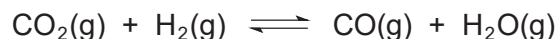


Which of the following systems could the graphs represent?

- |          |   |  |
|----------|---|--|
| <b>A</b> | $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$                                     | $\Delta H = +181 \text{ kJ mol}^{-1}$  |
| <b>B</b> | $2\text{SO}_3(\text{g}) \rightleftharpoons 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$                                 | $\Delta H = +380 \text{ kJ mol}^{-1}$  |
| <b>C</b> | $2\text{CO}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{C}(\text{s})$                                      | $\Delta H = -173 \text{ kJ mol}^{-1}$  |
| <b>D</b> | $4\text{NH}_3(\text{g}) + 3\text{O}_2(\text{g}) \rightleftharpoons 2\text{N}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$ | $\Delta H = -1267 \text{ kJ mol}^{-1}$ |



- 13 The equilibrium constant  $K_p$  for the following reaction is 0.726 at 1000 °C.

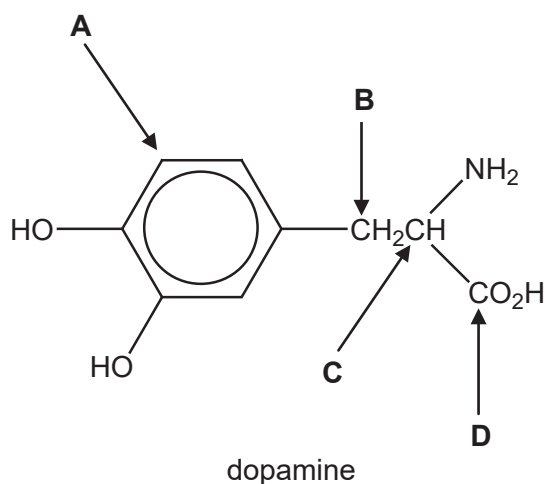


Which of the following gives the composition of the equilibrium mixture (in mol) when 0.50 mol of  $\text{CO}_2$  and 0.50 mol of  $\text{H}_2$  are mixed at 1 atm and 1000 °C?

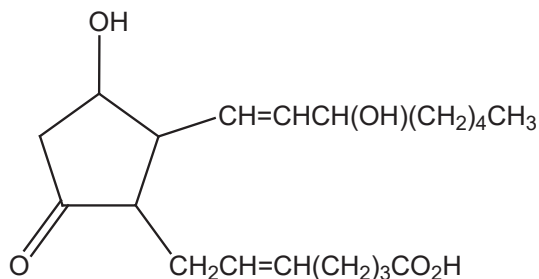
	<u><math>\text{CO}_2</math></u>	<u><math>\text{H}_2</math></u>	<u><math>\text{CO}</math></u>	<u><math>\text{H}_2\text{O}</math></u>
A	0.23	0.23	0.27	0.27
B	0.25	0.25	0.25	0.25
C	0.27	0.27	0.23	0.23
D	0.30	0.30	0.20	0.20

- 14 Dopamine is a neuro transmitter. Its absence from the human brain might lead to Parkinson's disease.

Which carbon atom in the molecule will be readily attacked by an electrophile?



- 15 The prostaglandins are a group of  $\text{C}_{20}$  carboxylic acid molecules containing a five-membered ring with two long side chains each. They have an extraordinarily wide range of biological effects. The structure of a prostaglandin is shown below.

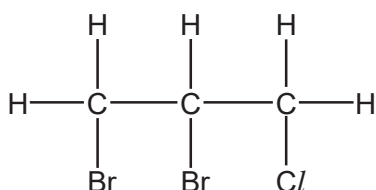


How many stereoisomers does it have?

- A 2                      B 8                      C 16                      D 64

- 16 Which of the following statements is true about cyclohexane, cyclohexene and methylbenzene?
- A Only cyclohexane decolourises bromine in the presence of light.
- B Only methylbenzene contains  $sp^2$  hybridised carbon atoms.
- C All three compounds decolourise hot acidified  $KMnO_4$  solution.
- D All three compounds react with chlorine gas under suitable conditions to produce hydrogen chloride gas.

- 17 1,2-Dibromo-3-chloropropane (DBCP) has been used in the control of earthworms in agricultural land. The structure of DBCP is shown below.



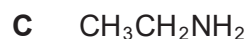
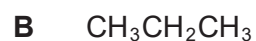
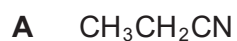
Which of the following is the best way of synthesising DBCP?

- A  $CH_2=CHCHBr_2 + HCl \rightarrow DBCP$
- B  $CH_2=CHCH_2Cl + Br_2 \rightarrow DBCP$
- C  $CH_3CH_2CH_2Cl + 2Br_2 \rightarrow DBCP + 2HBr$
- D  $CH_3CHBrCH_2Br + BrCl \rightarrow DBCP + HCl$
- 18 Which compound will **not** be formed in the reaction between ethene and aqueous bromine in the presence of aqueous ammonia?
- A  $CH_2(NH_2)CH_2OH$
- B  $CH_2BrCH_2OH$
- C  $CH_2BrCH_2Br$
- D  $CH_2BrCH_2NH_2$
- 19 Which property does benzene have as a consequence of the delocalised electrons present in its molecule?
- A It is a good conductor of electricity.
- B It is susceptible to attack by nucleophilic reagents.
- C Addition reactions of benzene take place more readily than substitution.
- D The carbon-carbon bond length is between that of a C–C bond and a C=C bond.
- 20 One mole of compound Y reacts with acidified potassium manganate(VII) solution to give off 2 moles of carbon dioxide.

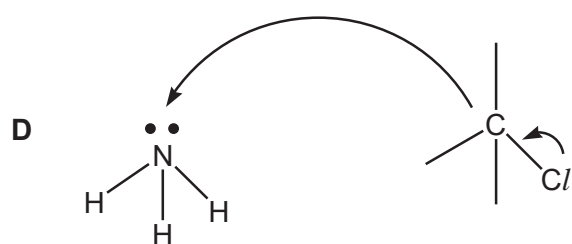
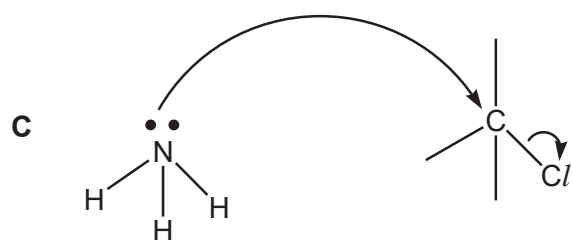
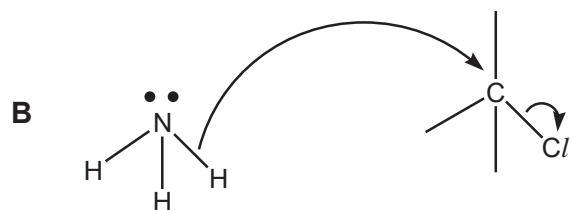
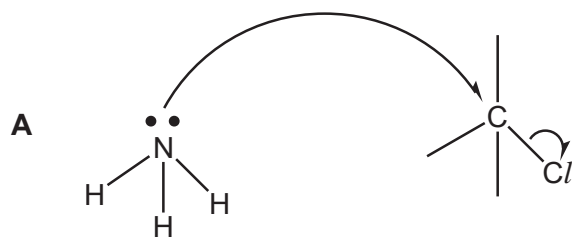
What is the possible structure of Y?

- A  $C_6H_5CH_3$
- B  $C_6H_5CH_2CH_3$
- C  $CH_2=CH_2$
- D  $CH_3CH=CH_2$

**21** Which of the following compounds could be prepared by reacting bromoethane with ethanolic potassium cyanide and then reducing the product?



**22** Which of the following diagrams correctly represents the transfer of electrons when ammonia reacts with a halogenoalkane?



## Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements you consider to be correct).

The responses **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2 only</b> are correct	<b>2 and 3 only</b> are correct	<b>1 only</b> is correct

No other combination of statements is used as a correct response.

- 23** When dilute acid is added to an aqueous solution containing nitrite ions, gases are evolved.



Which of the following statements correctly describe the process?

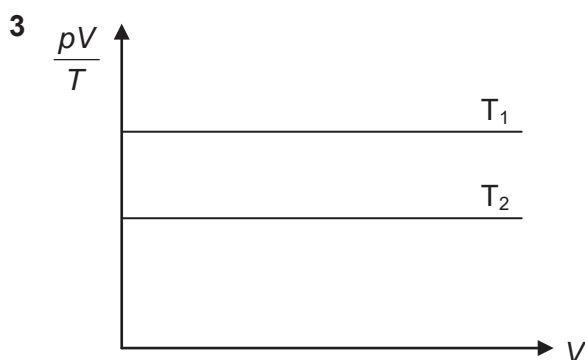
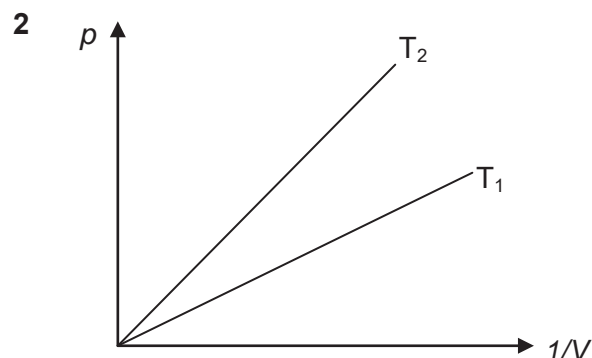
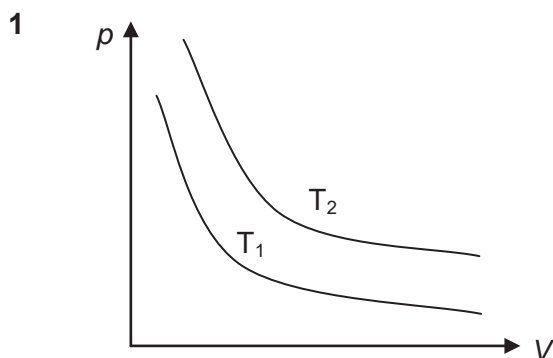
- 1**  $\text{NO}_2^-$  undergoes disproportionation.
  - 2**  $\text{H}^+$  is oxidised by  $\text{NO}_2^-$ .
  - 3**  $\text{H}^+$  acts as a catalyst.
- 24** In which sequences are the molecules listed in order of increasing bond angle?
- 1**  $\text{H}_2\text{O}$   $\text{NH}_3$   $\text{CH}_4$
  - 2**  $\text{SF}_6$   $\text{H}_2\text{O}$   $\text{BF}_3$
  - 3**  $\text{SF}_6$   $\text{CH}_4$   $\text{CO}_2$
- 25** Which of the following statements about the Group II metals, calcium, strontium and barium, are correct?
- 1** Second ionisation energy decreases from Ca to Ba.
  - 2** The magnitude of the lattice energy of the metal oxides decreases from Ca to Ba.
  - 3** The magnitude of the enthalpy change of hydration of the metal ions decreases from Ca to Ba.

The responses **A** to **D** should be selected on the basis of

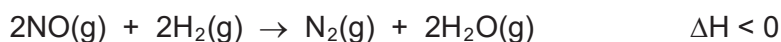
<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2 only</b> are correct	<b>2 and 3 only</b> are correct	<b>1 only</b> is correct

No other combination of statements is used as a correct response.

- 26** Which of the following graphs show the behaviour of a fixed mass of an ideal gas at two constant temperatures,  $T_1$  and  $T_2$  (where  $T_2 > T_1$ )?



- 27** The following kinetics data were obtained for the reaction between nitrogen(II) oxide and hydrogen at 700 °C.



Initial $[\text{NO}] / \text{mol dm}^{-3}$	Initial $[\text{H}_2] / \text{mol dm}^{-3}$	Initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$
0.250	0.05	$1.2 \times 10^{-6}$
0.250	0.10	$2.4 \times 10^{-6}$
0.125	0.10	$6.0 \times 10^{-7}$

Which of the following statements about the reaction are true?

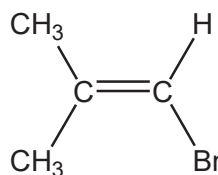
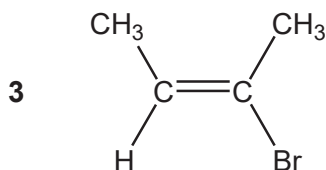
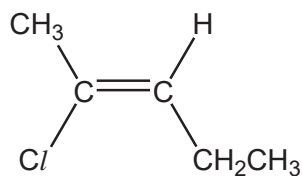
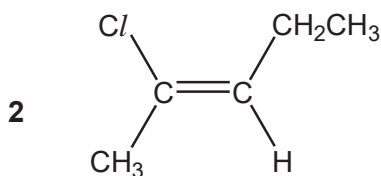
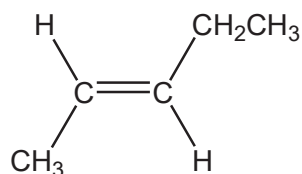
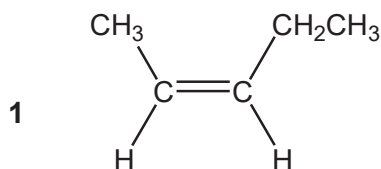
- 1** The order of reaction with respect to hydrogen is 1.
- 2** The overall order of reaction is 3.
- 3** The initial rate would decrease with increasing temperature.

The responses **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2 only</b> are correct	<b>2 and 3 only</b> are correct	<b>1 only</b> is correct

No other combination of statements is used as a correct response.

**28** Which of the following pairs illustrate geometric isomerism?

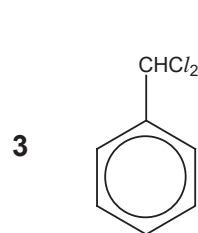
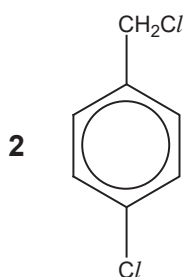
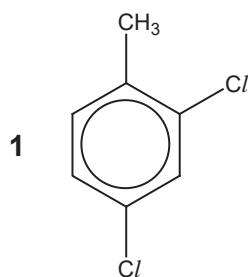


**29** Which of the following compounds will be detected in the reaction between  $\text{CH}_2\text{FCH}_2\text{F}$  and chlorine gas in the presence of light?



**30** A liquid, **L**,  $\text{C}_7\text{H}_6\text{Cl}_2$ , gives a white precipitate when shaken for some time with ethanolic silver nitrate.

What could **L** be?



**End of Paper**

# HWA CHONG INSTITUTION



## C1 PROMOTIONAL EXAMINATION H2 CHEMISTRY 9647 Paper 2: Structured and Free Response

7 October 2009

2 h

### INSTRUCTIONS TO CANDIDATES

1. This paper consists of **14** printed pages. You should also have a *Data Booklet*, a set of writing paper, a piece of graph paper and a cover page for **Section B**.
2. Answer **all** questions in **Section A** (Structured Questions) in the spaces provided in this Answer Booklet.
3. Answer **any 2 of the 3** questions in **Section B** (Free Response Questions) on the writing paper provided.  
Begin each question on a **FRESH** sheet of writing paper.
4. At the end of the examination, hand in your answers to **Section A** and **Section B SEPARATELY**.

A **NIL RETURN** is necessary for any unattempted question for **Section B**.

Tie your answer scripts to **Section B** behind the cover page provided.

### INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

You may use a calculator.

You are reminded of the need for good English and clear presentation in your answers.

### FOR EXAMINERS' USE

			TOTAL
Multiple Choice	Section A (Structured)	Section B (Free Response)	110
	Q1 / 7	Q1 / 20	
	Q2 / 10	Q2 / 20	
	Q3 / 7	Q3 / 20	
	Q4 / 7		
	Q5 / 9		
/ 30	Subtotal / 40	Subtotal / 40	

**Section A – Structured Questions [40 marks]**

Answer all the questions in the spaces provided.

**1** Chlorine exists as two isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ .

**(a) (i)** What do you understand by the term *isotopes*?

.....

.....

**(ii)** Explain why isotopes of the same element have similar chemical properties.

.....

.....

[2]

**(b)**  $\text{L}^{2+}$  has 18 electrons and is isoelectronic with  $\text{M}^{3-}$ .

**(i)** Write the electronic configuration of  $\text{M}^{3-}$ .

.....

**(ii)** Deduce the identities of **L** and **M**.

**L** is .....

**M** is .....

**(iii)** Explain why **L** has a melting point of 839 °C while **M** has a melting point of 44.1 °C.

.....

.....

.....

[5]

[Total: 7 marks]

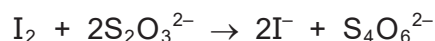


- 2 (a) In an experiment, 1.02 g of potassium iodate(V),  $\text{KIO}_3$ , is dissolved in 250  $\text{cm}^3$  of deionised water. 25.0  $\text{cm}^3$  of the  $\text{KIO}_3$  solution is transferred into a conical flask, acidified with dilute sulfuric acid and added with an excess of aqueous potassium iodide, KI.

In this reaction,  $\text{IO}_3^-$  is reduced to iodine,  $\text{I}_2$ , and  $\text{I}^-$  is oxidised to  $\text{I}_2$  as well.

- (i) Construct the overall balanced equation for the reaction between  $\text{IO}_3^-$  and  $\text{I}^-$ .

The  $\text{I}_2$  solution obtained is titrated with aqueous sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$ , using starch as an indicator. 29.80  $\text{cm}^3$  of the  $\text{Na}_2\text{S}_2\text{O}_3$  solution is needed for complete reaction:



- (ii) Calculate the concentration (in  $\text{mol dm}^{-3}$ ) of the  $\text{Na}_2\text{S}_2\text{O}_3$  solution.

[4]

- (b) In the experiment described in (a), the  $\text{I}_2$  liberated does not dissolve well in water but is soluble in aqueous KI.

The  $\text{I}_2$  molecules interact with the unreacted  $\text{I}^-$  ions, forming tri-iodide ions,  $\text{I}_3^-$ . The following *dynamic equilibrium* is set up:



- (i) What do you understand by the term, *dynamic equilibrium*?

.....  
 .....

- (b) (ii) *The equilibrium mixture of  $I_2$  and  $I_3^-$  was titrated with the  $Na_2S_2O_3$  solution as though the mixture was simply a solution of  $I_2$  in water.*

Suggest why the above statement in italics is so in terms of Le Chatelier's principle.

.....  
.....  
.....

- (iii) When a few drops of aqueous silver nitrate,  $AgNO_3$ , are added to the equilibrium mixture, a yellow precipitate is formed. The yellow precipitate does not dissolve in aqueous ammonia. State the identity of the yellow precipitate.

Identity of yellow precipitate: .....

- (iv) Draw the dot-and-cross diagram for the  $I_3^-$  ion.

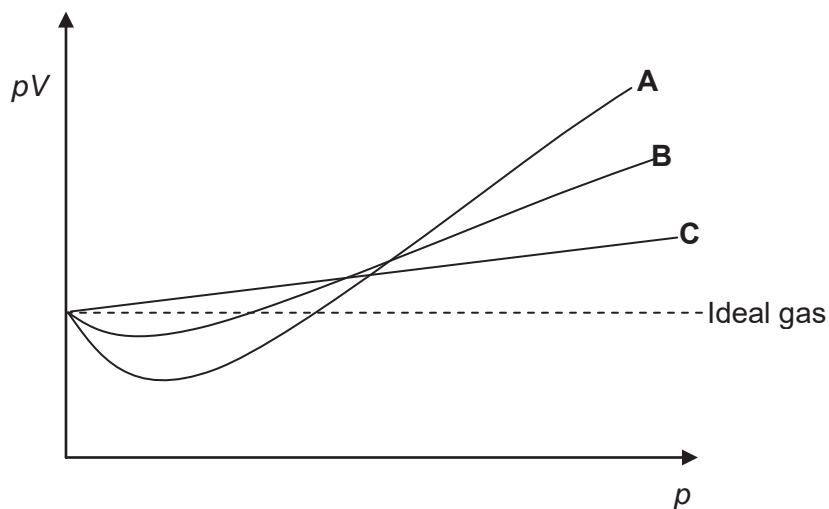
- (v) Suggest why  $I_2$  does not dissolve well in water but is soluble in aqueous KI.

.....  
.....  
.....

[6]

[Total: 10 marks]

- 3 (a) (i) The value of  $pV$  is plotted against  $p$  for the same number of moles of three gases, **A**, **B** and **C**, where  $p$  is the pressure and  $V$  is the volume of the gas.



Given that the three gases are carbon dioxide, helium and hydrogen fluoride, deduce the identities of **A**, **B** and **C**.

**A:** .....

.....

**B:** .....

.....

**C:** .....

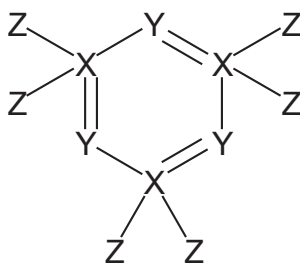
.....

- (ii) State the conditions of temperatures and pressures for A to behave most like an ideal gas.

.....

[4]

- (b) The structure of a stable molecule containing atoms of the elements, **X**, **Y** and **Z** of atomic numbers from **6** to **16** is as shown below.



Deduce the identities of the elements, **X**, **Y** and **Z**.

.....

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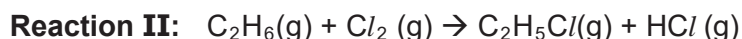
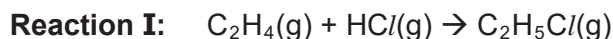
[3]

[Total: 7 marks]

- 4 Chlorine compounds have many industrial uses. One of the compounds, chloroethane,  $\text{C}_2\text{H}_5\text{Cl}$ , has its major use to produce tetraethyl lead (TEL), an anti-knock additive for gasoline.

The common method of producing chloroethane is through the reaction of ethene gas,  $\text{C}_2\text{H}_4$ , with hydrogen chloride gas, as shown in **Reaction I**. This reaction gives almost a 100% yield of pure  $\text{C}_2\text{H}_5\text{Cl}$ .

Another lesser known method produces chloroethane through direct reaction of ethane gas,  $\text{C}_2\text{H}_6$ , with chlorine gas, as shown in **Reaction II**. This reaction requires light as an energy source.



Some thermodynamical information is given below:

Compound	$\Delta G_f^\circ / \text{kJ mol}^{-1}$
$\text{C}_2\text{H}_4(\text{g})$	+68.0
$\text{HCl}(\text{g})$	−95.3
$\text{C}_2\text{H}_5\text{Cl}(\text{g})$	−60.5

- (a) (i) Calculate the standard free energy change of reaction,  $\Delta G_r^\circ$ , for **Reaction I**.

- (ii) Given that the standard entropy change of reaction,  $\Delta S^\circ$ , for **Reaction I** is  $-122 \text{ J mol}^{-1} \text{ K}^{-1}$ , calculate the standard enthalpy change of **Reaction I**.

- (iii) Explain the significance of the sign of  $\Delta S^\circ$ .

.....  
.....

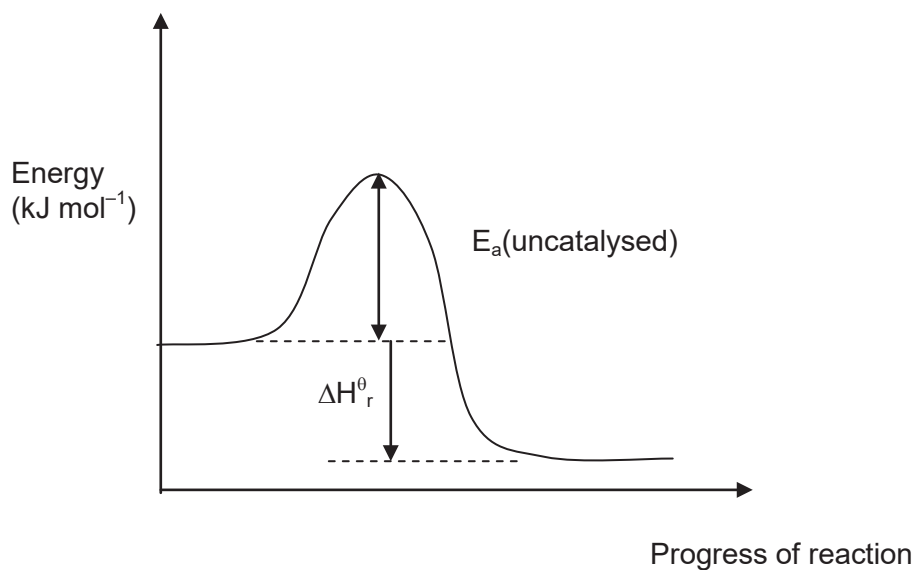
- (b) (i) It has been found that  $\Delta G_r^\theta$  for **Reaction II** is more negative than  $\Delta G_r^\theta$  of **Reaction I**. What can be concluded about the feasibility of the two reactions? [3]

.....  
.....

- (ii) In industrial production, **Reaction I** is chosen over **Reaction II**. Suggest two reasons to justify the choice of **Reaction I** over **Reaction II**.

.....  
.....  
.....

- (c) **Reaction I** may also be carried out in the presence of solid aluminium chloride catalyst. Sketch, on the reaction pathway diagram below, how the reaction would be affected by the presence of the catalyst.



[4]

[Total: 7 marks]

- 5 (a) (i) There are four compounds with molecular formula  $C_4H_8$  which decolourise bromine water in the absence of sunlight. Two of these compounds are geometric isomers.

Draw the structures of the four compounds below and identify the pair of geometric isomers.

<b>I:</b>	<b>II:</b>
<b>III:</b>	<b>IV:</b>

Geometric isomers: .....

- (ii) Which of the geometric isomers has a higher melting point? Explain.

.....

.....

.....

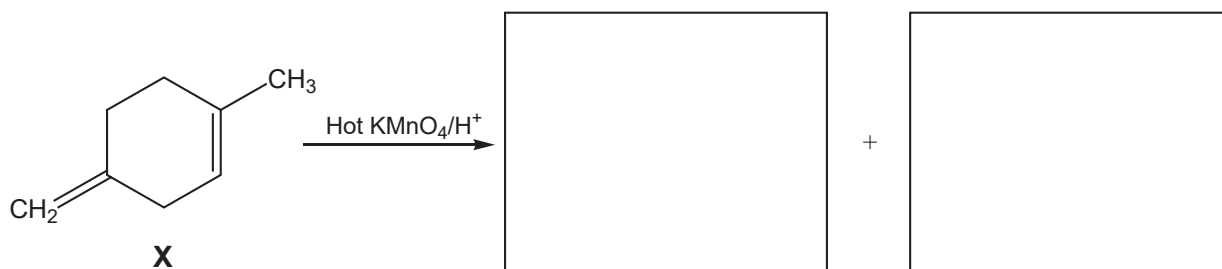
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- (iii) Draw the structure of a compound with the molecular formula  $C_4H_8$  which does not decolourise bromine water in the absence of sunlight.

[6]

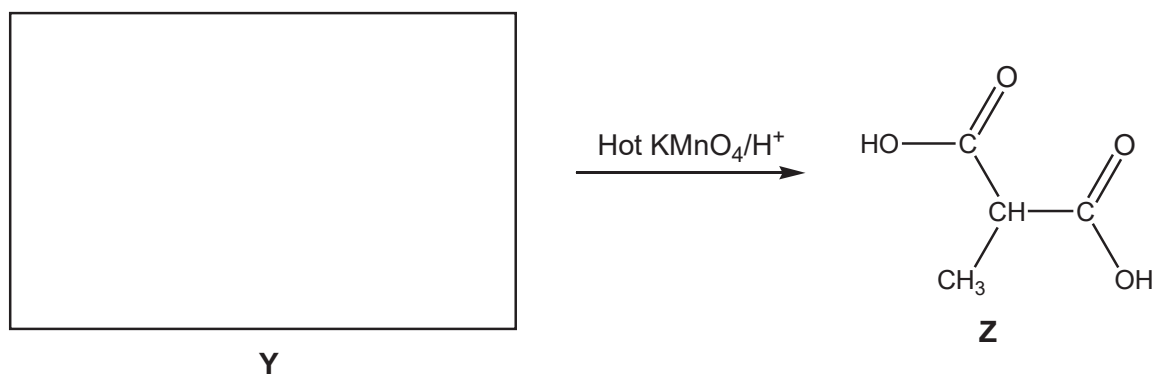
- (b) (i) An alkene, **X**, is treated with excess hot acidified potassium manganate(VII).

Draw the structures of carbon-containing products in the boxes below.



- (ii) **Y**, an isomer of **X**, produces **Z** as the **only** product when treated with excess hot acidified potassium manganate(VII).

Draw the structure of **Y** in the box below



[3]

[Total: 9 marks]



## Section B – Free Response Questions [40 marks]

Answer any **2** out the 3 questions.

Write your answers on the writing paper provided. Begin each question on a **fresh sheet** of writing paper.

**1** This question is about the chemistry of butane,  $C_4H_{10}$ .

- (a)** Butane is often used as a fuel for cooking and camping. To determine the standard enthalpy change of combustion of butane, a scientist carried out the combustion process in a bomb calorimeter.

In an experiment, 5 g of liquid butane was burnt in excess oxygen and the maximum rise in temperature of 1 kg of water was 38.0 °C.

- (i)** Write the equation, with state symbols, which represents the standard enthalpy change of combustion of butane.
- (ii)** Calculate the standard enthalpy change of combustion of butane given that only 80% of the heat produced was used to heat the water.

You may assume the specific heat capacity of water to be  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ .

- (iii)** By using the following data, and relevant bond energy data from the *Data Booklet*, construct an energy cycle to determine the standard enthalpy change of combustion of butane. Calculate this enthalpy change.

	$\Delta H / \text{kJ mol}^{-1}$
Enthalpy change of vapourisation of $C_4H_{10}(l)$	+21.0
Enthalpy change of vapourisation of $H_2O(l)$	+44.0

- (iv)** Suggest a reason for the difference between the values calculated in **(a)(ii)** and **(a)(iii)**.

[9]

**(b)** Compounds **A** and **B** have molecular formula  $C_4H_{10}$ .

- (i)** Given that **A** has a higher boiling point than **B**, identify the structures of **A** and **B**. Explain.

When **A** reacts with chlorine gas in the presence of light, three products with the formula of  $C_4H_9Cl$ , **C**, **D** and **E** are formed, amongst which **D** and **E** are optical isomers.

- (ii)** Draw the structure of **C** and the structures of **D** and **E** to illustrate optical isomerism.
- (iii)** Describe the mechanism of **A** with chlorine to form **C**.

When **B** reacts with chlorine in the presence of light, two products with the formula of  $C_4H_9Cl$ , **F** and **G**, are formed.

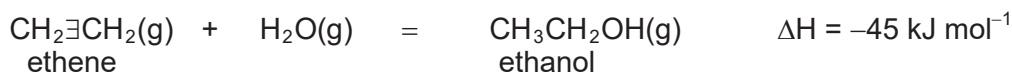
- (iv)** Identify **F** and **G** by drawing their structural formulae.

[11]

[Total: 20 marks]

2 Ethene is the most produced organic compound in the world. An important use of ethene is in the manufacturing processes of ethanol and bromoethane.

- (a) Industrially, ethanol is manufactured by the reaction of ethene with steam in the presence of concentrated phosphoric acid catalyst, which is coated onto a solid silicon dioxide support.



- (i) State *Le Chatelier's principle*.
- (ii) The reaction is carried out at a pressure of 60 atm and a temperature of 300 °C.
- I In what respects are these conditions not what you might have expected.  
II Suggest why these particular conditions are used.
- (iii) Write an expression for the equilibrium constant,  $K_p$ , for the reaction.
- (iv) Equal volumes of ethene and steam at a total initial pressure of 240 atm are allowed to reach equilibrium in a closed vessel. The final pressure is found to be 160 atm. Calculate a value for  $K_p$ , stating its units.
- (v) Since water is readily available, it would seem sensible to use an excess of steam to drive the reaction forward. However in practice, a steam:ethene ratio of 0.6:1 was used. From the information about this process given above, suggest why the use of excess steam is avoided.

[10]

- (b) 1,2-dibromoethane,  $\text{CH}_2\text{BrCH}_2\text{Br}$ , is formed from the reaction of ethene with  $\text{Br}_2(\text{l})$ .

- (i) Describe the mechanism of this reaction.
- (ii) Give the full structural formula of the major product formed when ethene reacts with aqueous bromine instead.

[5]

- (c) Another unsaturated hydrocarbon that is also an important precursor to many chemical reactions is benzene. *However, the  $\pi$  bond in ethene is localised while the  $\pi$  electron system in benzene is said to be delocalized.*

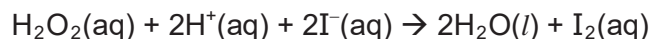
- (i) With the aid of diagrams, explain what is meant by the statement given in *italics*.
- (ii) Suggest a reason why benzene would not react with bromine under the same conditions as that described in (b) for ethene.

[5]

[Total: 20 marks]

- 3 Hydrogen peroxide,  $\text{H}_2\text{O}_2$ , is a colourless liquid, commonly used as an oxidising agent, disinfectant, bleach for hair and cloth, and in rocketry as a propellant.

- (a) Hydrogen peroxide reacts with acidified iodide ions to liberate iodine according to the following reaction:



The rate of reaction was followed by measuring the concentration of the remaining iodide ions after fixed time intervals. Two experiments were carried out, starting with different concentrations of hydrogen peroxide. The following results were obtained.

Time/s	Experiment 1 with $[\text{H}_2\text{O}_2] = 0.05 \text{ mol dm}^{-3}$	Experiment 2 with $[\text{H}_2\text{O}_2] = 0.10 \text{ mol dm}^{-3}$
	$[\text{I}^-] / \text{mol dm}^{-3}$	$[\text{I}^-] / \text{mol dm}^{-3}$
0	$10.00 \times 10^{-4}$	$10.00 \times 10^{-4}$
25	$7.45 \times 10^{-4}$	$5.15 \times 10^{-4}$
50	$5.60 \times 10^{-4}$	$2.70 \times 10^{-4}$
75	$4.25 \times 10^{-4}$	$1.55 \times 10^{-4}$
100	$3.15 \times 10^{-4}$	$0.75 \times 10^{-4}$

- (i) To monitor the concentration of the remaining iodide ions, aqueous sodium hydroxide was added to portions of the reaction mixture at fixed time interval before titrating with a standard solution of aqueous sodium thiosulfate.

Explain why aqueous NaOH was added.

- (ii) Using the same axes, plot graphs of  $[\text{I}^-]$  against time for the two experiments.
- (iii) Given that the order of reaction with respect to  $\text{H}^+$  is zero, use your graphs to determine the order of reaction with respect to  $\text{H}_2\text{O}_2$  and to  $\text{I}^-$ , showing your working clearly.
- (iv) Construct a rate equation for the reaction and use it to calculate a value for the rate constant, including units.

[8]

- (b) Under room conditions, hydrogen peroxide decomposes in aqueous solution, liberating a slow stream of oxygen. However, with addition of aqueous  $\text{FeCl}_3$ , oxygen is rapidly evolved.

- (i) State the role of aqueous  $\text{FeCl}_3$  in the decomposition of hydrogen peroxide.
- (ii) With the aid of a Boltzmann distribution, explain how the presence of aqueous  $\text{FeCl}_3$  increases the rate of reaction.
- (iii)  $\text{FeCl}_3$  is often used for the chlorination of methylbenzene.

Describe the mechanism of the reaction between methylbenzene and chlorine.

[7]

**(c)** Hydrogen peroxide readily decomposes to give water and oxygen.

Hydrogen peroxide is sold by volume strength. For example, a 20-volume hydrogen peroxide yields 20 cm<sup>3</sup> of oxygen gas measured at r.t.p. for every 1 cm<sup>3</sup> of the aqueous H<sub>2</sub>O<sub>2</sub> solution.

- (i)** Construct an equation for the decomposition of hydrogen peroxide.
- (ii)** Determine the concentration, in mol dm<sup>-3</sup>, of the 20-volume hydrogen peroxide.
- (iii)** Calculate the volume of gas, in dm<sup>3</sup>, measured at 150 kPa and 30 °C that would be released by 1 cm<sup>3</sup> of the 20-volume hydrogen peroxide upon complete decomposition.

[5]

[Total: 20 marks]

**~ End of Paper ~**

2009 C1 H2 9647 Chemistry Promotional Examination  
ANSWERS FOR STUDENTS

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Paper 1 MCQ

1	B	6	A	11	D	16	D	21	D	26	B
2	B	7	C	12	B	17	B	22	C	27	B
3	A	8	C	13	C	18	A	23	D	28	D
4	A	9	C	14	A	19	D	24	A	29	B
5	D	10	B	15	D	20	C	25	A	30	C

PAPER 2 Structured Questions and Free Response Questions

Suggested Answers and Markers' Comments

Section A

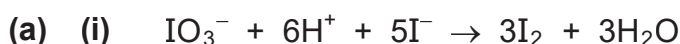
1 Marker - Chen Sue Ann

- (a) (i) Isotopes are different atoms of the same element which have the same number of protons (or same atomic number) but different number of neutrons (or different mass number).
- (ii) Isotopes have the same number of valence electrons or same electronic configuration.
- (b) (i)  $1s^2 2s^2 2p^6 3s^2 3p^6$
- (ii) L is calcium, M is phosphorus. [No marks given if no reasoning or working]
- E.g. no. of protons in L =  $18 + 2 = 20$ , L is calcium.  
 $M^{3-}$  has 18 electrons, M has 15 electrons or 15 protons, M is phosphorus.
- (iii) Ca has metallic structure, and thus, have strong electrostatic forces of attraction between the between  $Ca^{2+}$  cations and the sea of delocalised electrons.
- $P_4$  is simple covalent (or has simple molecular structure). Weaker dispersion forces (or van der Waals' forces or instantaneous dipole-induced dipole attractions) exist between  $P_4$  molecules.
- More energy needed to overcome metallic bonds than dispersion forces, so higher temperature required for melting.

## Marker's Comment

- Qn 1 (a)(i) Generally well defined except many candidates who failed to identify isotopes as atoms from the same element and some who defined isotopes as a compound/molecule/substance or as merely elements which have the same number of protons (or same atomic number) but different number of neutrons.
- Qn 1 (a)(ii) Many candidates attributed the similarity in the chemical reactions of isotopes to the same number of electrons but failed to state that chemical reactions involve the transfer/movement of valence electrons. Some also stated that chemical reactions are dependent on the number of protons of the isotopes.
- Qn 1 (b)(i) Some students gave 2,8,8, the electronic configuration they learnt in secondary school.
- Qn 1 (b)(ii) Candidates are required to show working or reasoning in their answers but many failed to do so, even though they managed to arrive at the correct final answer. Some candidates gave wrong identity due to wrong working.
- Qn 1 (b)(iii) Some candidates wrongly identified the bonding in calcium to be ionic instead of metallic. Many who correctly identified metallic bonding did not explain the nature of the bonding, i.e. strong electrostatic forces of attraction between  $\text{Ca}^{2+}$  cations and the sea of delocalised electrons. Some also stated the presence of intermolecular forces in metals. A number of candidates have a misconception that dispersion forces are a type of covalent bond e.g., simple covalent bond such as dispersion forces.
- Many candidates wrongly attributed the higher melting point of L to its atom's higher effective nuclear charge, causing its valence electrons to experience stronger forces of attraction, and thus require more energy to be removed. They may have confused energy required for melting with ionization energies.

## 2 Marker – Liw Meng Hong (09S60 to 09S70), Loy Hui Chun (09S71 – 09S7N)



(ii) No. of moles of  $\text{IO}_3^-$  in  $25.0 \text{ cm}^3 = \frac{1.02}{39.1 + 127 + 3 \times 16} \times \frac{25.0}{250} = 4.76 \times 10^{-4}$

No. of moles of  $\text{I}_2$  produced  $= 4.76 \times 10^{-4} \times \frac{3}{1} = 1.43 \times 10^{-3}$

No. of moles of  $\text{S}_2\text{O}_3^{2-}$  in  $29.80 \text{ cm}^3 = 1.43 \times 10^{-3} \times \frac{2}{1} = 2.86 \times 10^{-3}$

$[\text{Na}_2\text{S}_2\text{O}_3] = \frac{2.86 \times 10^{-3}}{29.80/1000} = 0.0959 \text{ mol dm}^{-3}$

- (b) (i) Dynamic equilibrium refers to a state of balance in a reversible reaction or process in which the **forward and reverse reactions are occurring at the same rate**. The concentrations of reactants and products remain constant.
- (ii) During the titration,  $I_2$  is removed from solution by reaction with  $S_2O_3^{2-}$ . By Le Chatelier's principle, position of the **equilibrium shifts to the left to form more  $I_2$** . Eventually, all the  $I_3^-$  will be converted to  $I_2$ .
- (iii)  $AgI$
- (iv) 
$$\left[ \begin{array}{c} \times \times \times \\ \times I \times \times \\ \times \times \times \end{array} : \begin{array}{c} \times \times \times \\ \times I \times \times \\ \times \times \times \end{array} \right]^-$$
- (v)  $I_2$  molecule is **non-polar** but water molecule is **polar**. The two **do not form favourable interactions**. Thus,  $I_2$  does not dissolve well in water.

OR:

$I_2$  molecule forms **dispersion forces** (accept: instantaneous dipole-induced dipole attractions / van der Waals forces) but water molecule forms **hydrogen bonding**. The two **do not form favourable interactions**.

$I_2$  is soluble in aqueous KI because the  **$I_3^-$  ion** produced **can form ion-dipole interactions** with water molecules.

### Marker's Comment

- This question was generally well done. Most candidates scored at least 6 marks.
- (a)(i):** A large number of candidates did not simplify the overall equation and gave the final answer as  $2IO_3^- + 12H^+ + 10I^- \rightarrow 6I_2 + 6H_2O$ . A few candidates included " $O_2$ ", " $H_2$ " or " $OH^-$ " as products. Do study the procedure for balancing redox equations. Always check your final equation again in terms of numbers of atoms of each element and charges.
- (a)(ii):** Most candidates remembered the scaling step (from  $250\text{ cm}^3$  to  $25\text{ cm}^3$ ). A significant number of candidates made mistakes in the molar mass of  $KIO_3$  eg, used proton numbers (of K and I) instead of  $A_r$ , did not include  $A_r$  of K. Candidates are advised to write clear statements, indicating chemical species referred to and units as appropriate, and in a standard/format of presentation that is acceptable for A-Level. Show clear working, e.g. multiplication by the mole ratio is intentionally left out by some candidates.
- (b)(i):** Some candidates wrote "rate of product formation is the same as the rate at which reactant is used up" -- this is true only if the mole ratio of product produced to reactant reacted is 1:1. Some candidates stated "both forward reaction and backward reaction are occurring at the same time" -- that would be an explanation of the term "dynamic" only.



- **(b)(ii).** Do give a “complete story” --  $I_2$  reacted with  $S_2O_3^{2-}$  (during titration), position of equilibrium shifts to the left so as to produce more  $I_2$ , phrased following Le Chatelier’s principle. A significant number of candidates only quoted Le Chatelier’s principle but that is as good as no answer!
- **(b)(iii):** A few candidates lost the mark for stating “aqueous  $AgI$ ”.
- **(b)(iv):** The answer can be deduced by “combining” the dot-and-cross diagrams of an  $I_2$  molecule and an  $I^-$  ion! Many candidates have electrons missing, some forgot to indicate the overall charge over square brackets. There should be 2 single bonds and 3 lone pairs around the central I. The following are rejected: open circles, open triangles to represent electrons, circular electron “orbits”. Some candidates gave a triangular arrangement of the 3 iodine atoms as if they are part of a ring. Some candidates drew the electrons in such a way that the markers cannot tell which atom do they belong to.
- **(b)(v):** Why  $I_2$  does not dissolve well in water? There should be a complete comparison between  $I_2$  and  $H_2O$  (either in terms of polarity or the type of intermolecular attractions formed by each), followed by a conclusion (eg, no favourable interactions between  $I_2$  and  $H_2O$  molecules). Candidates who argued in terms of relative strengths of intermolecular forces rarely gave a good answer. Some stated that dispersion forces formed between  $I_2$  and  $H_2O$  are not strong enough to overcome the hydrogen bonds of  $H_2O$ . A better argument would be: energy released during formation of attraction forces between  $I_2$  and  $H_2O$  does not compensate the energy required to overcome dispersion forces between  $I_2$  molecules and hydrogen bonds between  $H_2O$  molecules. “Like dissolves like” is a guide, there is no need to quote it because no mark will be given. Some stated “ $I_2$  is non-polar, so it does not form hydrogen bonds”, “ $I_2$  is non-polar, so it does not form ion-dipole interactions” -- these are irrelevant generalisations. Other incorrect ideas include: “ $I_2$  is a compound”, “ $KI$  is an organic solvent”, “ $KI$  is a non-polar solvent”, “ $KI$  molecules”, “ $KI$  forms dispersion forces”, “ $I_2$  forms ion-dipole interactions with  $KI$ ”, “break  $I-I$  bond”.

### 3 Marker – Ching Mee Yoon

- (a) (i) A** - hydrogen fluoride; it has **strong** intermolecular **H bonding** & hence shows greatest deviation from ideal gas behaviour.

**B** - carbon dioxide; it is **non-polar** with **stronger** intermolecular **dispersion forces** (larger no of e’s & hence polarisability) than He, but weaker than hydrogen bondings than in HF

Or

$CO_2$  is the largest but non-polar – volume of  $CO_2$  molecules is significant compared to the volume of container, thus it behaves less ideally than He.  $CO_2$  behaves more ideally than HF as dispersion forces are much weaker than H bonds.

**C:** helium, it is monatomic and **non-polar** with **weak dispersion forces**



between the atoms (smaller no of e's & hence polarisability) than CO<sub>2</sub>.

Or

Volume of small non-polar He atoms is insignificant compared to the volume of container, thus it behaves more ideally than CO<sub>2</sub>.

[must quote: ideal gases are of insignificant gas volume and intermolecular forces of attraction]

(ii) High temperature and low pressure

(b) **Z is F (or fluorine)** as it forms only 1 single covalent bond with **X** attain stable octet configuration, it must be a Group VII element in Period 2.

**Y is N (or nitrogen)** as it forms 3 covalent bonds to attain stable octet configuration (cannot expand its octet); it must be a Group V element in Period 2.

**X is P (or phosphorus)**. It forms 5 covalent bonds and can expand its octet configuration as it has 10 e's around it; it must be a Group V element in Period 3.

### Marker's Comment

- Most students got 4 – 6 m. A small number of students did not seem to have revised the topic of gases and hence got 0 m for (a).

#### 3(a)(i)

- did not give explanation to justify the identities of gases **A, B & C**
- did not identify the types of molecules (polar/non-polar) and intermolecular forces of attraction (H bonds, pd-pd, td-id, dispersion forces)
- did not know that **A** has intermolecular H bonding, gave pd-pd interactions instead
- simply arranged **A, B, C** in terms of their  $M_r$  /  $A_r$
- most did not know that He is monatomic with  $A_r$  of 4.0
- gave explanation in terms of size of e cloud or polarisability of each gas
- did not know how to read the curves in terms of deviation from ideal gas behaviour, so gave answers in the reverse order
- some did not read carefully, and gave hydrogen as the answer
- quite a number considered He to have no forces of attractions between the atoms as it is a noble gas.

#### (ii)

- most gave correct answers
- some gave r.t.p or s.t.p conditions of P & T or low T and high P; 1 candidate gave numerical values of 500 °C for high T and 60 kPa for low P
- a handful wasted time explaining why high T & low P

**(b)**

- many justified answers in terms of the number of bonds each element formed without making reference to the attainment of the stable octet configuration when a compound is formed; thus leading to deducing **Y** as a Group III element of Al or B and **Z** as a Group I element of Na or Li
- some did not realise atomic number should be from 6 – 16; so gave H as an answer for **Z**
- some mistook **X** as O or S based on claim that it formed 6 bonds
- some gave the either or answers, e.g., **Y** can either be N or P
- some mistook **X**  $\equiv$  **Y**  $\equiv$  C and **Z**  $\equiv$  H and thus the molecule is benzene or some benzene like organic compounds (based on the alternating single and double bonds)

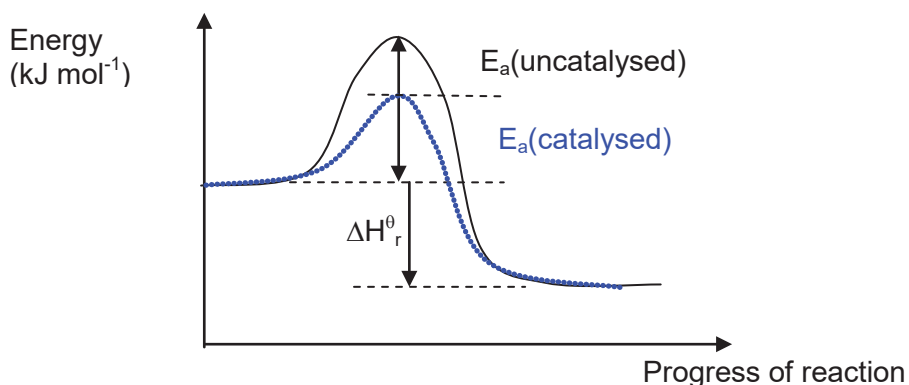
#### 4 Marker – Meta Lee

- (a) (i) 
$$\Delta G^\circ_r = \sum G^\circ_f (\text{products}) - \sum \Delta G^\circ_f (\text{reactants})$$
$$= -60.5 - (+68.0 + (-95.3))$$
$$= \underline{\underline{-33.2 \text{ kJ mol}^{-1}}}$$
- (ii) 
$$\Delta H^\circ_r = \Delta G^\circ_r + T\Delta S^\circ_r$$
$$= -33.2 + (298)(-0.122)$$
$$= \underline{\underline{-69.6 \text{ kJ mol}^{-1}}}$$
- (iii) Standard entropy change of reaction is negative as the system becomes **more orderly** due to a **decrease in the no. of gaseous molecules in the reaction**.
- (b) (i) **Reaction II** is more spontaneous/feasible than **Reaction I**.
- (ii) **Reaction II** is **slower** as it has **higher activation energy**, as reflected by the use of light as an energy source.

**Reaction II** is a **free-radical substitution** reaction. Hence, there will be a **low yield of the desired product**, chloroethane due to **multiple substitution** of ethane/ **presence of side-products** due to the termination stage of the reaction, e.g. butane.

**Separation of gaseous products** is necessary for Reaction II due to presence of gaseous HC/ by-product, which incurs additional cost. This additional step is not necessary for Reaction I **if molar quantities of reactants are used**.

(c)



### Marker's Comment

#### (a)(i)

- This question is generally well-done with candidates obtaining the answer through drawing of the energy cycle or equation.
- However, some candidates reversed the equation or reversed the direction of arrows in the energy cycle.
- A few candidates stated the wrong units or failed to give any units.

#### (a)(ii)

- Most candidates were able to use the Gibbs's free energy to derive the relationship  $\Delta H_r^\circ = \Delta G_r^\circ + T\Delta S_r^\circ$ .
- A lot of candidates failed to realise that the conditions given are set at standard conditions (298 K, 1 atm), as indicated by "°" annotation. Hence, they were unable to substitute the correct T into the relationship.
- A significant number of candidates had difficulty in manipulating the mathematical equation or failed to realise the discrepancy in the units of  $\Delta H_r^\circ$  calculated ( $\text{kJ mol}^{-1}$ ) and  $\Delta S_r^\circ$  ( $\text{J mol}^{-1} \text{K}^{-1}$ ).

#### (a)(iii)

- A lot of candidates failed to discuss the sign of  $\Delta S_r^\circ$  with respect to the one given for Reaction I.
- Most candidates lost mark by not explaining the reason for the decrease in entropy in terms of the decrease in the no. of gaseous particles in the reaction.

#### (b)(i)

- This question is generally well-done.
- Some candidates failed to make the comparison between the feasibility of the two reactions.
- A few candidates confused "feasibility" of the reaction with its "likelihood" of taking place. The two terms are not synonymous – for instance, a reaction may be spontaneous due to its negative  $\Delta G_r^\circ$  but with very low likelihood of it taking place due to its very slow rate, e.g. decomposition of diamond.

**(b)(ii)**

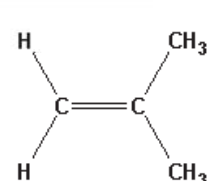
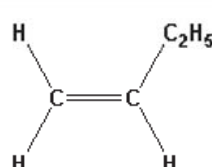
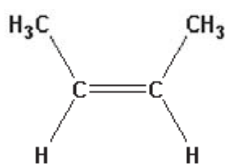
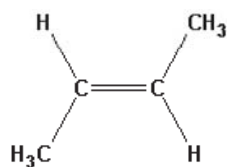
- Most candidates did not obtain full marks as they failed to provide reasons for the low yield of Reaction II. Some candidates gave the vague answers of “variety of products” or “multiplicity of products” due to free-radical substitution mechanism without providing reasons or at least examples of these products.
- A significant number of candidates had the misconception that production of  $\text{HCl}$  in Reaction II lowers the yield of the reaction.
- A very common mistake is that most students associated the need for light energy in Reaction II to higher cost. This is not true as this light energy is free when sunlight/uv light is used. Cost-efficiency of a reaction is not based on just one material or one source of energy alone but depends on a multitude of other factors, such as cost of reaction vessels, etc.
- The answer that emission of  $\text{HCl}$  in Reaction II is toxic and environmentally unfriendly is unacceptable as it is also used as a reactant in Reactant I and may also be present in excess. Furthermore, it is also removed in industries from the product mixture before emission through methods such as neutralisation. A safety and hazard analysis would also have been carried out before production on any toxic reactant or waste with appropriate care taken during handling of toxic materials.

**(c)**

- Most candidates obtained full marks for this question.
- A common mistake is that students mistook  $\text{AlCl}_3$  to be a homogeneous catalyst.
- Please note that the x-axis of the reaction pathway diagram is progress of reaction and not time.
- A few candidates confused reaction pathway diagram with Maxwell-Boltzmann diagram.
- Some candidates did not join the drawn curve smoothly to the original curve, resulting in a new, separate curve within the original curve.

**5 Marker – Li Jiexun (09S60 to 09S72), Sophie Bobillier (09S73 to 09S7N)**

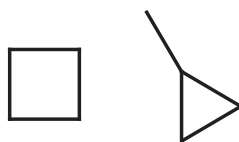
**(a) (i)**



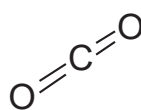
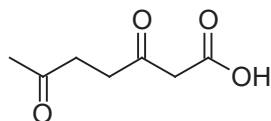
**(ii)** The trans isomer has higher melting point.

This is because it allows for better/closer packing in solid state and the intermolecular forces work better.

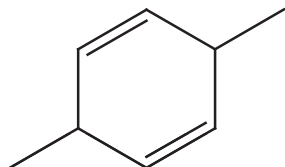
(iii)



(b) (i)



(ii)



### Marker's Comment

#### (a)(i)

- Many students are unable to recognize that 2 isomers are the same when the orientation of the drawn structure is changed. They think they are different isomers and give duplicate answers that are simply re-orientation of another.
- Handful of students misinterpret question and give structure of product after reaction with Bromine

#### (a)(ii)

- Handful of references to cis-cis, cis-trans isomers. It could be confusion of naming of isomers or confusion with isomers that have 2 double bonds leading to 4 geometric isomers.
- Did not mark for linking to dispersion forces and energy but it should be included.

#### (b)(i)

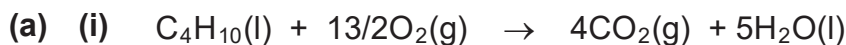
- Common mistake for students to miss out one of the functional groups either acid on carbon 1 or ketone on carbon 3. Or they will random insert –OH groups into the structure

#### (b)(ii)

- Many students draw structures with “C” and leave out the –H, they cannot do so other than for skeletal formula
- Many students either do not read the question or make use of the information that X and Y are isomers and simply join up the 2 C=O bonds.

## Section B

1 Marker – Ho Lai Ying (09S60 to 09S73), Sam Lee (09S74 to 09S7N)

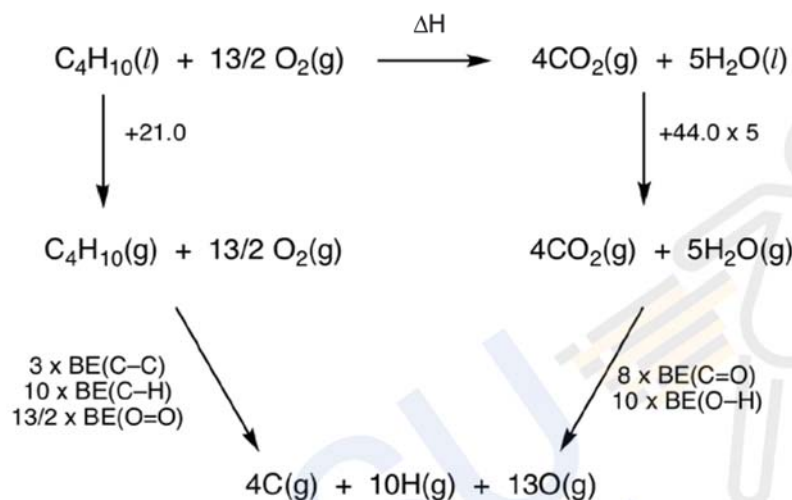


(ii) No. of moles of butane =  $5 / (12.0 \times 4 + 10) = 0.0862 \text{ mol}$

$$0.8 \times \Delta H_c = (1000 \times 4.18 \times 38.0) / 0.0862$$

$$\Delta H_c = -2304 \text{ kJ mol}^{-1}$$

(iii)



$$\begin{aligned}
 \Delta H_c &= 21 + \{(3 \times 350) + (10 \times 410) + (6.5 \times 496)\} - \{(8 \times 740) + (10 \times 460)\} - (44.0 \times 5) \\
 &= -2345 \text{ kJ mol}^{-1}
 \end{aligned}$$

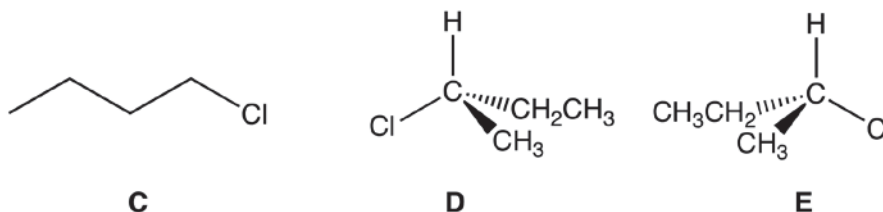
(iv) Bond energies used for the calculations are based on average bond energies of many compounds and may not be the value for the actual bonds in the reaction.

(b) (i)



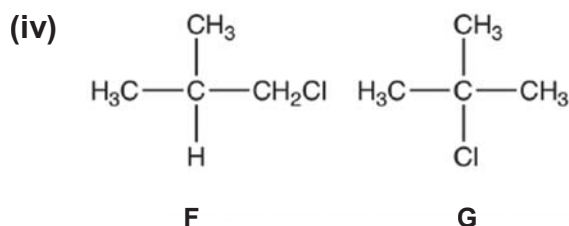
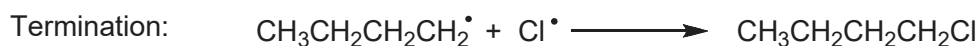
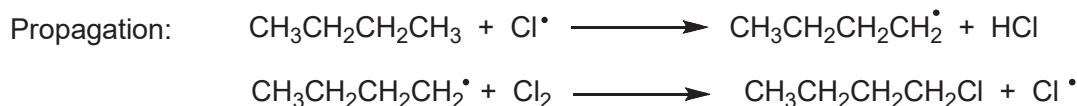
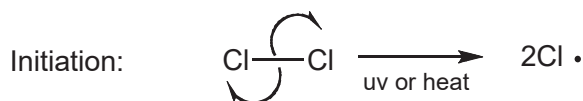
Straight chain molecules have bigger surface area, more polarizable.

(ii)





(iii) Free Radical Substitution



**Marker's Comment**

This question was the most attempted among the three and most scored well in **(b)** but very poorly in **(a)**.

**(a)(i)** Due to the specific nature of the question, many candidates were penalized for wrong state symbols, e.g.  $\text{C}_4\text{H}_{10}(\text{g})$ ,  $\text{H}_2\text{O}(\text{g})$  or used 2 moles of  $\text{C}_4\text{H}_{10}$  instead of 1. Other mistakes include the wrong formula for butane and some candidates have no idea what combustion involves.

**(a)(ii)** This was a straight-forward question and markers were quite surprised that many candidates still did not know what the  $m$  in  $mc\Delta T$  should be, many candidates used 5g (of fuel) instead of 1000g (of water) as the value for  $m$ . There were considerable omissions or the wrong use of the 80% in the calculation. The markers were frustrated by the lack of the  $(-)$  sign for the calculated  $\Delta H$  value of an exothermic reaction!

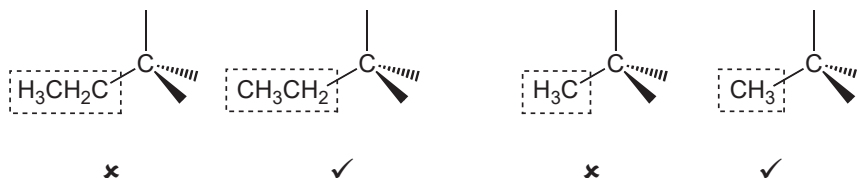
**(a)(iii)** Many candidates did not know how to draw a proper energy cycle. In cases where there was an energy cycle, candidates either did not atomise oxygen molecules, did not vapourise water or indicated the wrong number of bonds broken (4 C–C instead of 3 C–C). Some cycles even include  $\Delta H_f$  and linked it to elements. For the calculations, many candidates did not multiply 5 for the vapourisation of water.

**(a)(iv)** Almost all candidates scored the mark here. Only a handful of candidates were denied the mark due to vague answer or by stating heat loss to the surrounding. The markers accepted heat absorbed by the bomb calorimeter as an alternative answer.

**(b)(i)** Most candidates correctly identified the structures of **A** and **B** by drawing it out. The

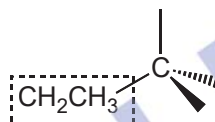
markers accepted answers by naming the compounds but warn that this practice should be avoided in the future unless specifically asked to do so. This is because the correct name for  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$  is *n-butane* and not just *butane*.

- (b)(ii) Many candidates did not use the 3D structure to illustrate the structures of **D** and **E**. Also, the quality of the 3D structures can be improved by drawing the way as shown in the answer scheme. The markers also noticed (but did not penalize) many candidates who drew the structure  $\text{CH}_3\text{CH}_2$  as  $\text{H}_3\text{CH}_2\text{C}$  as illustrated below:



The markers would like to advise candidates to draw the correct structure (as shown) in the future as this was highlighted by the Cambridge Examiners during their visit this year.

However, we did penalize candidates if they drew the following structure:

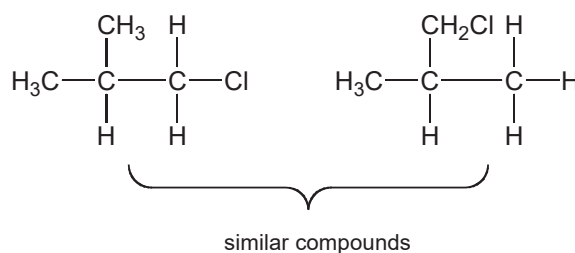


- (b)(iii) Many candidates did not score full marks for this section due to the following reasons:

1. No mention of the name of mechanism
2. No arrows indicating homolytic fission of  $\text{Cl}-\text{Cl}$  bond
3. No indication of *initiation*, *propagation* or *termination* steps
4. Wrote only one step for propagation so the regeneration of chlorine radical was not shown
5. Formula of radical was shown as  $\text{C}_4\text{H}_9\bullet$  or  $\text{C}_3\text{H}_7\text{CH}_2\bullet$
6. Wrong position of unpaired electron that does not result in compound **C**.

Candidates should avoid using molecular formula where the structure of the radical / compound is ambiguous.

- (b)(iv) This was generally well done except for a number of candidates who did not realize that they drew two similar compounds (as illustrated below):





**2 Marker – Lee Chay Koon (09S60 to 09S73), Wong Hwee Ming (09S74 to 09S7N)**

- (a) (i) Le Chatelier's Principle states that when a system in equilibrium is subjected to a change in conditions, the **position of equilibrium** will shift in a way so as to **reduce** that change.
- (ii) The pressure used for the reaction is not very high even though the forward reaction will be favoured at **high pressures** in order to form **less number of moles of gaseous products**.

However, there is **high cost** incurred to build **structures that can withstand high pressures** which might not be offset by the increased revenue from the higher yield.

The temperature used for this reaction is quite high and this is not expected as the forward reaction is favoured by **low temperature** so that the **exothermic reaction** can increase the amount of heat in the system.

However, if temperature used is too low, **rate of the reaction will be too slow** and hence, you will not be able to reach equilibrium quickly.

(iii) 
$$K_p = \frac{P_{\text{CH}_3\text{CH}_2\text{OH}}}{P_{\text{CH}_2=\text{CH}_2} \times P_{\text{H}_2\text{O}}}$$



Initial P	120	120	
change in P	-x	-x	+x
Eqm P	120 - x	120 - x	x

$$2(120 - x) + x = 160$$

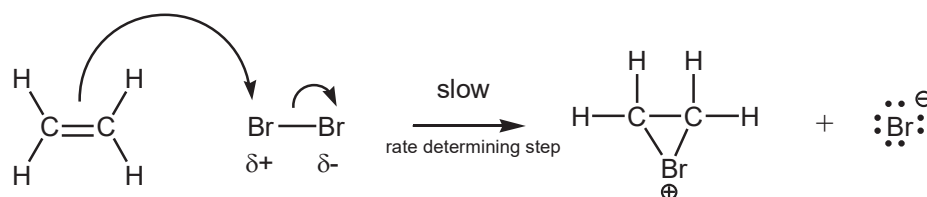
$$x = 80 \text{ atm}$$

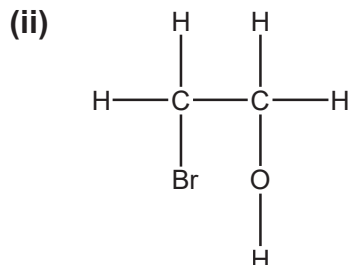
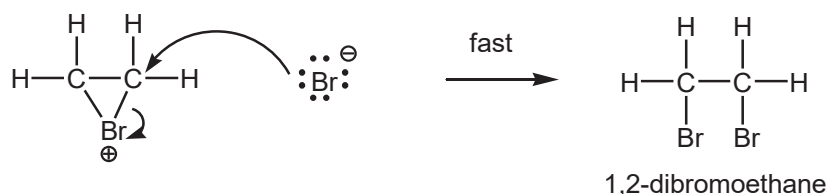
$$K_p = (80) / (40)^2$$

$$= 0.05 \text{ atm}^{-1}$$

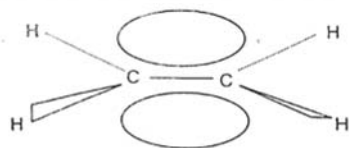
- (v) The concentrated phosphoric acid catalyst which is coated onto a solid silicon dioxide support, might dissolve in excess steam and so catalytic function is affected.

- (b) (i) Electrophilic addition

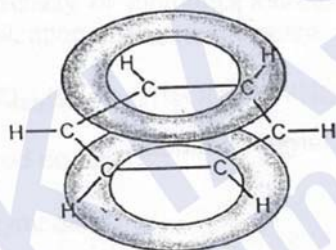




- (c) (i) Two **p orbitals overlap sideways** to form one localized  $\pi$  bond over two carbon atoms. The electrons are found between these two carbon atoms.



The six  $\pi$  orbitals contain **six electrons** which are not localized between particular pairs of carbon atoms but are **spread over all six carbon atoms**.



- (ii) The resonance structure gives benzene increased stability towards electrophilic reaction, hence a stronger electrophile is needed.

### Marker's Comment

#### (a)(i)

- Some candidates mentioned “**equilibrium** shifts” rather “**position of equilibrium** shifts”. This is accepted but do remember the correct phrasing in future.
- No mark will be awarded if candidates mentioned “the system will respond to counteract these changes” or “it will react in a way to reduce that change...”

#### (a)(ii)

- Reason must be given when mentioning shift of eqm. position. e.g under high

pressure, eqm. position shifts to right to form less no. of moles of gaseous products.

- Reason must be given for high cost incurred. No marks awarded if student just mentioned “not economical” or “high production cost”

**(a)(iii)**

- Many students wrote the units for  $K_p$  as  $\text{Pa}^{-1}$  even though it should be  $\text{atm}^{-1}$ . (no penalty in this part as they will be penalized in (iv))
- Some candidate expressed  $K_p$  using [ ], **no marks** as [ ] represents concentration in  $\text{mol dm}^{-3}$ .

**(a)(iv)**

- Most are able to perform the calculation.
- Many wrote the wrong units for  $K_p$  (same problem as (iii)). They will lose the last mark for that (1 mark for answer + correct units)
- If candidates have converted their answers from  $\text{atm}$  to  $\text{Pa}$ , they must show working in order to score the mark.

**(a)(v)**

- Many students think that silicon dioxide (a common form is sand) will dissolve in steam!!

**(b)(i)**

- Generally well done, showed that they put in the effort to study the mechanism. However, some students did not start / end their arrows at the right positions.

**(b)(ii)**

- Many omitted the bond between O – H and left it as OH.

**(c)(i)**

- Must show C atoms in diagrams. If not, student will score 1 mark only if both diagrams are shown correctly.
- In alkene, most students did not mention overlapping of the two p orbitals. Many just mentioned “ $\pi$  bond is formed between 2 C atoms and therefore is localised”
- In benzene, many did not mention the “the 6 electrons are not delocalised between particular pairs of C atoms and spread over all 6 C atoms”

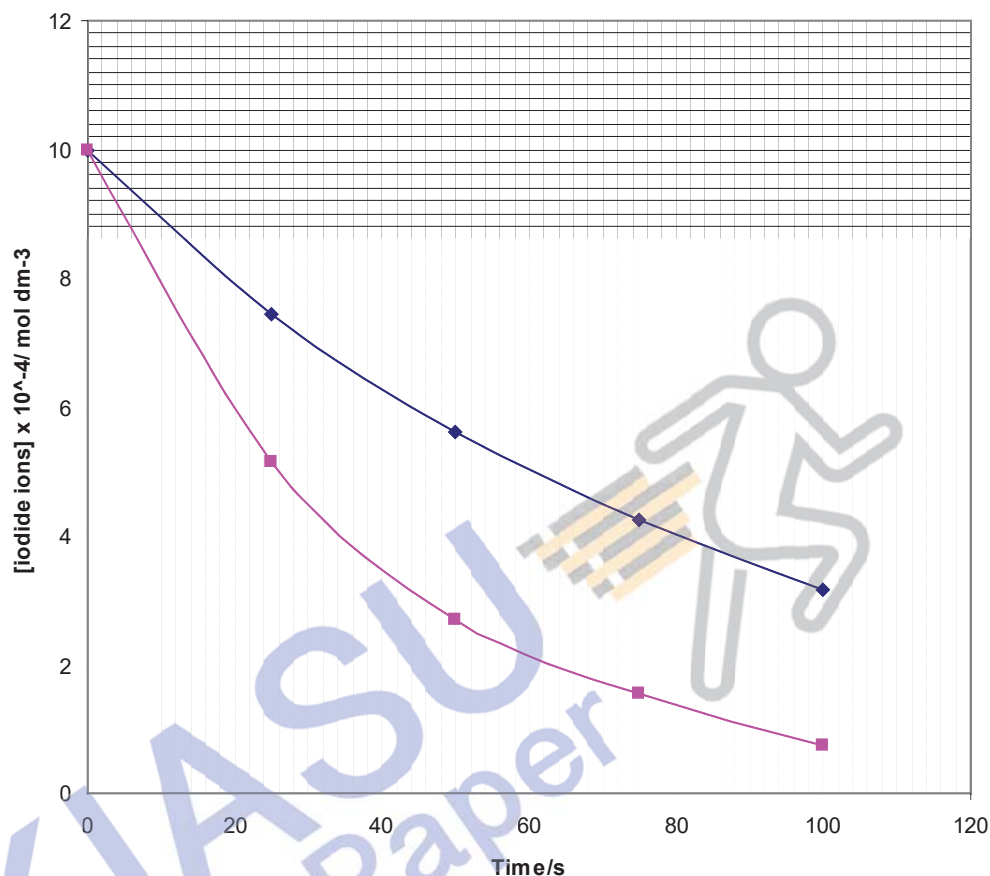
**(c)(ii)**

- Candidates must mention resonance structure for extra stability and not just benzene is stable. Most of them scored 1 mark here but they wrote much more than required.

**3 Marker – Ooi Ah Guat (09S60 to 09S73), Phee Peh Ling (09S74 to 09S7N)**

(a) (i) NaOH is to remove the  $\text{H}^+$  so as to quench the reaction.

(ii) Correctly plot both graphs with labelled axes.



(iii) Since half life is constant at approximately 26 s, it is first order with respect to iodide ions.

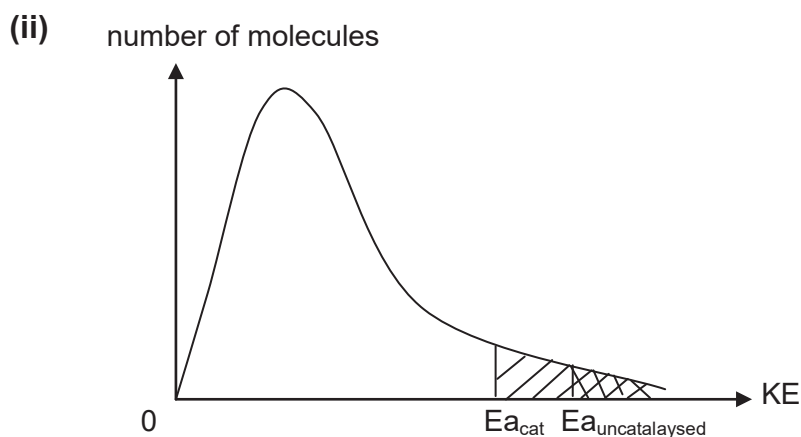
Find initial rate

When  $[\text{H}_2\text{O}_2]$  doubles, initial rate doubles, therefore it is first order with respect to  $\text{H}_2\text{O}_2$

(iv)  $\text{Rate} = k[\text{H}_2\text{O}_2][\text{I}^-]$

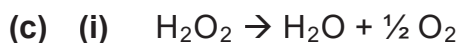
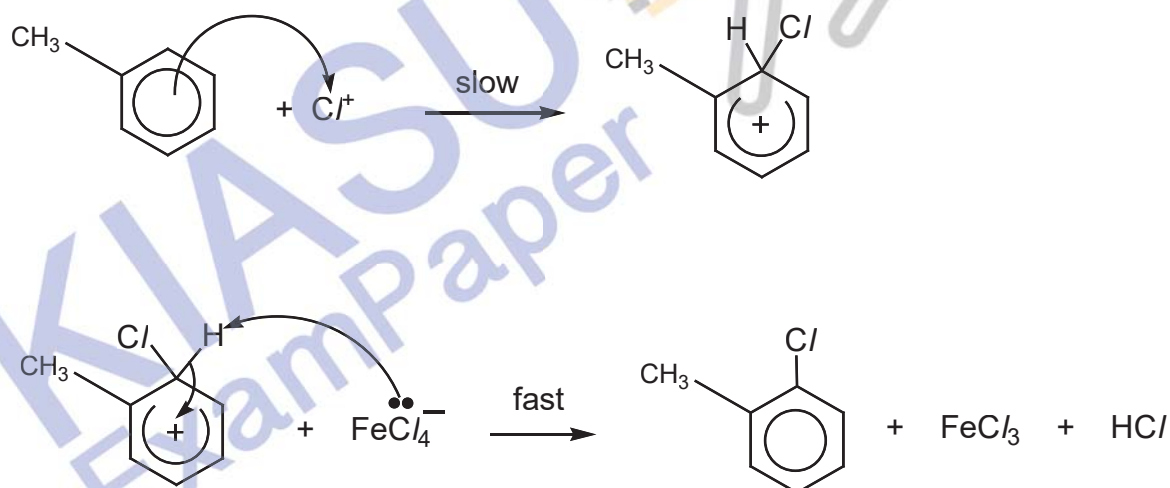
$$k = 0.224 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

(b) (i) Homogeneous catalyst



Catalyst provides an alternative pathway with lower  $E_a$ . There is greater proportion of molecules with KE greater or equal to  $E_a$ , leading to increased frequency of effective collision and thus rate increases.

(iii) Electrophilic substitution



- (ii) Volume of  $\text{O}_2$  generated =  $20 \text{ cm}^3$   
 No. of moles of  $\text{O}_2 = 20 / 24000 = 8.333 \times 10^{-4}$   
 No. of moles of  $\text{H}_2\text{O}_2 = 1.667 \times 10^{-3}$

$$[\text{H}_2\text{O}_2] = 1.667 \times 10^{-3} \div 0.001 = 1.67 \text{ mol dm}^{-3}$$

- (iii)  $pV = nRT$   
 $(150 \times 10^3)(V) = (8.333 \times 10^{-4})(8.31)(273 + 30)$   
 $V = 1.40 \times 10^{-2} \text{ dm}^3$

## Marker's Comment

- This is the least popular question out of the three Free Response questions, and is generally not well done.

### (a)(i)

- Quite a handful of students do not know the purpose of adding in aqueous NaOH. No marks will be given if candidate merely mentioned that aqueous NaOH is for neutralizing the  $\text{H}^+$  present. The main aim of neutralizing the  $\text{H}^+$ , i.e. to quench the reaction, must be mentioned.

### (a)(ii)

- Some students are unable to plot points properly or even label the wrong axes. This will lead to penalty.

### (a)(iii)

- There are a few candidates who do not know how to find half-life from the graph. After finding the wrong half-life, they even insist that the half-lives are constant even when they are obviously not! Some concluded that since the half-lives are not constant, it must be a second order reaction. This is not true. If half-lives are not constant, you can only conclude that it is not a first order reaction (if it is a curve).
- A large number of candidates did not show the working for half-lives on their graph and insist that the half-lives are constant. Do take note that the markers are NOT going to read the half-lives from your graph for you to determine whether they are constant. You have to label it on your graph yourself and the half-lives to be stated. Any unclear working that requires the markers to read the graphs on the candidates' behalf will lead to no credit.
- The majority of the candidates missed out the ' $\times 10^{-4}$ ' of the concentration of  $\text{I}^-$ . As a result, the values of the initial rates are determined wrongly. For such cases, you are either penalize under (a)(iii) or (a)(iv) **once** for wrong initial rate values.
- Some candidates disappointed the markers by the inability to calculate gradient. You have to make use of the formula:  $\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1}$ . If unsure of how to calculate gradient, do refer to your Secondary 1 or 2 Mathematics Textbook.
- Gradient is negative in this case but rate cannot be negative. Thus Rate = - Gradient.
- The rates to be calculated in this question should be initial rate and not rate at any other points. If taking rate at other time, the concentration of  $\text{H}_2\text{O}_2$  may no longer be at  $0.05 \text{ mol dm}^{-3}$  or  $0.10 \text{ mol dm}^{-3}$  anymore.

### (a)(iv)

- Error carried forward from (a)(iii) is allowed. However, if no order of reaction is deduced in (a)(iii), then no credit will be given for the rate equation.



- Some candidates use  $k = \frac{\ln 2}{t_{1/2}}$  to find rate constant for this reaction, forgetting that this equation is only true if overall order of reaction is one.

**(b)(i)**

- MOST candidates did not mention the word 'homogeneous'. Some even write down 'Lewis acid catalyst' as the answer.

**(b)(ii)**

- Do take note that Boltzmann distribution curve should start from the origin and should not end up touching the x-axis. The graph should not be symmetrical as well.
- For candidates who did not label the two  $E_a$  clearly, stating that one is with catalyst and the other without, no marks will be given.

**(b)(iii)**

- As question mentioned the use of  $\text{FeCl}_3$ , only electrophilic substitution is accepted.
- Some candidates were unable to give correct equation between reaction of  $\text{Cl}_2$  and  $\text{FeCl}_3$  and hence  $\text{Cl}^-$  or  $\text{FeCl}_4^+$  were wrongly used as electrophile to attack the benzene ring of methylbenzene.
- Quite a number of candidates did not write down  $\text{HCl}$  at the last step.
- Penalty is also given if the 'horse-shoe' of the intermediate is not drawn properly.
- Some candidates failed to recognize that the methyl group is 2,4-directing. If 3-chloromethylbenzene is given instead, one mark will be deducted.

**(c)(i)**

- Some give  $\text{H}_2$  and  $\text{O}_2$  as the products even though the question clearly states that water and oxygen are the products.

**(c)(ii)**

- This question will be marked based on your equation in (c)(i), but no ecf within (c)(ii).

**(c)(iii)**

- A large number of students used the number of moles of hydrogen peroxide instead of the number of moles of oxygen **& did not realize that they are calculating volume of hydrogen peroxide instead of volume of oxygen**.
- Some failed to convert the volume of the gas to  $\text{dm}^3$  despite the question asking for the final answer to be in  $\text{dm}^3$ .



**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

CANDIDATE NAME

CT GROUP

10S

**CHEMISTRY**

**9647/01**

Paper 1 Multiple Choice

**7 October 2010**

**45 minutes**

Additional Materials: Multiple Choice Answer Sheet  
Data Booklet.

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Complete the information on the optical mark sheet (OMS) as shown below.

1. Enter your NAME ( as in NRIC ).

Write your **name**

2. Enter the SUBJECT TITLE.

3. Enter the PAPER NUMBER.

Write your **CT group**

4. Enter your CT GROUP.

5. Date.

6. Enter your NRIC NUMBER or  
FIN NUMBER.

7. Now SHADE the corresponding  
lozenge in the grid for  
EACH DIGIT or LETTER

NRIC / FIN															
S	0	0	0	0	0	0	0	0	0	A	K	U			
F	1	1	1	1	1	1	1	1	1	B	L	V			
G	2	2	2	2	2	2	2	2	2	C	M	W			
T	3	3	3	3	3	3	3	3	3	D	N	X			
	4	4	4	4	4	4	4	4	4	E	O	Y			
	5	5	5	5	5	5	5	5	5	F	P	Z			
	6	6	6	6	6	6	6	6	6	G	Q				
	7	7	7	7	7	7	7	7	7	H	R				
	8	8	8	8	8	8	8	8	8	I	S				
	9	9	9	9	9	9	9	9	9	J	T				

Write and  
shade your  
NRIC  
or FIN number

There are **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.



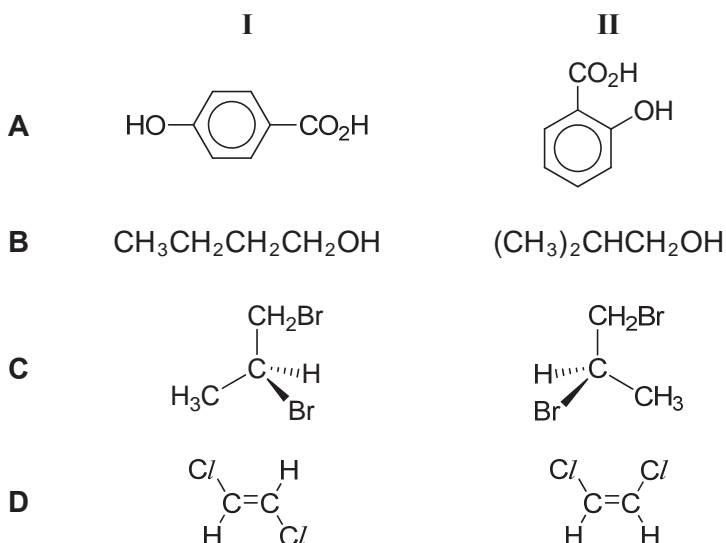
## Section A

- 1 When a  $10\text{ cm}^3$  sample of hydrocarbon was burned in  $100\text{ cm}^3$  of oxygen (an excess), the final gaseous mixture which contained carbon dioxide and unreacted oxygen was found to have a volume of  $75\text{ cm}^3$ . This final volume of gas was treated with an excess of aqueous potassium hydroxide and a further reduction of  $40\text{ cm}^3$  was observed. All gas volumes were measured at the same temperature and pressure.

What is the formula of the hydrocarbon?

- A  $\text{C}_2\text{H}_4$   
B  $\text{C}_2\text{H}_6$   
C  $\text{C}_4\text{H}_8$   
D  $\text{C}_4\text{H}_{10}$
- 2  $100\text{ cm}^3$  of  $0.02\text{ mol dm}^{-3}$  of  $\text{VO}^{2+}(\text{aq})$  is oxidized by  $50\text{ cm}^3$  of  $0.02\text{ mol dm}^{-3}$  of an oxidizing agent,  $\text{KXO}_4$ . If  $\text{VO}^{2+}$  is oxidized to  $\text{VO}_3^-$  by  $\text{KXO}_4$ , what is the final oxidation state of **X**?
- A +3  
B +4  
C +5  
D +6
- 3 The electronic configuration of four elements are given below.  
Which of the following elements have the highest 2<sup>nd</sup> ionization energy?
- A  $1s^2 2s^2 2p^1$   
B  $1s^2 2s^2 2p^2$   
C  $1s^2 2s^2 2p^6 3s^2 3p^1$   
D  $1s^2 2s^2 2p^6 3s^2 3p^2$
- 4 Which of the following particles would, on losing an electron, have a half-filled p subshell?
- A N  
B Si  
C  $\text{P}^-$   
D  $\text{O}^+$
- 5 In which one of the following pairs do the molecules have similar shapes?
- A  $\text{CO}_2$  and  $\text{SO}_2$   
B  $\text{AlCl}_3$  and  $\text{NCl}_3$   
C  $\text{SF}_4$  and  $\text{SiCl}_4$   
D  $\text{PCl}_5$  and  $\text{SbF}_5$

- 6 In which pair of molecules is the boiling point of molecule I lower than that of molecule II?



- 7 Which of the following would behave most like an ideal gas at room temperature?

- A Ne  
B  $\text{CH}_4$   
C  $\text{CO}_2$   
D  $\text{Cl}_2$

- 8 A sample of  $m$  g of an organic compound is vaporised in a gas syringe and occupies  $V \text{ cm}^3$  at  $T \text{ K}$  and  $p$  atm.

What is the relative molecular mass of the compound?

- |   |   |   |   |
|---|---|---|---|
| A | $\frac{m \times 22400 \times T}{p \times V \times 273}$         | C | $\frac{m \times 22400 \times 273 \times p}{V \times T}$         |
| B | $\frac{m \times 22400 \times (T + 273)}{p \times V \times 273}$ | D | $\frac{m \times 22400 \times 273 \times p}{V \times (T + 273)}$ |

- 9 Which equation defines the enthalpy change of atomisation of sulfur?

- A  $\frac{1}{8}\text{S}_8(\text{s}) \rightarrow \text{S}(\text{s})$   
B  $\frac{1}{8}\text{S}_8(\text{s}) \rightarrow \text{S}(\text{g})$   
C  $\text{S}_8(\text{s}) \rightarrow 8\text{S}(\text{g})$   
D  $\text{S}_8(\text{g}) \rightarrow 8\text{S}(\text{g})$

- 10 Crystallization is a purification process which is used to isolate pure, crystalline solids from a solution. This process will occur when a supersaturated solution is left to stand, allowing solid crystals to precipitate out of the solution.

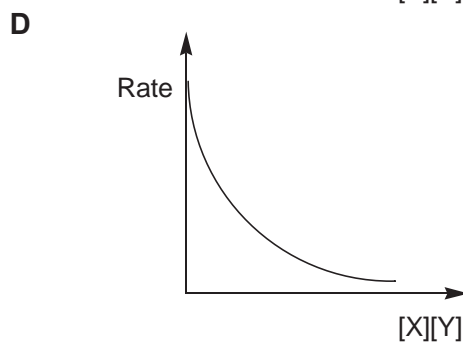
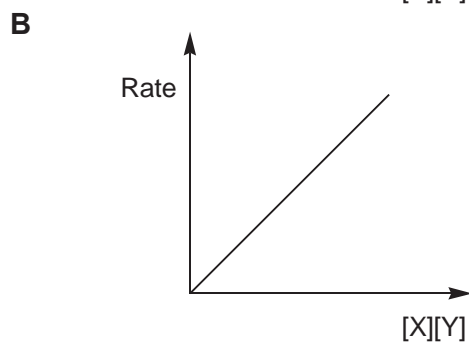
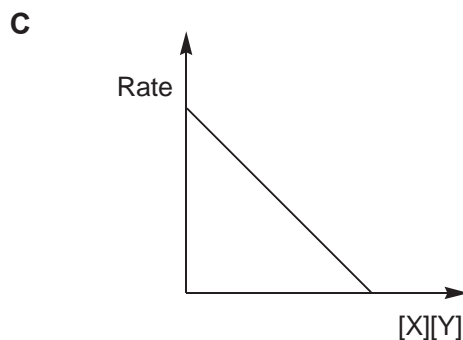
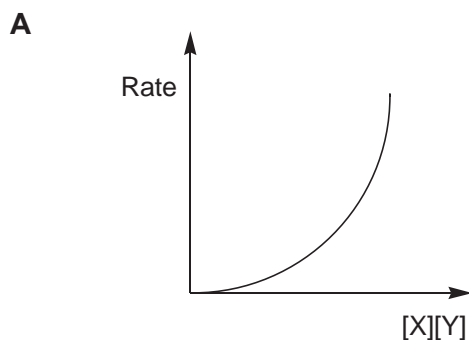
Which of the following best describes the thermodynamic parameters of crystallization?

	$\Delta H$	$\Delta S$
A	$< 0$	$< 0$
B	$> 0$	$< 0$
C	$< 0$	$> 0$
D	$> 0$	$> 0$

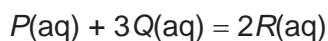
- 11 A reaction has the following rate determining step:



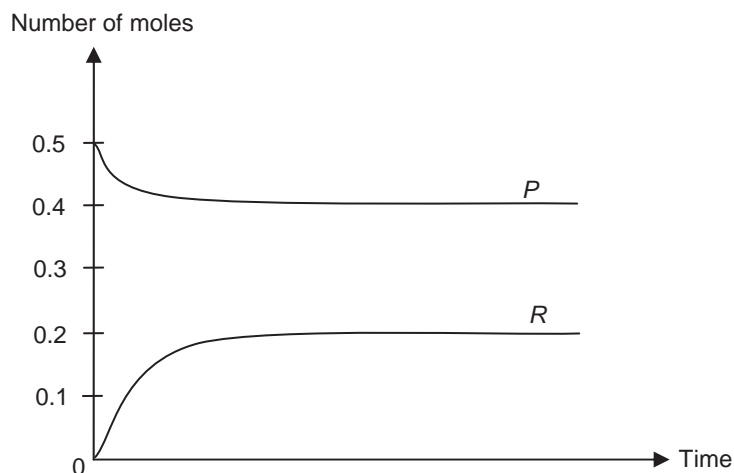
Which of the following graphs will be obtained when the rate is plotted against the product of the concentrations of X and Y,  $[X][Y]$ ?



- 12 Consider the following reaction between  $P$  and  $Q$  to form  $R$ :

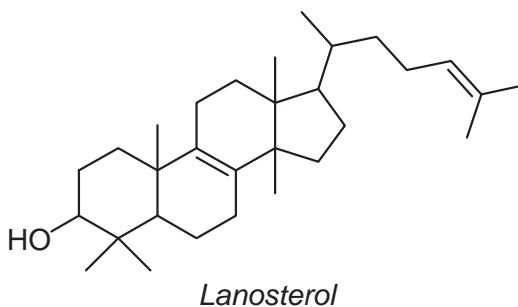


Equal amounts of  $P$  and  $Q$  were mixed and allowed to come to equilibrium. The diagram below shows the change in number of moles of  $P$  and  $R$  with time. The total volume of the reaction mixture was kept at  $2\text{ dm}^3$ .



What is the numerical value of the equilibrium constant,  $K_c$ ?

- |               |                |
|---------------|----------------|
| <b>A</b> 50.0 | <b>C</b> 6.25  |
| <b>B</b> 12.5 | <b>D</b> 0.231 |
- 13 The compound *Lanosterol* is a tetracyclic triterpenoid from which all steroids are derived.

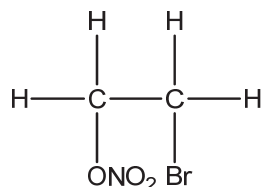


How many stereoisomers does *Lanosterol* have?

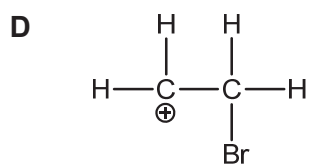
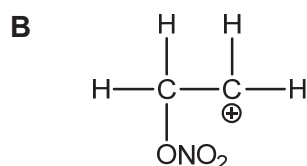
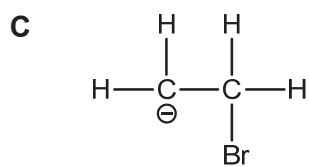
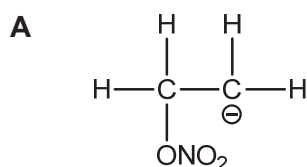
- |                |                |
|----------------|----------------|
| <b>A</b> $2^6$ | <b>C</b> $2^8$ |
| <b>B</b> $2^7$ | <b>D</b> $2^9$ |
- 14 Which one of the following molecules is **not** planar?
- |                       |                              |
|-----------------------|------------------------------|
| <b>A</b> ethene       | <b>C</b> methylbenzene       |
| <b>B</b> chloroethene | <b>D</b> 1,4-dichlorobenzene |

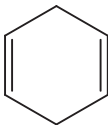
- 15 Which of the following compounds could be formed when dichloromethane is reacted with excess bromine in the presence of sunlight?
- A  $\text{H}_2$  and  $\text{CHCl}_2\text{Br}$   
 B  $\text{CHCl}_2\text{Br}$  and  $\text{CCl}_2\text{BrCHCl}_2$   
 C  $\text{CHCl}_2\text{Br}$  and  $\text{CH}_2\text{ClCCl}_2\text{Br}$   
 D  $\text{CCl}_2\text{BrCHCl}_2$  and  $\text{CH}_2\text{ClCCl}_2\text{Br}$
- 16 Ethane reacts with chlorine in the presence of ultraviolet light to form a mixture of products. Which of the following statements is **false** regarding this reaction?
- A Both initiation and propagation steps involve homolytic fission.  
 B Both initiation and propagation steps produce chlorine radicals.  
 C Both propagation and termination steps produce hydrogen chloride.  
 D Both propagation and termination steps involve C–Cl bond formation.
- 17 Compound **W** is produced when ethene reacts with bromine in the presence of concentrated aqueous potassium nitrate,  $\text{KNO}_3$ .

Compound **W**:



Which one of the following could be the intermediate formed in this reaction?

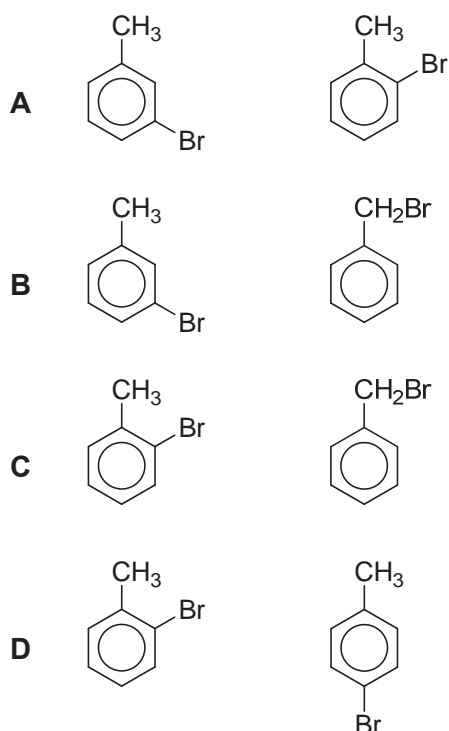


- 18 Which alkene gives ethanoic acid as the only product when treated with hot acidified potassium manganate(VII)?
- A  $\text{CH}_3\text{CH}=\text{CHCH}_3$   
 B  $(\text{CH}_3)_2\text{C}=\text{CHCH}_3$   
 C  $(\text{CH}_3)_2\text{C}=\text{C}(\text{CH}_3)_2$   
 D 

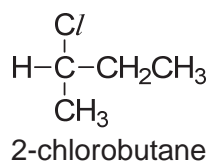
19 Methylbenzene is nitrated by a mixture of concentrated nitric acid and concentrated sulfuric acid. Which of the following statement about this reaction is correct?

- A The mechanism is nucleophilic substitution.
- B The major product is 3-nitromethylbenzene.
- C The electrophile is  $\text{NO}_3^-$  ion.
- D Concentrated sulfuric acid acts as the catalyst in this reaction.

20 When methylbenzene is treated with bromine in the presence of a catalyst and in the dark, a mixture of two monobromo isomers is formed. What are the structures of these two isomers?

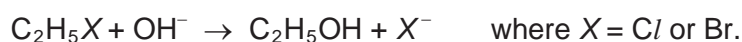


21 How many possible alkenes (including *cis-trans* isomers) can be obtained when 2-chlorobutane is heated under reflux with alcoholic KOH?



- A 1                      B 2                      C 3                      D 4

**22** Consider the following reaction:



Which of the following statements is true?

- A** The reaction takes place more rapidly when  $\text{X}$  is  $\text{Cl}$  than when  $\text{X}$  is  $\text{Br}$  because  $\text{Cl}^-$  has more exothermic enthalpy change of hydration than  $\text{Br}^-$ .
- B** The reaction takes place more rapidly when  $\text{X}$  is  $\text{Cl}$  than when  $\text{X}$  is  $\text{Br}$  because  $\text{C}-\text{Cl}$  bond is more polar than  $\text{C}-\text{Br}$  bond.
- C** The reaction takes place more rapidly when  $\text{X}$  is  $\text{Br}$  than when  $\text{X}$  is  $\text{Cl}$  because  $\text{Br}^-$  is a better nucleophile than  $\text{Cl}^-$ .
- D** The reaction takes place more rapidly when  $\text{X}$  is  $\text{Br}$  than when  $\text{X}$  is  $\text{Cl}$  because  $\text{C}-\text{Br}$  bond is weaker than  $\text{C}-\text{Cl}$  bond.

### Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct. (You may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1</b> , <b>2</b> and <b>3</b> are correct	<b>1</b> and <b>2</b> only are correct	<b>2</b> and <b>3</b> only are correct	<b>1</b> only is correct

No other combination of statements is used as a correct response.

**23** Which statements about a 2.0 g sample of  $^4\text{He}$  are correct?

- 1** The number of atoms is the same as the number of oxygen atoms in  $24 \text{ dm}^3$  of oxygen gas at r.t.p.
- 2** The number of atoms is the same as the number of ions in 20.29 g of aqueous iron(III) chloride.
- 3** The number of atoms is the same as the number of electrons in 0.5 g of hydrogen gas.

**24**  $\text{AlCl}_3$  and  $(\text{CH}_3)_3\text{N}$  reacts in a 1:1 ratio. Which of the following statements are correct?

- 1**  $(\text{CH}_3)_3\text{NAlCl}_3$  is obtained as a product.
- 2** The bonds around  $\text{Al}$  atom in the product are tetrahedrally arranged.
- 3** There is a dative bond from  $\text{Al}$  to  $\text{N}$  in the product.

The responses **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

No other combination of statements is used as a correct response.

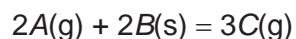
- 25** In which of the following will the enthalpy change of reaction be the same in both processes?

- 1** Combustion of carbon; Formation of carbon dioxide
- 2** Atomization of fluorine; Bond energy of fluorine
- 3** Neutralization of sodium hydroxide; Dissolution of sodium hydroxide

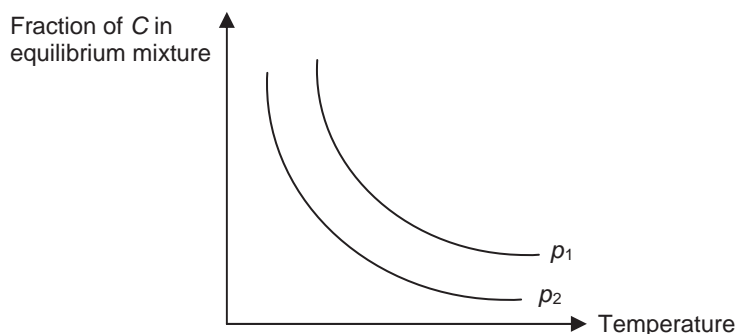
- 26** Which statements about the properties of a catalyst are correct?

- 1** A catalyst increases the average kinetic energy of the reacting particles.
- 2** A catalyst increases the rate of the reverse reaction.
- 3** A catalyst has no effect on the enthalpy change of the reaction.

- 27** *A* and *B* react in a closed vessel to form *C*:



The graph below shows the variation in fraction of *C* in the equilibrium mixture with temperature at two different total pressures,  $p_1$  and  $p_2$ .



Which of the following statements are true?

- 1** The forward reaction is exothermic.
- 2**  $p_2$  is greater than  $p_1$ .
- 3**  $K_p$  increases when the volume of the reaction vessel is increased.



The responses **A** to **D** should be selected on the basis of

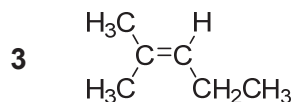
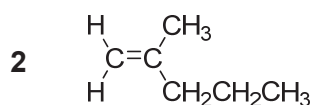
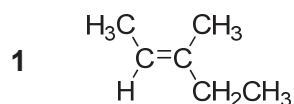
<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

No other combination of statements is used as a correct response.

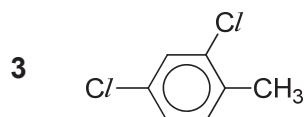
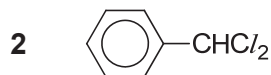
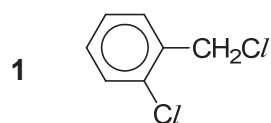
**28** In what ways could two compounds of molecular formula  $C_3H_4Cl/Br$  be related to each other?

- 1** optical isomers
- 2** structural isomers
- 3** geometrical isomers

**29** Which of the following alkenes produces 2-bromo-2-methylpentane as the major organic compound when hydrogen bromide is added to each of them?



**30** A liquid **L**,  $C_7H_6Cl_2$ , gives a white precipitate when shaken for some time with ethanolic silver nitrate. Which of the following could be **L**?



~ End of Paper ~

2010 C1 H2 Chemistry Promotional Examination Paper 1 Answers

1	D	16	C
2	C	17	D
3	A	18	A
4	C	19	D
5	D	20	D
6	D	21	C
7	A	22	D
8	A	23	C
9	B	24	B
10	A	25	D
11	B	26	C
12	A	27	B
13	B	28	A
14	C	29	C
15	B	30	B



**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**10S**

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**CHEMISTRY**

**9647/02**

Paper 2 Section A

**7 October 2010**

Structured Questions

**1 hour**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet.

---

**INSTRUCTIONS TO CANDIDATES**

- 1) Write your **name** and **CT class** clearly in the spaces at the top of this page.
- 2) Answer **all** questions in the spaces provided in this Question Booklet.

**INFORMATION FOR CANDIDATES**

The number of marks is given in brackets [ ] at the end of each question or part question.

A *Data Booklet* is provided.

You may use a calculator.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use	
1	/ 14
2	/ 9
3	/ 8
4	/ 9
Total	/ 40

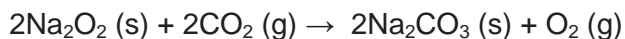
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This document consists of **10** printed pages

**Section A – Structured Questions [40 marks]**

Answer all the questions in the spaces provided.

- 1 (a) Sodium peroxide,  $\text{Na}_2\text{O}_2$ , is used in submarines for absorbing atmospheric carbon dioxide and regenerating oxygen. The reaction produces sodium carbonate as a by-product.



- (i)  $\text{Na}_2\text{O}_2$  is an ionic compound consisting of  $\text{Na}^+$  and  $\text{O}_2^{2-}$  ions. Draw the dot-and-cross diagram for the  $\text{O}_2^{2-}$  ion.

- (ii) Write the oxidation number of oxygen in each of following compounds:

$\text{Na}_2\text{O}_2$ : .....

$\text{Na}_2\text{CO}_3$ : .....

- (iii) Identify the reactant that underwent disproportionation in the above reaction.

.....

- (iv) A sample of sodium peroxide was completely reacted with excess carbon dioxide. The sodium carbonate formed was reacted with  $50.0 \text{ cm}^3$  of  $1.50 \text{ mol dm}^{-3}$  hydrochloric acid (in excess). Any carbon dioxide in the solution was removed.  $10.0 \text{ cm}^3$  of the resultant solution required  $23.0 \text{ cm}^3$  of  $0.50 \text{ mol dm}^{-3}$  sodium hydroxide for neutralization.

Calculate the mass of the sodium peroxide in the sample.

[6]

- (b)** When air is inhaled by a person in the submarine, it enters the alveoli of the lungs. Varying amounts of the component gases exchange with dissolved gases in the blood. The resulting composition of the alveolar gas mixture is quite different from that of the submarine atmospheric mixture.

The following table presents data on the composition of four gases in the submarine atmosphere and in the alveoli.

gas	submarine atmosphere/ % by mol	alveoli/ % by mol
N <sub>2</sub>	78.6	74.7
O <sub>2</sub>	20.9	13.8
CO <sub>2</sub>	0.04	5.3
H <sub>2</sub> O	0.46	6.2

- (i)** Suggest a reason for the difference in the percentage composition of oxygen in the submarine atmosphere and in the alveoli.

.....  
 .....

- (ii)** Given that the total pressure of alveolar gas mixture is 760 Torr, calculate the partial pressure of oxygen (in Torr) in the alveoli.

- (iii)** The volume of the alveolar gas mixture at 37.0 °C is 500 cm<sup>3</sup>.

Calculate the amount of O<sub>2</sub> molecules in the alveolar gas mixture, assuming that the total pressure of the mixture remains at 760 Torr.  
 (760 Torr = 1.01 × 10<sup>5</sup> Pa)

**[4]**

- (c) Blood plasma, which constitutes 55% of blood, is mostly made up of water. Water functions as a solvent for the nutrients needed by the body. Some of these nutrients are soluble in water through hydrogen bond formation.

- (i) Describe the requirements needed for two molecules to form a hydrogen bond between them.

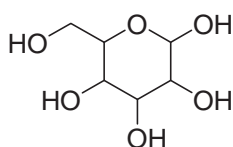
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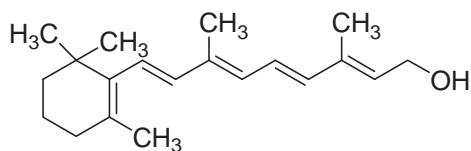
- (ii) Glucose is an example of a water-soluble nutrient needed by the body.

On the diagram given below, draw one of the hydrogen bonds formed between a glucose molecule and water, showing clearly which atoms take part in the intermolecular interaction.



glucose

- (iii) Vitamin A is another nutrient needed by the body. However, it is insoluble in water.



vitamin A

Explain why vitamin A is insoluble.

.....

.....

[4]

[total: 14]

- 2 (a)** Under suitable conditions, methane reacts with chlorine to form chloromethane,  $\text{CH}_3\text{Cl}$ , which was once widely used as a refrigerant. However, due to its toxicity, chloromethane is no longer present in consumer products.

**(i)** Name the mechanism for the reaction between methane and chlorine.

.....

**(ii)** Write two equations to show the propagation steps of the chlorination of methane to form chloromethane.

**(iii)** Suggest and explain suitable reaction condition which maximizes the production of chloromethane.

.....

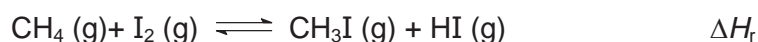
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**[4]**

- (b)** In contrast, the iodination of methane is not a useful reaction as it is a reversible process. The reaction is often carried out in the presence of oxidising agents such as iodic acid,  $\text{HIO}_3$ , to increase the yield of iodomethane,  $\text{CH}_3\text{I}$ .



**(i)**  $\text{HIO}_3$  is known to react with  $\text{HI}$  to produce  $\text{I}_2$  as the only iodine-containing product. Suggest why the use of  $\text{HIO}_3$  increases the yield of  $\text{CH}_3\text{I}$  during the iodination of methane.

.....

.....

.....

- (ii) Given the data below, construct an energy cycle and use it to determine the enthalpy change of reaction,  $\Delta H_r$ , for the iodination of methane.

Standard enthalpy change of formation of  $\text{CH}_4(\text{g}) = -74.6 \text{ kJ mol}^{-1}$   
 Standard enthalpy change of formation of  $\text{CH}_3\text{I}(\text{g}) = +14.4 \text{ kJ mol}^{-1}$   
 Standard enthalpy change of formation of  $\text{HI}(\text{g}) = +26.5 \text{ kJ mol}^{-1}$   
 Standard enthalpy change of sublimation of  $\text{I}_2(\text{s}) = +62.4 \text{ kJ mol}^{-1}$

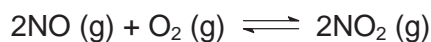
- (iii) Given that the entropy change of reaction,  $\Delta S_r$ , for the iodination of methane is  $+13.7 \text{ J mol}^{-1} \text{ K}^{-1}$ , determine the minimum temperature at which the reaction becomes spontaneous.

[5]

[Total: 9]



- 3 (a) Nitrogen monoxide gas (NO) is an air pollutant produced by cigarette smoke, automobile engines and power plants. It reacts with oxygen to form NO<sub>2</sub> (g).



The kinetics of the reaction was studied and the following results were obtained.

Experiment	Initial concentrations / mol dm <sup>-3</sup>		Initial rate of formation of NO <sub>2</sub> / mol dm <sup>-3</sup> s <sup>-1</sup>
	[NO]	[O <sub>2</sub> ]	
1	0.001	0.001	7.0 × 10 <sup>-6</sup>
2	0.001	0.002	1.4 × 10 <sup>-5</sup>
3	0.002	0.003	8.4 × 10 <sup>-5</sup>

Deduce the order of reaction with respect to each of the reactants, hence write the rate equation for the reaction.

[3]

- (b) The following table provides data on how the equilibrium constant,  $K_p$ , of the reaction in (a) varies with temperature.

Temperature/ K	ln $K_p$
300	28.27
400	21.20
500	16.96
600	14.14

- (i) Write the  $K_p$  expression for the above equilibrium.

- (ii) Using the data provided, deduce whether the forward reaction is exothermic or endothermic. Explain your reasoning.

.....

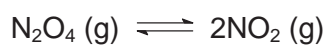
.....

.....

.....

[3]

- (c)  $\text{NO}_2(\text{g})$  can also be formed from the dissociation of  $\text{N}_2\text{O}_4(\text{g})$ .

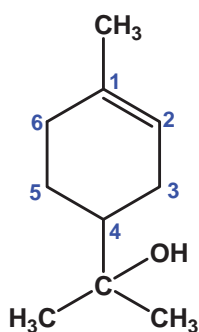


At a certain temperature and an equilibrium pressure of 2 atm,  $\text{N}_2\text{O}_4(\text{g})$  is 40.0% dissociated.

Calculate the equilibrium constant,  $K_p$ , at this temperature, giving its units.

[2]  
[total: 8]

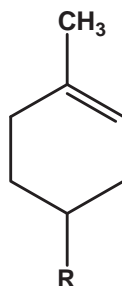
- 4  $\alpha$ -terpineol is a volatile oil obtained by distillation from the leaves of the myrtaceous tree. The structure of  $\alpha$ -terpineol is given below:



- (a) State the type of hybridisation exhibited by carbon-4 in  $\alpha$ -terpineol. Sketch the hybrid orbitals around it, showing the correct orientation.

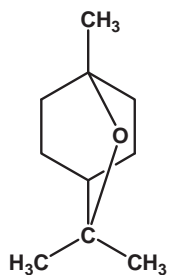
[2]

- (b)  $\alpha$ -terpineol reacts with HBr readily. Name and outline the reaction mechanism for the reaction between  $\alpha$ -terpineol and HBr for the formation of the major product. You may use the following structure to represent  $\alpha$ -terpineol when you draw the mechanism:



[3]

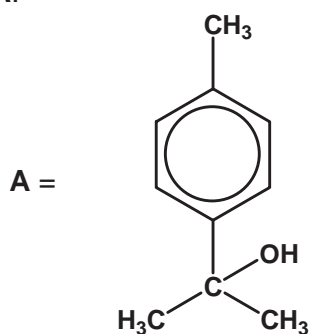
- (c) In the reaction of  $\alpha$ -terpineol with HBr, a side product, cineole, with the following structure is obtained:



Suggest how cineole could be formed.

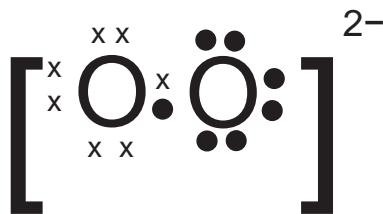
- (d) Give the structural formula of the organic product when  $\alpha$ -terpineol is heated with concentrated acidified potassium manganate (VII). (Note that the alcohol on the side chain is resistant to oxidation.) [1]

- (e) Describe a simple chemical test to distinguish between  $\alpha$ -terpineol and the following compound **A**: [1]



[2]  
[total: 9]

1ai)



[1]

ii)  $\text{Na}_2\text{O}_2$ : -1 $\text{Na}_2\text{CO}_3$ : -2

[1]

iii)  $\text{Na}_2\text{O}_2$  [1]iv) Number of moles of NaOH used =  $23/1000 \times 0.5 = 0.0115 \text{ mol}$ Number of moles of HCl in excess in  $50 \text{ cm}^3 = 5 \times 0.0115 = 0.0575 \text{ mol}$  [1]Number of moles of HCl reacted with carbonate =  $50/1000 \times 1.5 - 0.0575 = 0.0175 \text{ mol}$  [1]Number of moles of sodium carbonate formed =  $0.5 \times 0.0175 = 0.00875 \text{ mol}$   
= number of moles of sodium peroxideMass of sodium peroxide in sample =  $0.00875 \times (2 \times 23.0 + 2 \times 16.0) = 0.683 \text{ g}$  [1]  
[ecf allowed – only if working is shown]

bi) Any possible reason - [1]

- some oxygen molecules have dissolved in the blood
- some oxygen molecules are consumed by the body
- some oxygen molecules are bonded to the haemoglobin

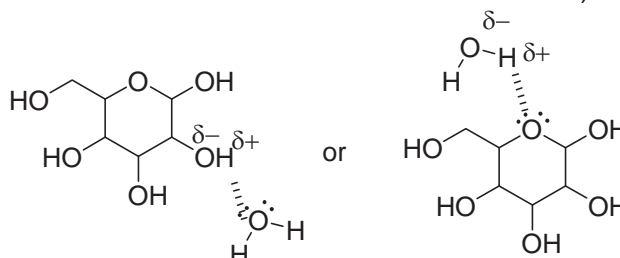
ii) Partial pressure of  $\text{O}_2$  in alveolar gas mixture =  $(13.8/100 \times 760) = 105 \text{ Torr}$  [1]iii)  $pV = nRT$   
 $(105/760 \times 1.01 \times 10^5) \times 500 \times 10^{-6} = n \times 8.31 \times (37.0 + 273)$   
 $n_{\text{O}_2} = 2.71 \times 10^{-3} \text{ mol}$ [1] – use of  $pV = nRT$  equation & correct substitution

[1] – numerical answer and unit (ecf for answer)

ci) Requirements: presence of lone pair on electronegative O, N or F atom in one molecule [1] and  
presence of hydrogen atom bonded to electronegative O, N or F atom in the other molecule. [1]

(-1 m if student does not mention about molecules in their answer)

ii)



Any reasonable hydrogen bond with relevant lone pair and partial charges shown [1]

iii) Vitamin A is not soluble in water as its large non-polar hydrocarbon group is not able to form favourable interactions with polar water molecule. (or anything to this effect) [1]

[-1 m overall for no units or wrong s.f. in Q1]

2 (a) (i) Free radical substitution [1]

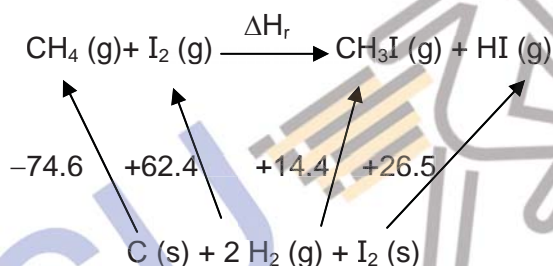


(iii) Use excess methane or limited chlorine [1]

This maximises the probability that the chlorine radical attack methane / minimizes the probability that the chlorine radical will attack  $\text{CH}_3\text{Cl}$  or  $\text{CH}_3\text{Cl}_2$  [1] because their concentrations will always be relatively small.

(b) (i) The reaction between  $\text{HIO}_3$  and  $\text{HI}$  would lower the concentration of  $\text{HI}$  / increase the concentration of  $\text{I}_2$ . This causes the equilibrium to shift forward [1], hence increasing the yield of  $\text{CH}_3\text{I}$ .

(ii)



[1]: Correct energy cycle with state symbols. Deduct 0.5m for wrong or no state symbols

$$\Delta H_r = -(-74.6) - (+62.4) + 14.4 + 26.5 = +53.1 \text{ kJ mol}^{-1}$$

[1]: Correct working based on energy cycle. Allow ecf. [If no sign, 0m]

[2]

(iii)  $\Delta H_r - T\Delta S_r \leq 0$

$$T \geq \frac{\Delta H_r}{\Delta S_r} = \frac{+53.1}{+0.0137}$$

[1]: Allow ecf from answer in part b(iii)

$$= 3.88 \times 10^3 \text{ K} \quad \text{or} \quad 3607^\circ\text{C} \quad [1]$$

0m if student didn't convert  $\Delta S_r$  into  $\text{kJ mol}^{-1} \text{ K}^{-1}$

No penalty if student used =, < or > signs instead of  $\leq$  or  $\geq$

[2]

3 (a)

Comparing Experiment 1 and 2, when  $[O_2]$  doubles, the rate doubles  
 $\Rightarrow 1^{\text{st}}$  order w.r.t  $O_2$  [1] – mark not awarded if working not shown

Comparing Experiment 1 and 3,

$$\frac{8.4 \times 10^{-5}}{7 \times 10^{-6}} = \frac{(0.002)^m (0.003)}{(0.001)^m (0.001)}$$

$$m = 2$$

Order of reaction w.r.t NO  $\Rightarrow 2^{\text{nd}}$  order. [1] – mark not awarded if working not shown

Rate equation: Rate =  $k[NO]^2[O_2]$  [1] – allow for ecf

(b)

(i)

$$K_p = \frac{(P_{NO_2})^2}{(P_{NO})^2 (P_{O_2})} \quad [1]$$

(ii)

As temperature increases, the value of the equilibrium constant decreases. This suggests that the backward reaction is favoured as temperature increases.

By Le Chatelier's Principle, when temperature increases, the system will offset the increase in temperature by favouring the endothermic reaction that absorbs heat. As the backward reaction is favoured, the backward reaction is endothermic, making the forward reaction exothermic.

[1] – deduction

[1] – reasoning

M,B (c)

	$N_2O_4$ (g)	=	$2NO_2$ (g)
Initial/ mol	1		
Change/ mol	- 0.4		+0.8
Equilibrium/ mol	0.6		0.8
Partial Pressure	$\frac{0.6}{1.4} \times 2$ = 0.8571		$\frac{0.8}{1.4} \times 2$ = 1.1429

[1]

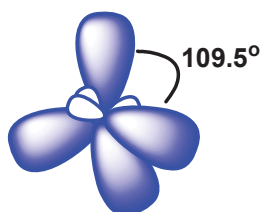
$$K_p = \frac{\left(\frac{0.8}{1.4} \times 2\right)^2}{\frac{0.6}{1.4} \times 2} = 1.52 \text{ atm} \quad [1] \quad [- \frac{1}{2} \text{ if no units}]$$

[total: 8 m]

4

(a)  $sp^3$ 

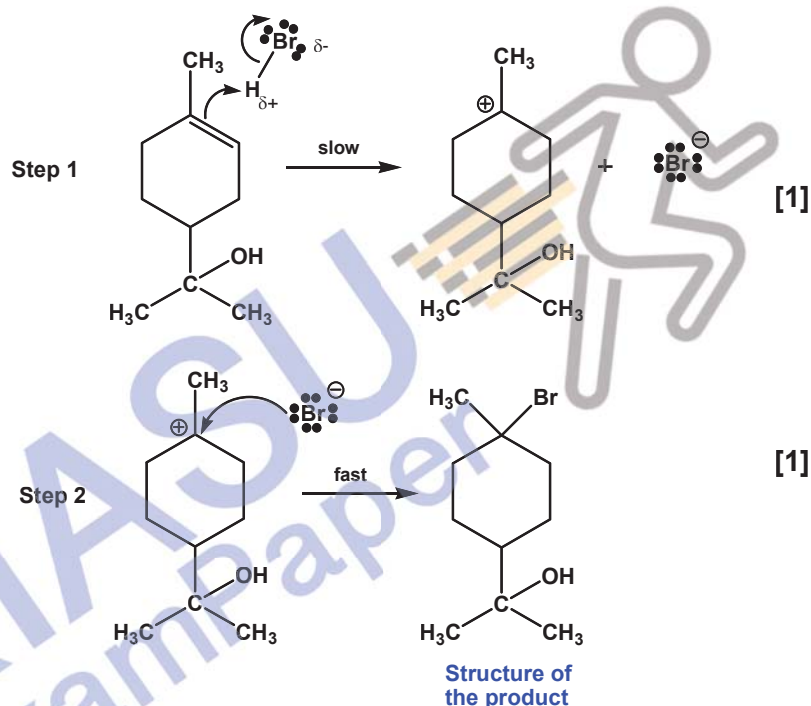
[1]



[1]

Requirement: 4 orbitals, each with one big and one small lobe. The shape must be correct. [angle **need not** be shown]

(b) Name of Mechanism: Electrophilic Addition [1]



[- ½ mark each for any missing items:  $\delta^+/\delta^-$ ; curly arrows, lone pair on  $\text{Br}^-$  in step 2 (lone pair on Br in step 1 not required); slow/fast. Each item penalize only once, max penalty is -2.]

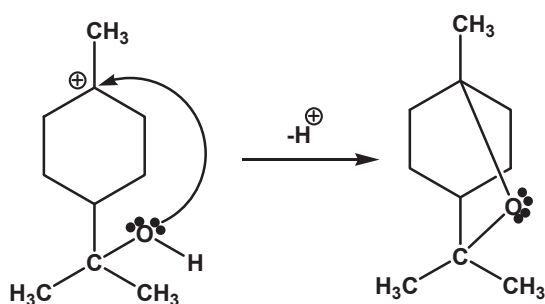
Accept answers that use the short hand notation (as suggested by the question) or the structural formula of  $\alpha$ -terpineol (as shown above)

(c) The hydroxyl group is nucleophilic and it will attack the carbocation in place of the bromide anion. [1]

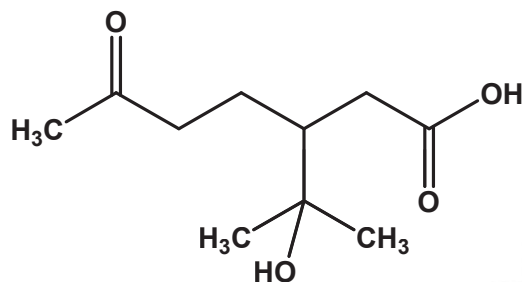
Note: Any explanations with the above meaning and makes chemical sense will earn the 1 mark.

If students show mechanism, their answer should be as follow:





(d)



[1]

Note: Accept both skeletal and full structural formula.

(e) Use bromine(aq)/liquid bromine in the dark/bromine in  $\text{CCl}_4$  in the dark. [1]

$\alpha$ -terpineol: Yellow orange  $\text{Br}_2(\text{aq})^*$  decolourised.

[1]

**A:** Yellow orange  $\text{Br}_2(\text{aq})^*$  is not decolourised.

\* OR reddish brown liquid bromine or bromine in  $\text{CCl}_4$



**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**10S**

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**CHEMISTRY**

**9647/02**

Paper 2 Section B

**7 October 2010**

Free Response

**1 hour**

Candidates answer on separate paper.

Additional Materials: Answer Paper

Data Booklet.

---

**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Answer any **two** questions.

Begin each question on a **new** piece of paper.

A *Data Booklet* is provided.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.

**Write down** the question numbers for the questions that you have attempted on the cover page provided.

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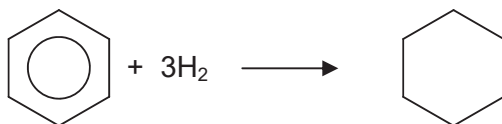
This document consists of **6** printed pages

## Section B – Free Response Questions [40 marks]

Answer 2 out of 3 questions.

- 1 (a) The enthalpy change of hydrogenation of an unsaturated hydrocarbon is the enthalpy change when one mole of the compound reacts completely with hydrogen to form a saturated hydrocarbon.

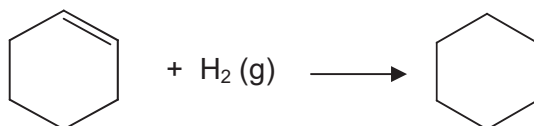
The equation for the hydrogenation of benzene is as follows:



- (i) Using the enthalpy change of combustion data in the following table, calculate the enthalpy change of hydrogenation of benzene.

Substance	$\Delta H_c / \text{kJ mol}^{-1}$
Benzene, $\text{C}_6\text{H}_6 (l)$	–3268
Cyclohexane, $\text{C}_6\text{H}_{12} (l)$	–3920
Hydrogen, $\text{H}_2 (g)$	–286

- (ii) By using appropriate bond energy data from the *Data Booklet*, calculate another value for the enthalpy change of hydrogenation of benzene.
- (iii) Suggest **two** reasons for the discrepancy between the values calculated in (i) and (ii).
- (iv) The enthalpy change of hydrogenation of cyclohexene is  $-120 \text{ kJ mol}^{-1}$ .



A student did a simple calculation using this data and proposed the enthalpy change of hydrogenation of benzene to be  $-360 \text{ kJ mol}^{-1}$ .

Draw a structure of benzene that the student used to arrive at his answer.

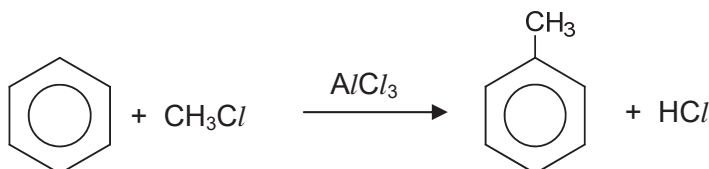
Explain the discrepancy between the student's value and the enthalpy change calculated in (i), based on the structure and stability of benzene.

[8]

- (b) (i) Benzene reacts with chlorine in the presence of  $AlCl_3$  catalyst to form chlorobenzene.

Describe the mechanism of the reaction under these conditions.

- (ii) Benzene reacts with  $CH_3Cl$  in the presence of  $AlCl_3$  catalyst to form methylbenzene, as shown in the following equation.



The reaction follows a two-step mechanism, similar to that for the chlorination of benzene.

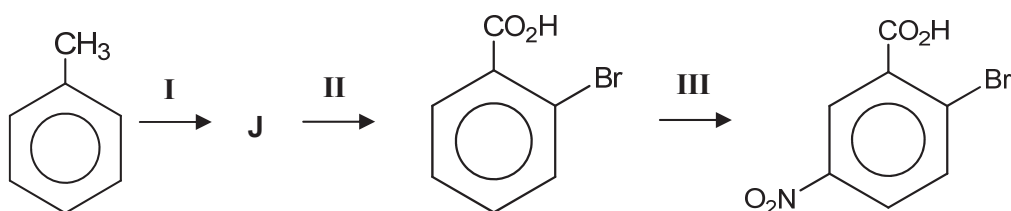
Suggest the structures of the electrophile and the intermediate ion involved in the reaction mechanism.

- (iii) The Lewis acid catalyst,  $AlCl_3$ , is a solid which sublimes at  $178^\circ\text{C}$ .  $AlF_3$ , on the other hand, is a solid which melts at  $1291^\circ\text{C}$ .

Account for the difference in melting points of these two compounds in terms of structure and bonding.

[8]

- (c) Methylbenzene can be used as a starting reagent in the following synthesis.



- (i) Draw the structural formulae of the intermediate J.
- (ii) Suggest reagents and conditions for step I, II and III.

[4]

[total: 20]

2 This question is about nitrogen and its oxides.

- (a) (i)  $\text{N}^{3-}$  is *isoelectronic* with  $\text{F}^-$  and  $\text{Na}^+$ . Define the term *isoelectronic*.  
 (ii) Sketch a graph of the successive ionisation energies of all the electrons of a nitrogen atom. [3]

- (b)  $\text{N}_2\text{O}_3$  is a pale blue solid at very low temperatures. As the temperature is raised,  $\text{N}_2\text{O}_3$  dissociates to form colourless NO and brown  $\text{NO}_2$ . The interesting feature of this reaction is that both products are molecular radicals, each with an unpaired electron on the nitrogen atom.



Draw the dot-and-cross diagram for  $\text{N}_2\text{O}_3$ , stating the shapes and bond angles about each N atom. [3]

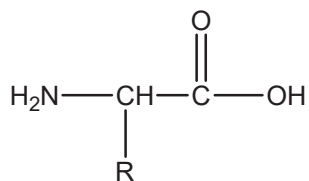
- (c) On warming 2 moles of solid  $\text{N}_2\text{O}_3$  in a  $1.5 \text{ dm}^3$  container, an equilibrium was established at a temperature of 18.1 K. The partial pressure of  $\text{NO}_2$  at equilibrium was found to be 50 kPa.

- (i) Write an expression for the equilibrium constant,  $K_c$ , for this reaction.  
 (ii) Calculate the number of moles of  $\text{NO}_2$  at equilibrium.  
 (iii) Determine the value of  $K_c$ , stating its units. [4]

- (d) (i) State Le Chatelier's Principle.  
 (ii) Sketch a graph of percentage dissociation of  $\text{N}_2\text{O}_3$  against each of the following properties:  
**I** Pressure  
**II** Temperature  
 (iii) A student wrote the following in his exam script: "When an extra 2 moles of solid  $\text{N}_2\text{O}_3$  are added to the equilibrium mixture in part (c), the brown colour in the container intensified." State and explain the error in his reasoning.

[5]

- (e) Nitrogen monoxide is an important signaling molecule in the human physiology and is produced when the amino acid, L-arginine, is converted to another amino acid, L-citrulline. The abbreviated structure of L-citrulline is given below:



L-citrulline



Using the abbreviated structure, state and illustrate the type of stereoisomerism exhibited by L-citrulline. [2]

- (f)  $\text{NO}_2$  was found to catalyse the isomerisation of alkenes. Draw the structures of the three alkenes that may be formed by the isomerisation of but-1-ene. [3]

[total: 20]

- 3 (a) Ethanedioic acid,  $(\text{CO}_2\text{H})_2$ , is an organic acid which can be oxidized by acidified  $\text{KMnO}_4$  to  $\text{CO}_2$ , while reducing the manganate(VII) to  $\text{Mn}^{2+}$ . In an experiment, a sample of ethanedioic acid was reacted with excess acidified  $\text{KMnO}_4$ . The  $\text{CO}_2$  collected was found to occupy  $53.60 \text{ cm}^3$  at room temperature and pressure.

(i) Write a balanced equation for the reaction between ethanedioic acid and the  $\text{MnO}_4^-$  ions in acidic conditions.

(ii) Calculate the amount of ethanedioic acid present in the sample.

[2]

- (b) The reaction between ethanedioic acid and excess acidified potassium manganate(VII) is slow at room temperature and only proceeds at a reasonable rate at  $60^\circ\text{C}$ . Dilute sulfuric acid is used to acidify the solution. This is an example of an autocatalytic reaction.

(i) Explain what is meant by an *autocatalytic* reaction.

(ii) In the experiment described in (a), the volume of  $\text{CO}_2$  gas liberated was recorded over a period of time. Sketch a graph of volume of  $\text{CO}_2$  collected against time from the moment of mixing the reactants to the completion of the reaction.

(iii) Suggest why dilute sulfuric acid, and not dilute hydrochloric acid, is used in this reaction.

(iv) In this experiment, the kinetics appeared to be zero order with respect to the  $\text{MnO}_4^-$  ion. Suggest a reason for this.

(v) Explain, with the aid of a sketch of the Boltzmann distribution, why a temperature of  $60^\circ\text{C}$  is necessary for the reaction to proceed at a reasonable rate compared to room temperature.

[9]

- (c) There are many structural isomers with the formula  $\text{C}_6\text{H}_{10}$ . Two of them, **A** and **C**, are described below.

**A** reacts with bromine in  $\text{CCl}_4$  in the dark to form a compound **B**,  $\text{C}_6\text{H}_{10}\text{Br}_2$ . **B** has two chiral carbons. **A** reacts with hot, acidified  $\text{KMnO}_4$ , to form hexanedioic acid,  $(\text{HO}_2\text{C})\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2(\text{CO}_2\text{H})$ .

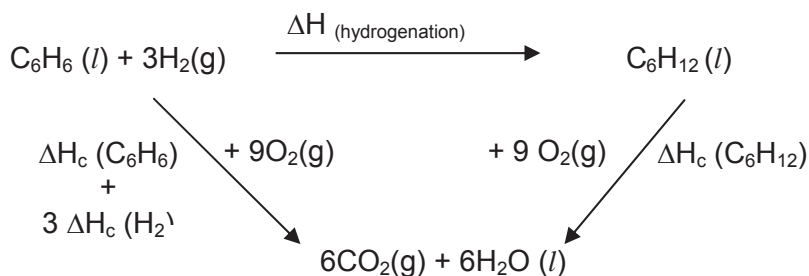
One mole of **C** reacts with 2 moles of bromine in  $\text{CCl}_4$  in the dark. In the reaction of **C** with hot, acidified  $\text{KMnO}_4$ ,  $\text{CO}_2$  gas is given off and ethanoic acid,  $\text{CH}_3\text{CO}_2\text{H}$ , is the only organic product formed. **C** also exhibits stereoisomerism.

Deduce and draw the structures of **A**, **B** and all possible stereoisomers of **C**. Your answers should include (i) the type of reaction for each of the reactions described, and (ii) the functional group or organic structure responsible for each reaction.

[9]

[total: 20]

1 (a) (i)



$$\begin{aligned}
 \Delta H_{\text{(hydrogenation)}} &= -3268 + 3(-286) - (-3920) \\
 &= \underline{\underline{-206 \text{ kJ mol}^{-1}}}
 \end{aligned}$$

Formula (in words or show substitution) or cycle [1]  
 Final ans, allow ECF [1]

No answer mark if wrong sign or wrong units.

$$\begin{aligned}
 \text{(ii)} \quad \Delta H_{\text{(hydrogenation)}} &= [6(520) + 6(410) + 3(436)] - [6(350) + 12(410)] \quad [1] \\
 &= \underline{\underline{-132 \text{ kJ mol}^{-1}}} \quad [1] \quad [\text{no ecf allowed}]
 \end{aligned}$$

No answer mark if wrong sign or wrong units.

- (iii) In order to use bond energy values in (ii), all the bonds have to be 'gaseous'. For the combustion equation in (i), benzene and cyclohexane are in the liquid state. [1]

The bond energies given in the Data Booklet are the average bond energies of that particular covalent bond in different types of molecules. [1]

(iv)



[1]

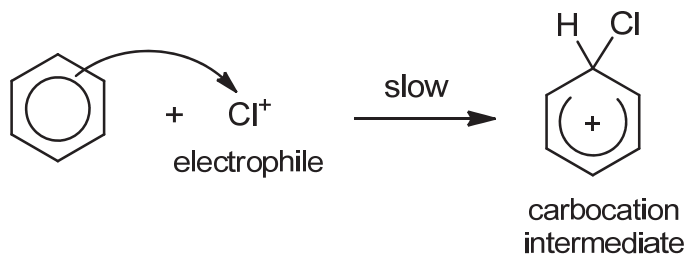
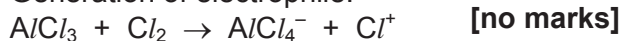
The extra stability of benzene is due to the delocalized  $\pi$  electron cloud which stabilizes the benzene ring. [1]

[8]

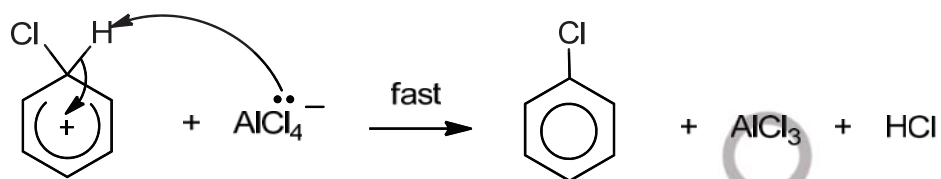


## 1 (b) (i) Electrophilic substitution [1]

Generation of electrophile:



[1]



[1]

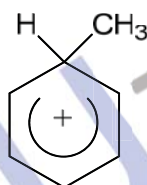
[2]

Any error -0.5 mark

(ii)



[1]



[1]

(iii)  $\text{AlF}_3$  has a giant ionic lattice [0.5] with strong electrostatic forces of attraction / ionic bonds between  $\text{Al}^{3+}$  and  $\text{F}^-$  ions [0.5].

$\text{AlCl}_3$  has a simple molecular structure [0.5] with (weak) dispersion forces [0.5] between molecules.

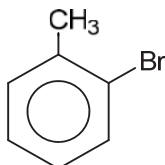
A larger amount of energy [0.5] if required to overcome the stronger [0.5] bonds in  $\text{AlF}_3$ , giving it a high melting point.

(OR

Ionic bonds are much stronger than dispersion forces, therefore more energy is required to break these bonds and the melting point of  $\text{AlF}_3$  is much higher.)

[8]

(c) (i)



[1]

(ii)

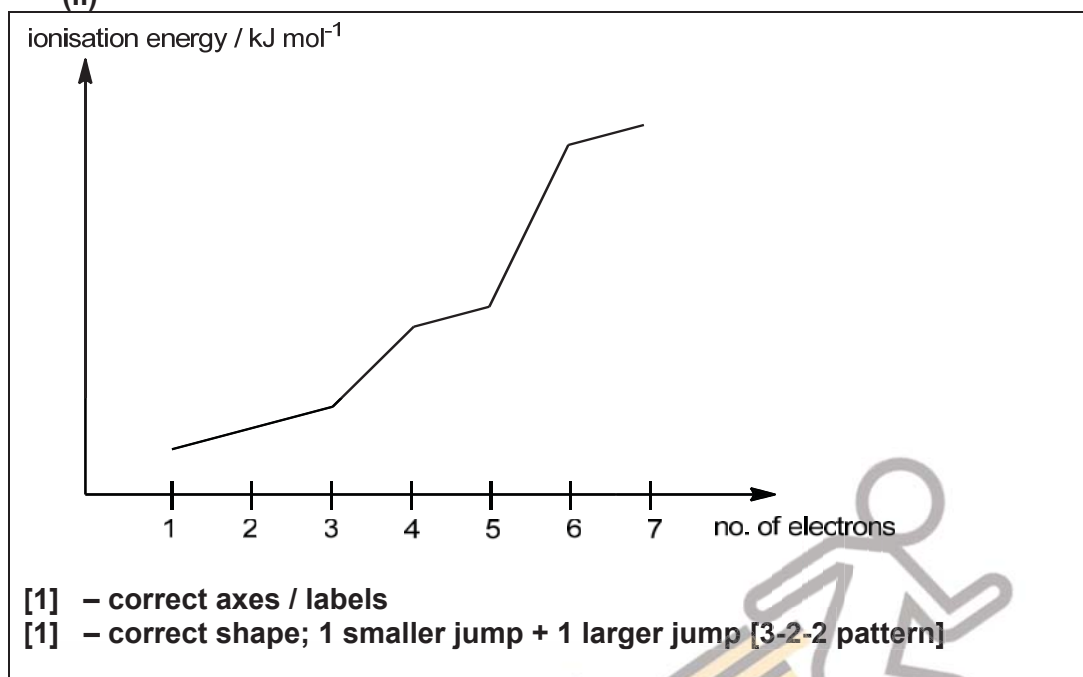
Step I	$\text{Br}_2$ in $\text{CCl}_4$ , $\text{AlBr}_3$ (or Fe or $\text{FeBr}_3$ )	[1]
Step II	$\text{KMnO}_4$ (aq), dil. $\text{H}_2\text{SO}_4$ , heat	[1]
Step III	Concentrated $\text{HNO}_3$ , concentrated $\text{H}_2\text{SO}_4$ , heat (Accept any temperature $> 55^\circ\text{C}$ )	[1]

[4]

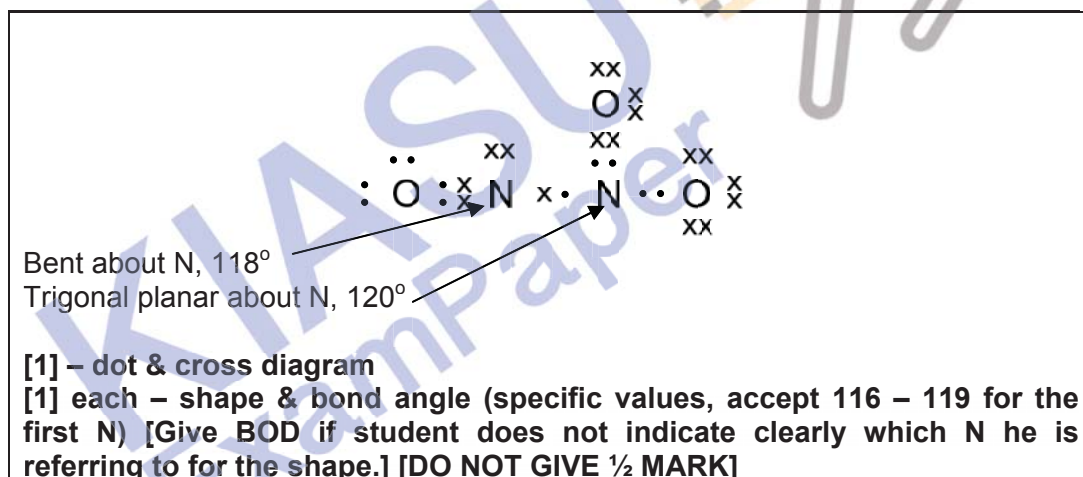
[Total: 20]

2

- (a) (i) Same number of electrons. [1]  
 (ii)



(b)



(c)

(i)  $K_c = [\text{NO}][\text{NO}_2]$  [1]

(ii)  $pV = nRT$   

$$n = \frac{pV}{RT}$$
 [1]  

$$n_{\text{NO}_2} = \frac{50000 \times 1.5 \times 10^{-3}}{8.31 \times 18.1} = 0.500 \text{ mol}$$

(iii) 
$$K_c = \left( \frac{0.500}{1.5} \right)^2 = 0.111 \text{ mol}^2 \text{ dm}^{-6}$$

[1] – correct substitution ( $\div$  vol.) + ans.

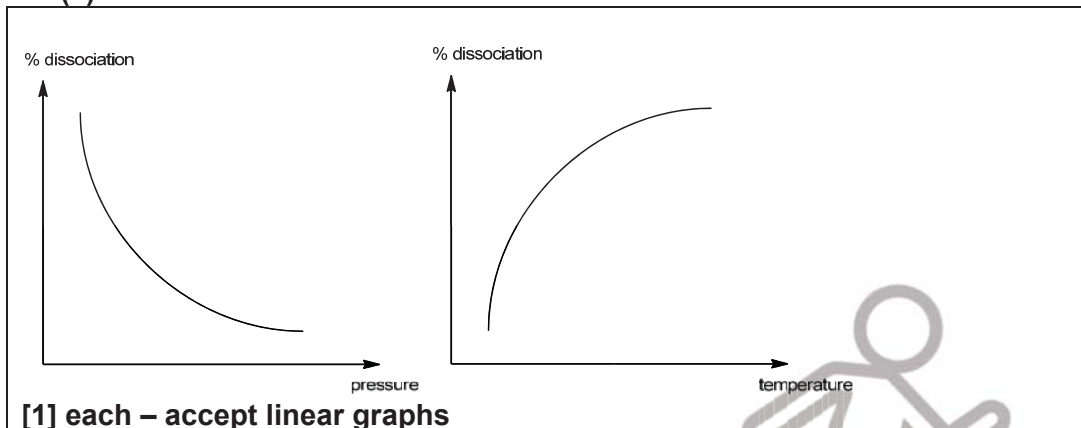
[1] – correct units

Allow ecf from part (c)(ii) for value of  $n$

- 2 (d) (i) Le Chatelier's Principle states that when **a system in equilibrium** is subjected to a **change in conditions** which disturbs the equilibrium, the **position of equilibrium** will **shift** in such a way so as to **reduce** that **change**.

[1] – allow abbreviations, POE, LCP

(ii)



[1] each – accept linear graphs

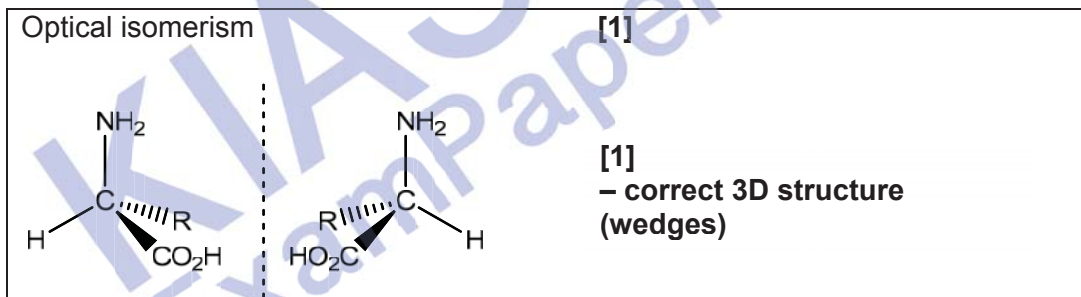
- (iii) A more intense brown colour suggests that the equilibrium position has shifted to the RHS on addition of solid  $N_2O_3$ .

[1] – identify error

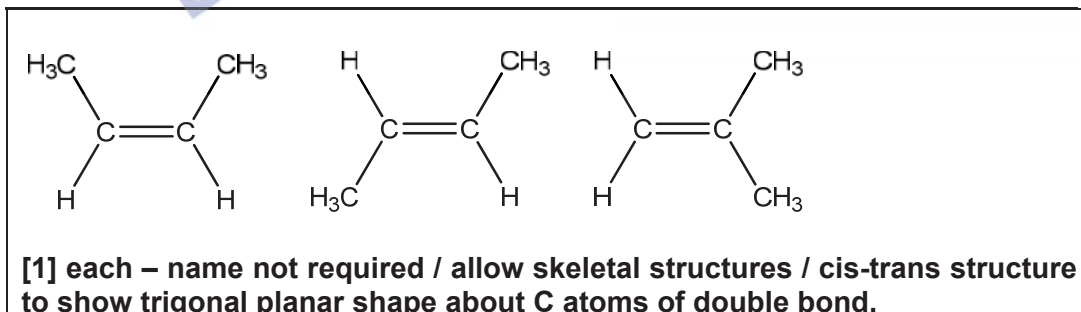
But addition of solid  $N_2O_3$  actually does not affect the equilibrium position as the concentration of a solid is constant (or unity).

[1] – explain

(e)



(f)

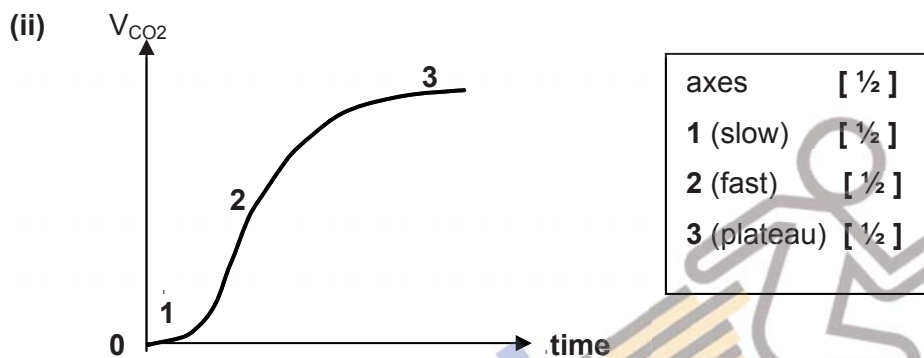


- 3 (a) (i)  $5 (\text{CO}_2\text{H})_2 + 2 \text{MnO}_4^- + 6 \text{H}^+ \rightarrow 10 \text{CO}_2 + 2 \text{Mn}^{2+} + 8 \text{H}_2\text{O}$   
(accept [1])



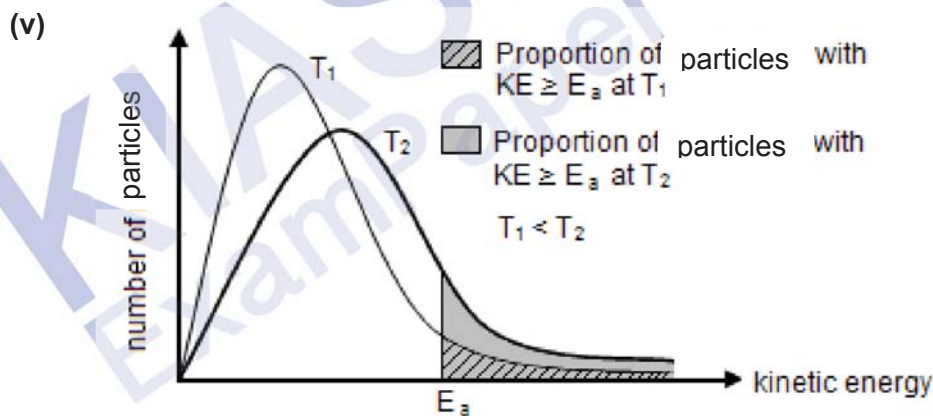
- (ii) No. of moles of  $\text{CO}_2$  collected =  $53.60/24000 = 2.23 \times 10^{-3} \text{ mol}$   
No. of moles of ethanedioic acid present =  $2.23 \times 10^{-3} \times \frac{1}{2}$   
=  $1.12 \times 10^{-3} \text{ mol}$  (ecf allowed) [1]

- (b) (i) An autocatalytic reaction is a reaction where the product formed is a catalyst for the reaction itself. [1]



- (iii) Dilute hydrochloric acid (or  $\text{Cl}^-$ ) will also be oxidized by  $\text{MnO}_4^-$ . [2]  
[1]

- (iv)  $\text{MnO}_4^-$  was in excess. [1]



$T_1$  = room temp

$T_2$  = 333 K

[−½ for every mistake]

diagram [2]

At higher temperature, the average kinetic energy of the particles increases, hence the proportion of ions/particles with kinetic energy  $\geq$  activation energy increases [1]

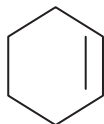
$\Rightarrow$  frequency of effective collisions increases  $\Rightarrow$  rate of reaction increases [1]

[total: 9]

- 3 (c) Reaction with  $\text{Br}_2/\text{CCl}_4$  [1] [do not accept 'addition' only]  
 → electrophilic addition  
 → carbon-carbon double bond (optional: 1 in **A**, 2 in **C**) or alkene present [1]  
**[Do not accept 'double bond' only.]**

**A** only has one C=C bond and forms hexanedioic acid without loss of C upon oxidative cleavage [1] → cyclic alkene

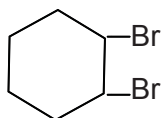
**A** = cyclohexene.



[1]

**B** = 1,2-dibromocyclohexane

[1]

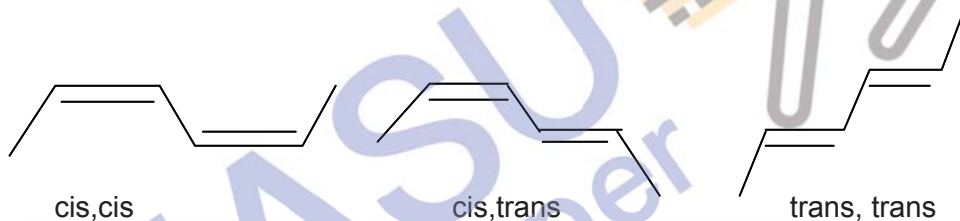


oxidative cleavage [give 1m if not mentioned earlier] of **C** gives

$\text{CO}_2$  → terminal alkene ( $=\text{CH}_2$ ) or  $=\text{CH}-\text{CH}=$  present in **C** [1]

Ethanoic acid formed →  $\text{CH}_3\text{CH}=$  present in **C** [1]

**C** is  $\text{CH}_3\text{CH}=\text{CH}-\text{CH}=\text{CH}-\text{CH}_3$  [1] x 3 (cis, cis; cis,trans; and trans, trans)



[1] x3

(answers need not be in skeletal forms)

(Max 9 of 10)



**HWA CHONG INSTITUTION**  
**C1 PROMOTIONAL EXAMINATION**  
**Higher 2**

CANDIDATE  
NAME

CT GROUP

11

**CHEMISTRY**

**9647/01**

Paper 1 Multiple Choice

**4 October 2011**

**40 min**

Additional Materials: Multiple Choice Answer Sheet

Data Booklet.

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Complete the information on the optical mark sheet (OMS) as shown below.

1. Enter your NAME ( as in NRIC ). \_\_\_\_\_

Write your **name**

2. Enter the SUBJECT TITLE. \_\_\_\_\_

3. Enter the PAPER NUMBER. \_\_\_\_\_

Write your **CT group**

4. Enter your CT GROUP. \_\_\_\_\_

5. Date. \_\_\_\_\_

6. Enter your NRIC NUMBER or  
FIN NUMBER.

7. Now SHADE the corresponding  
lozenge in the grid for  
EACH DIGIT or LETTER

NRIC / FIN											
S	0	0	0	0	0	0	0	0	A	K	U
F	1	1	1	1	1	1	1	1	B	L	V
G	2	2	2	2	2	2	2	2	C	M	W
T	3	3	3	3	3	3	3	3	D	N	X
	4	4	4	4	4	4	4	4	E	O	Y
	5	5	5	5	5	5	5	5	F	P	Z
	6	6	6	6	6	6	6	6	G	Q	
	7	7	7	7	7	7	7	7	H	R	
	8	8	8	8	8	8	8	8	I	S	
	9	9	9	9	9	9	9	9	J	T	

Write and  
shade your  
**NRIC**  
or **FIN number**

There are **twenty-five** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

## Section A

- 1 0.5 g of an oxide  $\text{MO}$  of a hypothetical metal  $\text{M}$  was dissolved in excess dilute sulfuric acid to form  $\text{M}^{2+}$  ions. Given that  $25.0 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  potassium manganate(VII) was required to oxidise all the  $\text{M}^{2+}$  ions to  $\text{M}^{3+}$  ions, what is the relative atomic mass of  $\text{M}$ ?

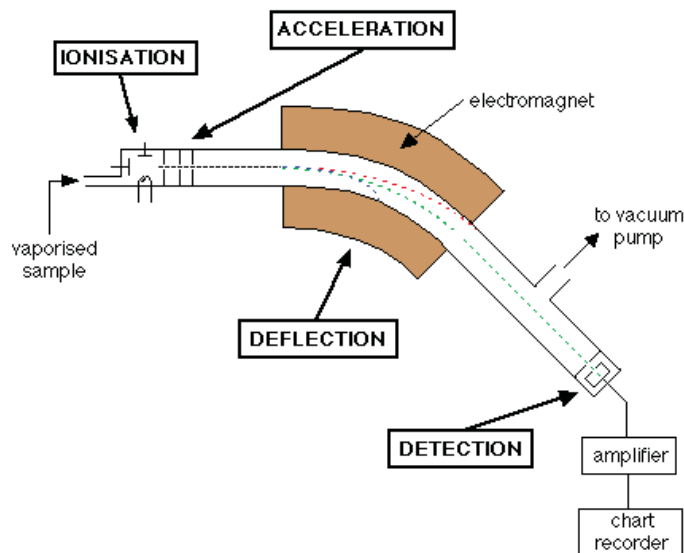
- A 24
- B 40
- C 64
- D 184

- 2 A sample of nitrogen gas was found to have a density of  $1.2472 \text{ g dm}^{-3}$  at s.t.p. Chemically pure nitrogen has a density of  $1.2505 \text{ g dm}^{-3}$  at s.t.p.

Which other gas present in the sample could have caused this discrepancy?

- A Ne
- B Ar
- C NO
- D  $\text{SO}_2$

- 3 Mass spectrometry makes use of a magnetic field to deflect positively charged particles according to their charge to mass ratios. There are four stages in the process, shown in the diagram below:



Which one of the following pieces of information about an element **cannot** be obtained by using a mass spectrometer?

- A relative atomic mass
- B relative masses of the isotopes
- C number of isotopes
- D electron configuration of atoms

- 4 Silicon has a giant covalent structure similar to that of diamond. At room temperature, it is a very poor conductor. However, when heated to higher temperatures, its electrical conductivity increases.

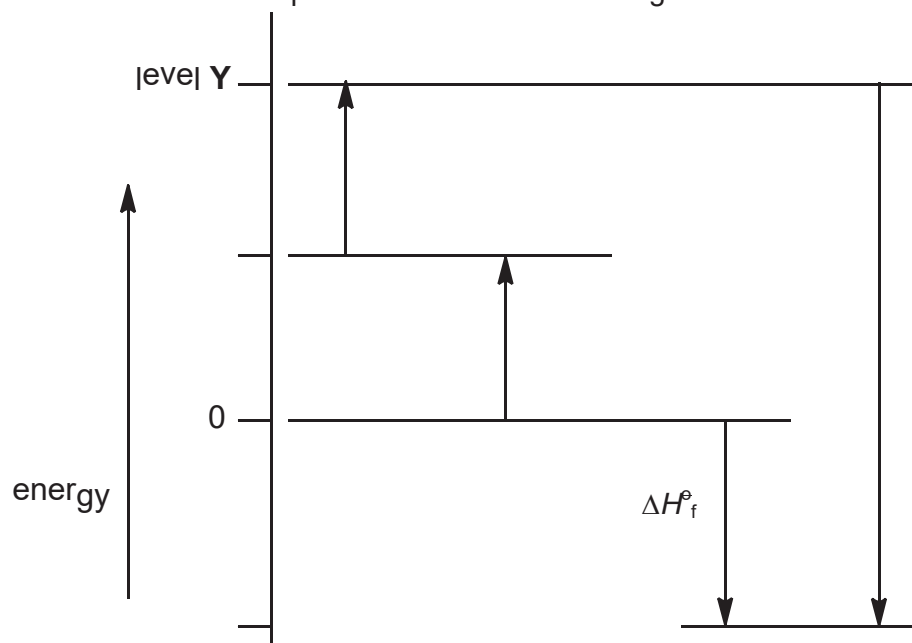
What is the best explanation for this observation?

- A** Heating ionises silicon to give  $\text{Si}^{4+}$  ions.  
**B** Heating increases the frequency of vibrations of silicon atoms.  
**C** Heating breaks some of the Si-Si bonds, allowing silicon particles to move.  
**D** Heating excites some of the valence electrons to higher energy levels such that they can be delocalised.
- 5 Which of the following statements best explains why propylamine,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$  ( $M_r = 59$ ), has a higher boiling point than trimethylamine,  $(\text{CH}_3)_3\text{N}$  ( $M_r = 59$ )?
- A** Propylamine is polar but trimethylamine is not.  
**B** Propylamine molecule has a larger surface area than the trimethylamine molecule.  
**C** The sum of all the bond energies in propylamine is larger than that in trimethylamine.  
**D** Propylamine molecules are able to form hydrogen bonds with one another, unlike trimethylamine molecules.
- 6 In which of the following pairs does the first species have a larger bond angle than the second?
- A**  $\text{CF}_4$  and  $\text{BF}_3$   
**B**  $\text{SO}_2$  and  $\text{CO}_2$   
**C**  $\text{ClO}_3^-$  and  $\text{H}_2\text{S}$   
**D**  $\text{PO}_4^{3-}$  and  $\text{NO}_3^-$
- 7 Two separate bulbs contain ideal gases **A** and **B** respectively. The density of gas **A** is thrice that of gas **B**. The relative molecular mass of gas **A** is one quarter that of gas **B**. Given that the temperature of gas A is  $30^\circ\text{C}$  and that of gas B is  $20^\circ\text{C}$ , what is the value of  $\frac{\text{pressure of gas A}}{\text{pressure of gas B}}$ ?
- A** 0.776                      **B** 1.13                      **C** 11.6                      **D** 12.4

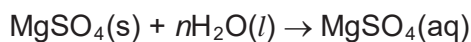


- 8 The following energy cycle represents the enthalpy changes in the formation of carbon dioxide from its constituent elements in their standard states.

What substances are present at level Y in this diagram?



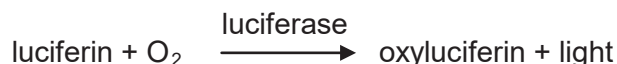
- A  $\text{C(g)} + 2\text{O(g)}$   
 B  $\text{C(g)} + \text{O}_2\text{(g)}$   
 C  $\text{C}^{4+}\text{(g)} + 2\text{O}^{2-}\text{(g)}$   
 D  $\text{CO}_2\text{(g)}$
- 9 Instant 'hot packs' are often used by athletes to conveniently treat injuries. One type of 'hot packs' is composed of powdered magnesium sulfate and water separated by a thin plastic membrane. When the pack is squeezed, the membrane breaks and the magnesium sulfate dissolves in water.



Which of the following options gives the correct signs of  $\Delta H$ ,  $\Delta S$  and  $\Delta G$  for the overall process?

	$\Delta H$	$\Delta S$	$\Delta G$
A	–	+	–
B	–	–	+
C	+	+	+
D	+	–	–

- 10 Chemiluminescence is the emission of light by a chemical reaction. The oxidation of luciferin is one such reaction which produces light, and is responsible for the natural glow of fireflies. The reaction is catalysed by the enzyme luciferase, and can be simplified as follows:



The reaction follows typical enzyme-catalysed reaction kinetics. It is possible to study the rate of the reaction by measuring the intensity of light given off.

Consider a series of experiments where the concentration of luciferase is kept the same. Which of the following statements is **incorrect**?

- A The concentration of luciferase is approximately to be constant throughout the course of the reaction.
  - B The relationship between light intensity and the concentration of luciferin is always linear.
  - C Reducing the concentration of luciferase will decrease the rate of the reaction.
  - D When luciferase is the limiting reagent, the reaction is zero order with respect to luciferin.
- 11 Azomethane decomposes when heated according to the following equation.



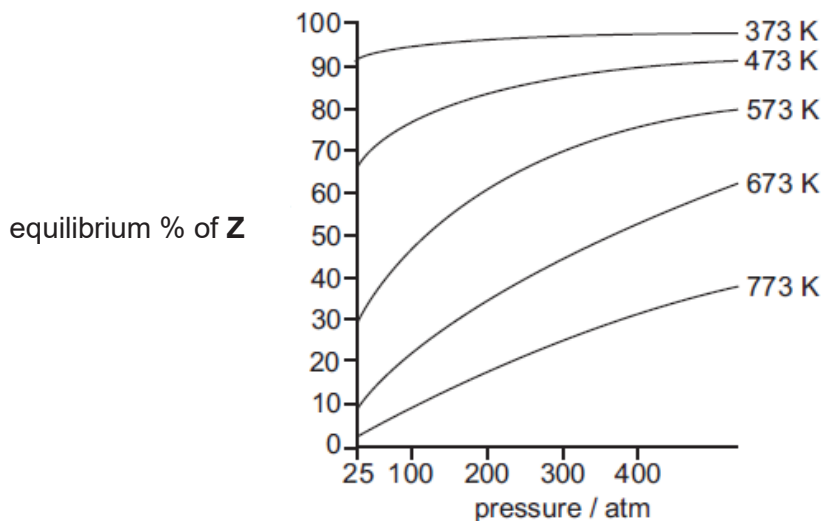
This reaction is first order with respect to azomethane with a half-life of 20 min.

In one experiment, azomethane was allowed to decompose at 16 kPa and 600 K. The pressure of the reaction mixture was measured at various times with the temperature kept constant. What is the time taken for the total pressure to reach 30 kPa?

- |          |                             |
|----------|-----------------------------|
| A 20 min | C 60 min                    |
| B 40 min | D Between 60 min and 80 min |

- 12 In an industrial process, two gases **X** and **Y** react together reversibly to form a single gaseous product **Z**.

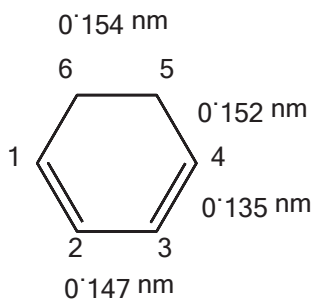
The percentage yield of product **Z** varies with pressure and temperature as shown below:



Which statement about this equilibrium reaction is correct?

- A Decreasing the temperature decreases the equilibrium constant.
  - B Increasing the pressure increases the equilibrium constant.
  - C Decreasing the temperature increases the rate of reaction.
  - D The forward reaction is exothermic.
- 13 The bond lengths in cyclohexa-1,3-diene differ from what they might be expected to be.

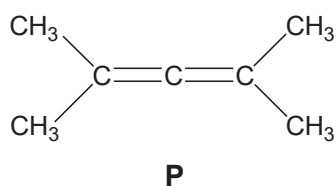
The carbon-carbon bond length in ethane is 0.154 nm and in ethene is 0.134 nm. However, the C4-C5 single bond in cyclohexa-1,3-diene is 0.152 nm.



What helps to explain this C4-C5 bond length?

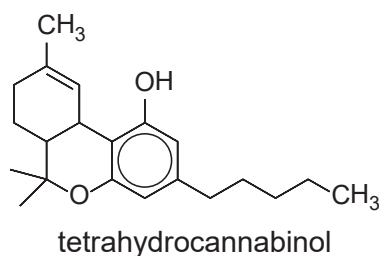
- A It is an  $sp^2-sp^2$  overlap.
- B It is an  $sp^2-sp^3$  overlap.
- C The  $sp^3-sp^3$  bonding is pulled shorter by a p-p ( $\pi$ -bond) overlap.
- D The delocalisation of electrons in the molecule shortens the C4-C5 bond.

- 14 Allenes are compounds in which one carbon atom forms double bonds with two adjacent carbons. Molecule **P** is an example of an allene.



What is the maximum number of carbon atoms that can possibly be on the same plane in molecule **P**?

- A** 3                      **B** 5                      **C** 6                      **D** 7
- 15 The structure of a psychoactive substance, tetrahydrocannabinol, found in the plant cannabis, is shown below.



What is the total number of stereoisomers that can be formed when tetrahydrocannabinol reacts with chlorine in  $\text{CCl}_4$  in the dark?

- A** 4                      **B** 16                      **C** 32                      **D** 64
- 16 Which of the following statements about the complete combustion of an alkene,  $\text{C}_n\text{H}_{2n}$ , is **incorrect**?

- A** The volume of oxygen required is directly proportional to the number of carbon atoms present in the molecule.
- B** It requires less oxygen per mole of alkene than that for the complete combustion per mole of an alkane with the same number of carbon atoms.
- C** The volume of gas produced at  $25^\circ\text{C}$  is the same as for the complete combustion of an alkane with the same number of carbon atoms per molecule.
- D** At  $120^\circ\text{C}$ , the volume of steam produced is twice the volume of carbon dioxide.

**17** An alkyl halide RX reacts with ammonia in a substitution reaction to form an amine.

The rate equation for this reaction is  $\text{rate} = k[\text{RX}]$ .

Which of the following statements is correct?

- A** The mechanism involves only one step.
- B** The alkyl halide acts as a nucleophile.
- C** Further substitution may form an ionic product.
- D** The rate of reaction is faster when  $\text{X} = \text{Cl}$  compared to when  $\text{X} = \text{Br}$ .

### Section B

For questions **18** to **25**, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct. (You may find it useful to put a tick against the statements that you consider to be correct.)

The response **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

No other combination of statements is used as a correct response.

**18** Which of the following particles contain at least one unpaired electron?

- 1**  $\text{Co}^{3+}$
- 2**  $\text{Cu}^{2+}$
- 3**  $\text{Cu}$

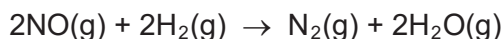
**19** The compound sodium borohydride,  $\text{NaBH}_4$ , is commonly used as a source of hydride anions for synthetic purpose.

Which of the following types of bonding are found in the compound?

- 1** ionic
- 2** covalent
- 3** hydrogen bonding

- 20 For a fixed mass of an ideal gas, which of the following pairs of plots would have the same shape?
- 1  $p$  against  $V$  (constant  $T$ ) and density against  $T$  (constant  $p$ )
  - 2  $pV$  against  $p$  (constant  $T$ ) and  $pV$  against  $1/V$  (constant  $T$ )
  - 3  $p$  against  $T$  (constant  $V$ ) and  $pV$  against  $T$

- 21 The following information concerns the gas-phase reaction of nitrogen monoxide with hydrogen:



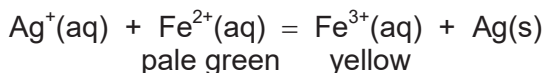
A series of experiments were carried out in a reaction vessel at constant temperature.

The initial rate of reaction increased by a factor of 2 when the initial partial pressure of NO was doubled and that of  $\text{H}_2$  was halved.

When both partial pressures were halved, the initial rate decreased by a factor of 8.

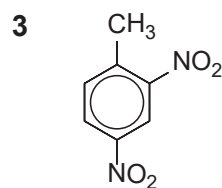
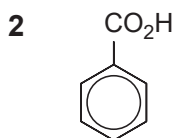
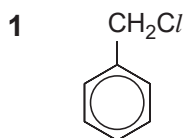
Which of the following statements are correct?

- 1 The reaction is first order with respect to nitrogen monoxide.
  - 2 The reaction is first order with respect to hydrogen.
  - 3 The overall order of reaction is 3.
- 22 The chemical equation for the redox reaction between iron(II) and silver(I) ions is given below:



The equilibrium constant was determined to be  $3.14 \text{ dm}^3 \text{ mol}^{-1}$  at  $25^\circ\text{C}$  and  $1.2 \text{ dm}^3 \text{ mol}^{-1}$  at  $35^\circ\text{C}$ . Which of the following statements are correct?

- 1 Increasing the temperature increases the rate of the forward reaction.
  - 2 Adding sodium chloride will affect the position of the equilibrium.
  - 3 Adding enough silver metal would cause the colour of the solution to change from yellow to pale green.
- 23 Which of the following compounds can be directly synthesized from methylbenzene?



The response **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

No other combination of statements is used as a correct response.

- 24** Chlorofluorocarbons (CFCs) pose environmental problems in that they cause the depletion of the ozone layer. Hydrochlorofluorocarbons (HCFCs) are alternatives which help to reduce the problem. The ozone depletion potential values of a CFC and a HCFC are given below.

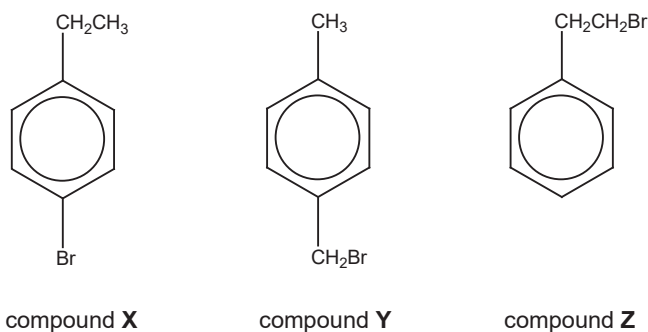
	Ozone Depletion Potential (ODP)*
$\text{CFCl}_3$ (CFC)	1.0
$\text{CF}_3\text{CHCl}_2$ (HCFC)	0.10

\* higher ODP values indicate greater depletion of the ozone layer

Which of the following could account for the difference in ODP?

- 1 Fluorine radicals are more stable than chlorine radicals.
- 2 The C–F and C–H bonds are stronger than C–Cl bond.
- 3 More chlorine radicals are generated per  $\text{CFCl}_3$  molecule than per  $\text{CF}_3\text{CHCl}_2$  molecule.

- 25** The following compounds have the molecular formula  $\text{C}_8\text{H}_9\text{Br}$ .



Which of the following reactions can successfully distinguish between the stated pair of compounds?

	Compounds	Reactions
<b>1</b>	<b>X and Z</b>	Heat with $\text{NaOH(aq)}$ , followed by acidified $\text{AgNO}_3$
<b>2</b>	<b>X and Y</b>	Heat with acidified $\text{KMnO}_4\text{(aq)}$
<b>3</b>	<b>Y and Z</b>	Heat with ethanolic $\text{KOH}$

~ End of Paper 1 ~



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**C1 PROMOTIONAL EXAMINATION**  
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**CANDIDATE  
NAME**

**CT GROUP**

**11**

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**CHEMISTRY**

**9647/02**

Paper 2 Section A: Structured Questions

**4 October 2011**

**1 h 10 min**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet.

---

**INSTRUCTIONS TO CANDIDATES**

- 1) Write your **name** and **CT class** clearly in the spaces at the top of this page.
- 2) Answer **all** questions in the spaces provided in this Question Booklet.

**INFORMATION FOR CANDIDATES**

The number of marks is given in brackets [ ] at the end of each question or part question.

You may use a calculator.

You are reminded of the need for good English and clear presentation in your answers.

**FOR EXAMINERS' USE ONLY**

<b>Paper 1</b>	<b>Paper 2</b>		<b>TOTAL</b>
<b>Multiple Choice</b>	<b>Section A (Structured)</b>	<b>Section B (Free Response)</b>	
	Q1 / 8	Q1 / 20	
	Q2 / 18	Q2 / 20	
	Q3 / 10	Q3 / 20	
	Q4 / 9		
/ 25	<b>Subtotal / 45</b>	<b>Subtotal / 40</b>	<b>110</b>



For  
Examiner's  
Use

- $$\text{S}_2\text{O}_8^{2-}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow \square 2\text{SO}_4^{2-}(\text{aq}) + \text{I}_2(\text{aq})$$

**(a)** Explain why the appearance of the blue colour is delayed.

---

---

[1]

- You are provided with the common laboratory apparatus and the above solutions.

Your answer should include

- correct sequence in the procedure, stating the apparatus to be used.
- correct quantities of each reagent.
- all measurements to be taken.

[illegible]

[3]

- (c) Draw an appropriate table for recording the data of the experiment you have designed.

For  
Examiner's  
Use

[2]

- (d) Show how you can use your results, graphically or otherwise, to prove that the reaction is first order with respect to potassium iodide.

.....

.....

.....

[1]

- (e) How would you expect the reliability of your experiment to be affected if the amount of sodium thiosulfate added is increased two-fold? Explain your answer.

.....

.....

.....

[1]

[Total: 8 marks]

- 2 Ammonia is manufactured from nitrogen and hydrogen by the Haber process. The typical conditions employed in the Haber process are 450 °C and 250 atm, as well as the use of an iron catalyst. The system is allowed to reach dynamic equilibrium, after which the ammonia formed is removed by condensation.

(a) (i) Write a balanced equation, with state symbols, for the manufacture of ammonia.

.....

(ii) Explain why the activation energy of the process is high.

.....

.....

(iii) Suggest two advantages of carrying out the process at high pressure.

Advantage 1:

.....

.....

.....

Advantage 2:

.....

.....

.....

[4]

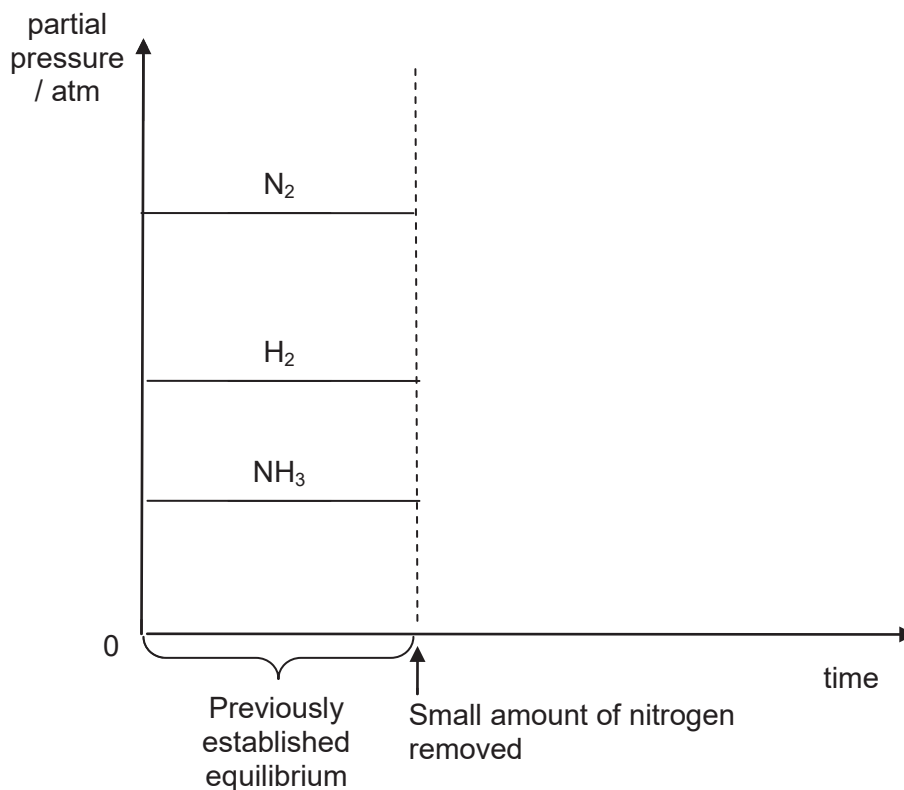
(b) (i) Explain what is meant by *dynamic equilibrium*.

.....

.....

- (ii) A small amount of nitrogen is suddenly removed from an equilibrium mixture containing nitrogen, hydrogen and ammonia, keeping the temperature constant. The mixture is then allowed to reach equilibrium again.

Complete the sketch below to show how the partial pressures of each of the three gases would change until a new equilibrium is established.



[3]

- (c) Given that the density of nitrogen gas is  $1.25 \text{ g dm}^{-3}$  in a  $1 \times 10^6 \text{ dm}^3$  reactor used for the Haber process, calculate the number of molecules of nitrogen gas present in the reactor.

[1]

- (d) Like the carbon atoms in ethane, ethene and ethyne, the nitrogen atom in ammonia is also able to undergo orbital hybridisation to give hybrid orbitals of equivalent energy.

By considering the shape about nitrogen in an ammonia molecule, suggest the type of hybridisation present in the ammonia molecule. Sketch the shape of the hybrid orbitals around the nitrogen atom in the ammonia molecule.

Type of hybridisation: .....

[2]

When two ammonia molecules are coupled together by removing a hydrogen atom each, a hydrazine molecule,  $\text{N}_2\text{H}_4$ , is produced. Hydrazine is a colourless, oily liquid which is used as a rocket fuel.

- (e) (i) Draw the structure of a hydrazine molecule.

- (ii) Explain why hydrazine is soluble in water.

.....  
.....

[2]

- (f) (i) Liquid hydrazine reacts with oxygen to give nitrogen gas and steam.

Write a balanced equation, including state symbols, for the above reaction.

.....

- (ii) By using appropriate bond energy data from the *Data Booklet*, calculate a value for the enthalpy change of the reaction in (f)(i).

- (iii) The actual enthalpy change of the reaction in (f)(i) is more exothermic than the calculated value in (f)(ii). One reason for this discrepancy in values is that the bond energy values from the *Data Booklet* are average bond energies.

Suggest another possible reason for this discrepancy.

.....  
.....

- (iv) The enthalpy change of combustion of ethane is found to be  $-1560 \text{ kJ mol}^{-1}$ . Suggest why hydrazine is used as a rocket fuel instead of ethane.

.....  
.....

- (v) Predict how the feasibility of the reaction in (f)(i) varies with temperature, showing your reasoning.

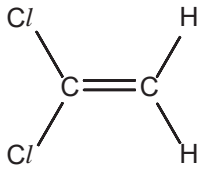
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[6]

[Total: 18 marks]

- 3 (a) (i) Dichloroethene is widely used in the industry as precursors for plastics. It exists as three possible isomers, **A**, **B** and **C**, where **A** and **B** are geometric isomers. The table below shows the physical properties of each of the three isomers.

Draw the structure of each isomer in the correct box below and label each isomer as "cis" or "trans" accordingly.

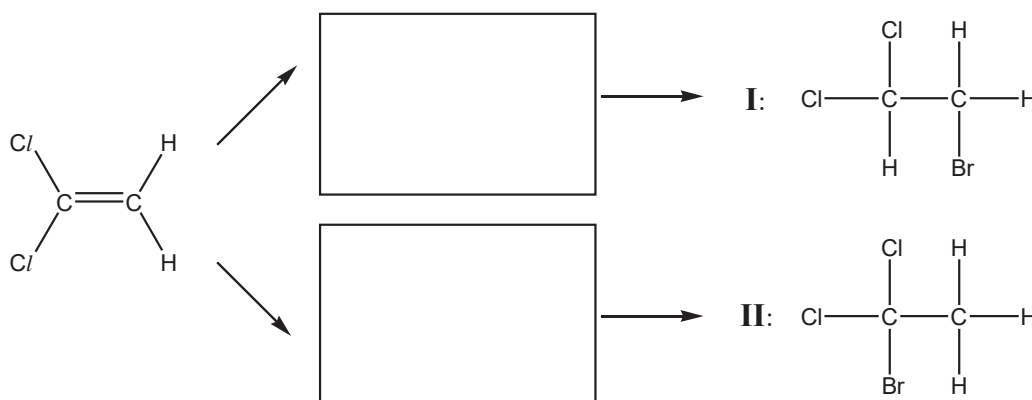
isomer	<b>A</b>	<b>B</b>	<b>C</b>
melting point/ °C	-50	-81	-122
boiling point/ °C	47.5	60.3	31.9
dipole moment/ D	0	1.9	1.3
structure			

- (ii) Explain how geometric isomerism arises in alkenes.

.....  
 .....  
 .....

[4]

- (b) (i) When isomer **C** reacts with HBr, there are 2 possible products. In the boxes below, draw the intermediate for the reaction that produces each of the products.



- (ii) In reality, product **I** is almost exclusively formed. With reference to the intermediates, explain why this is so.

.....

.....

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[2]

- (c) (i) An assumption of an ideal gas is that the collisions between gas particles are perfectly elastic. State two other assumptions of an ideal gas.

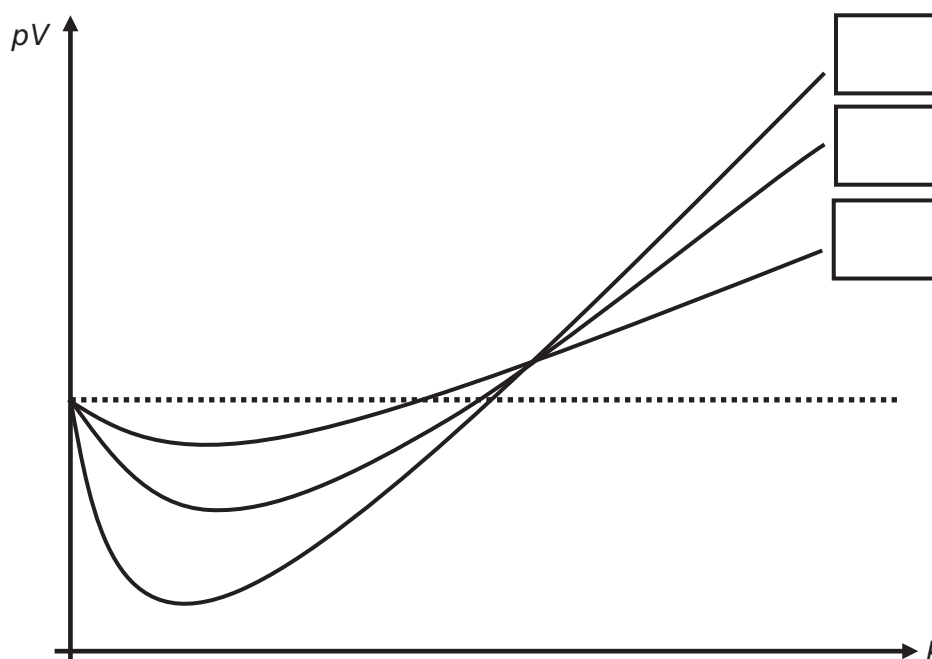
Assumption 1: .....

.....

Assumption 2: .....

.....

- (ii) The value of  $pV$  is plotted against  $p$  for each of the isomers of dichloroethene in the gaseous state in the diagram below.



Using relevant data from the table in (a)(i) and the boxes provided, identify the isomer **A**, **B** or **C** that is responsible for each of the graphs.

Explain your choice.

.....

.....

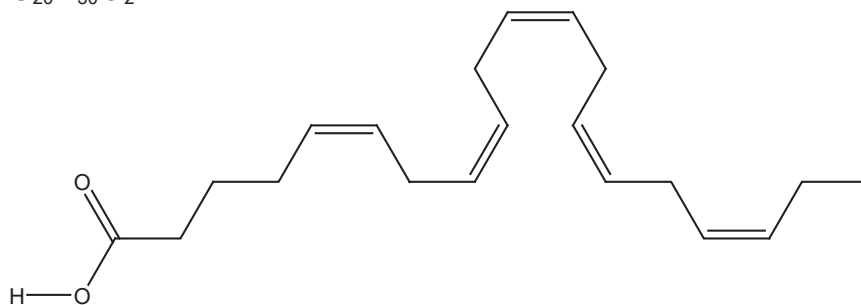
.....

[4]

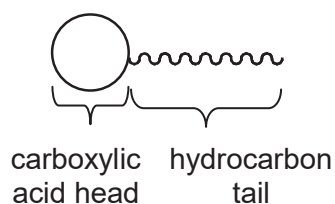
[Total: 10 marks]



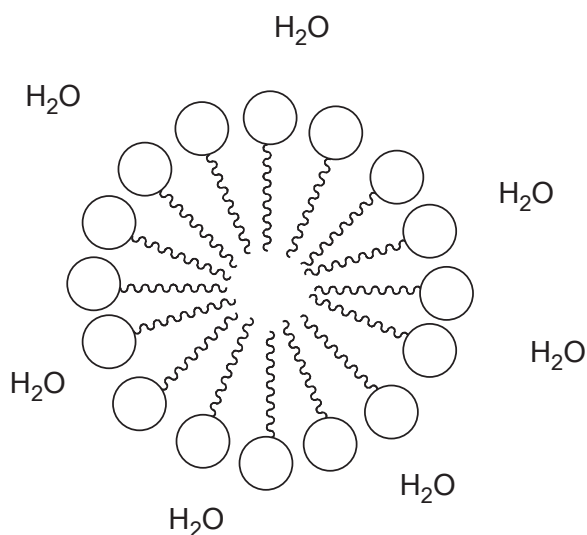
- 4 (a) Omega-3 fatty acids are essential fatty acids vital for normal metabolism. Eicosapentaenoic acid (EPA) is an example of a fatty acid with the molecular formula  $C_{20}H_{30}O_2$ .



It is also commonly represented as a circle linked to a tail, as shown below:



- (i) The following diagram shows the arrangement of EPA molecules in water.



Give reasons for this arrangement.

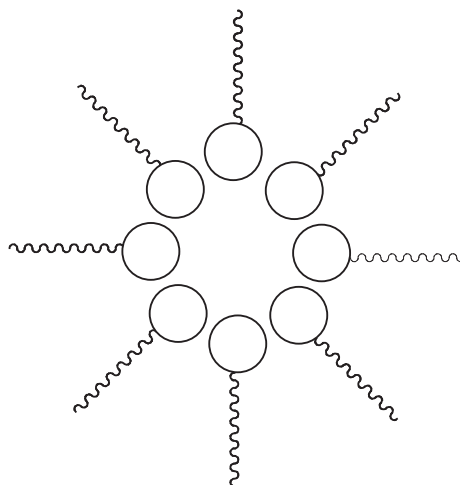
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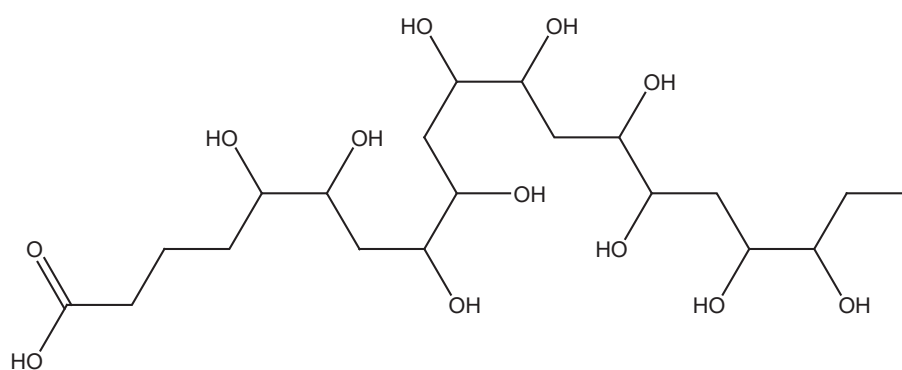
(ii) EPA molecules can also arrange themselves in the form shown below under certain conditions.



.....

.....

**(b)**



Compound **X**

.....

.....

[2]

- (c) Docosahexaenoic acid (DHA) is another unsaturated omega-3 fatty acid containing multiple double bonds. A 0.100 g sample containing equimolar quantities of EPA and DHA was dissolved in an appropriate solvent.

The solution was reacted with a freshly prepared solution of 1.60 g of bromine in 200 cm<sup>3</sup> of CCl<sub>4</sub>. It was found that 34.9 cm<sup>3</sup> of the bromine solution was required to completely react with the fatty acids.

(M<sub>r</sub> of Br<sub>2</sub> = 159.8; M<sub>r</sub> of EPA = 302; M<sub>r</sub> of DHA = 328)

- (i) Calculate the concentration (in mol dm<sup>-3</sup>) of the prepared solution of bromine in CCl<sub>4</sub>.

- (ii) Calculate the total number of moles of C=C double bonds present in the sample.

(You may assume that all other parts of EPA and DHA are unreactive.)

- (iii) Hence, calculate the number of C=C double bonds in one molecule of DHA.

[4]

[Total: 9 marks]

~ End of Paper 2 Section A ~



**HWA CHONG INSTITUTION**  
**C1 PROMOTIONAL EXAMINATION**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**11**

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**CHEMISTRY**

**9647/02**

Paper 2 Section B: Free Response

**4 October 2011**

**1 h**

Candidates answer on the Question Paper.

Additional Materials: Answer Paper

Data Booklet

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**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Answer **any 2 of the 3** questions on the writing paper provided.

Answer the questions on the writing paper provided.

Begin each question on a **new piece of paper**.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.

**Write down** the question numbers for the questions that you have attempted on the cover page provided.

**This question booklet consists of 7 printed pages, including the cover page.**

Write your answers on the writing paper provided.

- 1 Gasoline and diesel fuels are mixtures of hydrocarbons. In a typical car engine, hydrocarbons are burnt by combining with oxygen. Atmospheric nitrogen, which is also present in the engine, combines with oxygen to form nitrogen oxides.

- (a) A sample is found to contain the following hydrocarbons:

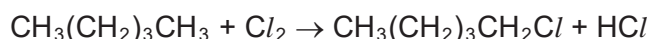
pentane, heptane, 3,3-dimethylpentane

Rank the hydrocarbons in order of increasing boiling points. Explain your answer.

Hence, suggest a method by which the hydrocarbons can be separated.

[3]

- (b) When pentane is mixed with chlorine in the presence of uv light, the following reaction takes place:



- (i) Briefly outline the mechanism of this reaction. You may use  $\text{RCH}_3$  to represent pentane.
- (ii) The presence of nitrogen monoxide, NO, is known to slow down the chlorination of pentane.

Draw a dot-and-cross diagram of a molecule of NO. By considering the electron distribution in the NO molecule, suggest how it slows down the reaction.

- (iii) Using data from the *Data Booklet*, explain why pentane is less readily brominated than chlorinated. Your answer should make reference to the process of propagation in your mechanism in (b)(i),

[7]

- (c) During the starting of vehicles, incomplete combustion of hydrocarbons is likely to occur due to low air-to-fuel ratios.

A sample of pentane was combusted in a car engine during vehicle starting. It was found that the enthalpy change when 1 mol of pentane was burnt in limited supply of air was  $-2707 \text{ kJ}$ . Under this condition, carbon monoxide, a poisonous gas, is produced along with carbon dioxide and steam.

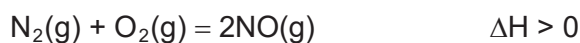
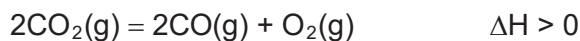
The enthalpy changes of formation of the compounds are given below.

Substance	$\Delta H_f / \text{kJ mol}^{-1}$
$\text{C}_5\text{H}_{12}(\text{l})$	$-147$
$\text{CO}_2(\text{g})$	$-394$
$\text{CO}(\text{g})$	$-110$
$\text{H}_2\text{O}(\text{g})$	$-242$

Using the given information, calculate the ratio of amount of carbon dioxide to carbon monoxide formed in this combustion.

[3]

- (d) In the exhaust gases of cars, carbon monoxide and nitrogen monoxide are present according to the following equilibria:



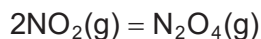
The amounts of carbon monoxide and nitrogen monoxide are to be minimized in order to achieve lower pollution level.

Explain qualitatively what temperature and pressure (high or low) you would suggest for the car engine in order to achieve low pollution.

[2]

- (e) 0.10 mol of  $\text{NO}_2(\text{g})$  is introduced into a  $1.48 \text{ dm}^3$  evacuated closed container at 300 K.

The following equilibrium is established:



and the equilibrium pressure is 1.00 atm (101 kPa).

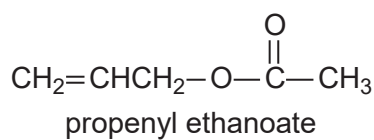
Calculate

- (i) the total number of moles of gases at equilibrium, assuming that the gases behave ideally.
- (ii) the percentage of  $\text{NO}_2$  that has reacted.
- (iii)  $K_p$  for the reaction at 300 K.

[5]

[Total: 20 marks]

- 2 (a) Ethene reacts readily with bromine in tetrachloromethane,  $\text{CCl}_4$ .
- Describe the mechanism of this reaction.
  - Identify the *rate-determining step* and explain why it is so. [4]
- (b) Alkenes are generally more reactive than alkanes because *the  $\pi$  electrons of the  $\text{C}=\text{C}$  double bond in alkenes are more vulnerable to attacking species than those in a  $\sigma$  bond.*
- With the help of a labelled diagram, explain why the statement in *italics* is true.
  - By using the bond energies given in the *Data Booklet*, determine the strength (in  $\text{kJ mol}^{-1}$ ) of the  $\sigma$  and of the  $\pi$  carbon-carbon bond in alkenes.  
Account for the difference in strength between the  $\sigma$  and the  $\pi$  bond. [4]
- (c) In concentrated ethanoic acid, a colourless liquid propenyl ethanoate reacts with bromine, an orange liquid, slowly enough for the reaction to be followed by usual laboratory techniques. The structure of propenyl ethanoate is given below.



To determine the order of reaction with respect to bromine, a series of experiments were carried out at a constant temperature and with the same initial concentration of propenyl ethanoate, varying only the initial concentration of bromine,  $[\text{Br}_2]$ . The following results were obtained.

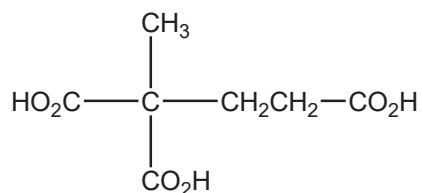
experiment number	1	2	3	4	5
$[\text{Br}_2] / \text{mol dm}^{-3}$	0.2	0.4	0.5	0.6	0.8
$[\text{Br}_2]^2 / \text{mol}^2 \text{ dm}^{-6}$	0.04	0.16	0.25	0.36	0.64
initial rate of change for [propenyl ethanoate] $/ \text{mol dm}^{-3} \text{ s}^{-1}$	0.065	0.26	0.40	0.59	1.00

- Use these data to plot a suitable graph and hence determine the order of reaction with respect to  $\text{Br}_2$ .
- Given that the rate of reaction is directly proportional to the concentration of propenyl ethanoate, write the rate equation for the reaction.
- Given that the initial concentration of propenyl ethanoate for each experiment is  $0.02 \text{ mol dm}^{-3}$ , calculate the rate constant for the reaction, stating its units.
- Estimate the time needed for 1% of propenyl ethanoate to have reacted in experiment number 1.

- (v) What visible changes would you expect to observe as the reaction proceeds?
- (vi) Suggest a suitable experimental technique that can be used to study the rate of the reaction between propenyl ethanoate and Br<sub>2</sub>.
- (vii) Suggest why water was not used as the solvent in this experiment.

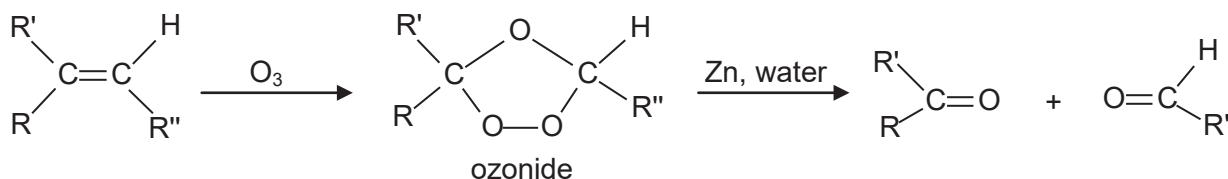
[9]

- (d) (i) Organic compound **A**, C<sub>8</sub>H<sub>12</sub>, reacts with hot, concentrated acidified KMnO<sub>4</sub> to form the following organic product.



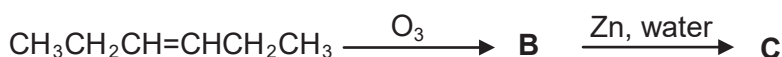
Draw the structure of **A**.

- (ii) When ozone gas, O<sub>3</sub>, is passed into a solution of an alkene, an ozonide is formed. Treatment of the ozonide with zinc dust and water produces two organic products.



(R, R' and R'' may be alkyl groups, benzene rings or hydrogen.)

Suggest the structures of the organic compounds **B** and **C** in the following reaction scheme.



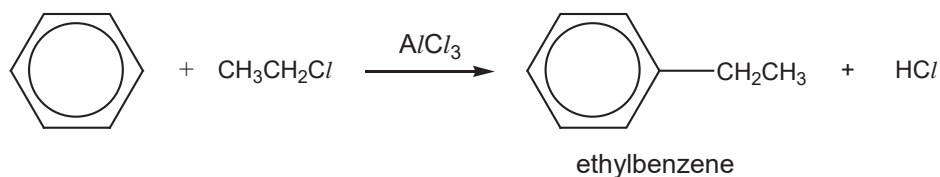
[3]

[Total: 20 marks]



3 (a) Ethylbenzene is an example of an aromatic hydrocarbon.

- (i) Write a balanced equation for the oxidation of ethylbenzene using hot, acidified  $\text{KMnO}_4$ .
- (ii) Given that the percentage yield is 80%, what is the mass of the organic product formed when 1.00 g of ethylbenzene undergoes the oxidation reaction in (a)(i)?
- (iii) Ethylbenzene can be prepared by the reaction of benzene with chloroethane,  $\text{CH}_3\text{CH}_2\text{Cl}$ . This reaction is Friedel-Crafts alkylation and it occurs via a mechanism similar to that of the chlorination of benzene.

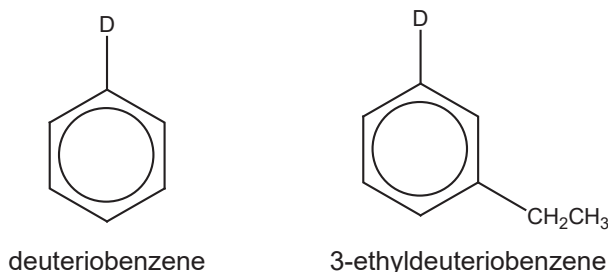


- I Explain why the reaction above would not occur in the absence of  $\text{AlCl}_3$ .
- II Describe the mechanism of this reaction.

[7]

(b) Deuterium, D, is a heavy isotope of hydrogen.

When deuteriobenzene undergoes Friedel-Crafts alkylation as in (a)(iii), a mixture containing ethylbenzene and 3-ethyldeuteriobenzene is produced.



Under the conditions used for alkylation, the carbon-deuterium bond is broken as often as a carbon-hydrogen bond.

Suggest why the molar ratio of ethylbenzene to 3-ethyldeuteriobenzene produced is 1:2.

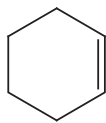
[2]

(c) The C-D bond actually has a higher bond strength than a C-H bond, yet predeuterated benzene,  $\text{C}_6\text{D}_6$ , is alkylated at the same rate as normal benzene,  $\text{C}_6\text{H}_6$ .

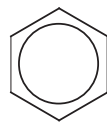
What conclusion can you draw about the mechanism of the alkylation reaction?

[1]

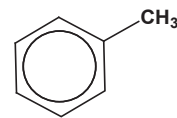
- (d) Suggest how you would distinguish the following compounds by carrying out only two simple chemical tests. You should state the reagents and conditions for each test, and describe the expected observations for each compound.



cyclohexene



benzene



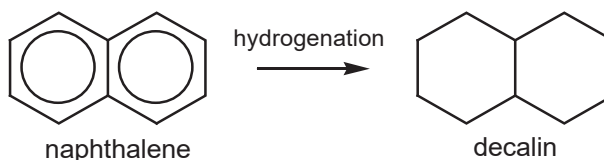
methylbenzene

[4]

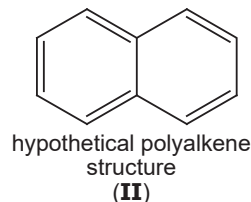
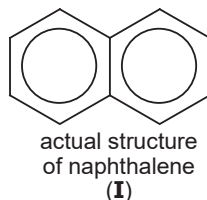
- (e) (i) The enthalpy change of hydrogenation of an unsaturated hydrocarbon is the enthalpy change when one mole of the compound reacts completely with hydrogen to form a saturated hydrocarbon. The enthalpy change of hydrogenation of cyclohexene,  $C_6H_{10}(l)$ , is  $-120 \text{ kJ mol}^{-1}$ .

Write an equation of the reaction that represents the enthalpy change of hydrogenation of cyclohexene.

- (ii) Naphthalene,  $C_{10}H_8(s)$ , is another example of an aromatic hydrocarbon. When naphthalene is fully hydrogenated, decalin,  $C_{10}H_{18}(s)$ , is formed. The enthalpy change of hydrogenation of naphthalene is  $-345 \text{ kJ mol}^{-1}$ .

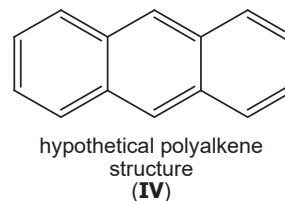
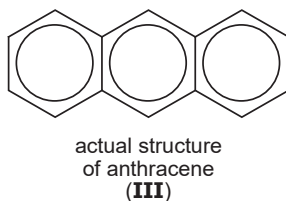


The resonance energy of naphthalene can be defined as the energy difference between the actual structure of naphthalene (**I**) and the hypothetical polyalkene structure (**II**).



Calculate the resonance energy of naphthalene, by drawing a suitable energy level diagram, and incorporating relevant data from (e).

- (iii) Explain the significance of the resonance energy.
- (iv) Using the information from above, calculate an approximate value for the enthalpy change of hydrogenation for the actual structure of anthracene.



[6]

[Total: 20 marks]

~ End of Paper 2 Section B ~

**2011 C1 CHEMISTRY PROMOTIONAL EXAMINATION  
ANSWERS**

**PAPER 1 - MCQ**

1	A	6	C	11	C	16	D	21	C
2	A	7	D	12	D	17	C	22	B
3	D	8	A	13	B	18	A	23	A
4	D	9	A	14	B	19	B	24	C
5	D	10	B	15	B	20	A	25	B

**PAPER 2 SECTION A - STRUCTURED QUESTIONS**

**Marker: Ho LY (11S60 – 11S69, 11S6B - 11S71); Kelvin Tan (11S6A, 11S72 – 11S7N)**

- 1 (a) Thiosulfate present reduces the iodine produced. The blue colour only appears after all the thiosulfate has been reacted. **[1 mark for both points, no ½ mark]**
- (b)
- Using a burette, transfer 10.00 cm<sup>3</sup> KI and using another burette transfer 1.00 cm<sup>3</sup> of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> into a 25 cm<sup>3</sup> conical flask. Use a measuring cylinder to measure and add 6 cm<sup>3</sup> water into the conical flask.
  - Using a third burette, transfer 2.00 cm<sup>3</sup> K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> into a small beaker. Using a second measuring cylinder, measure and add 1 cm<sup>3</sup> starch solution.
  - Quickly transfer contents from step (2) to the conical flask in step (1). Swirl once quickly.
  - Start the stopwatch immediately.
  - Stop the stopwatch at the first appearance of blue colouration.
  - Repeat steps 1 to 3 but varying the volumes of KI and water such that their combined volume remains 16 cm<sup>3</sup>. The volumes of the other reagents are kept constant across experiments.

*Note: students cannot use sampling and titrimetric method*

*Marking points:*

- Concept [1 mark]**  
*All reagents mixed together and measuring time taken for blue colour to appear. Carry out at least one more experiment where the volume of KI is varied.*
- Sequence [1 mark]**  
*Note: For solutions before mixing and starting timing*  
*S<sub>2</sub>O<sub>8</sub><sup>2-</sup> (oxidising agent) and S<sub>2</sub>O<sub>3</sub><sup>2-</sup> (reducing agent) cannot be in the same solution*  
*S<sub>2</sub>O<sub>8</sub><sup>2-</sup> and KI cannot be in the same solution*
- Apparatus for measuring of solutions (either measuring cylinder or burette is acceptable, but precision must be correct) and time (stopwatch) [½ mark]**
- Vary Volumes of KI and deionised water such that total volume of solution after mixing is kept constant across experiments [½ mark]**

(c)

Expt no.	Volume of KI (cm <sup>3</sup> )	Volume of Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> (cm <sup>3</sup> )	Volume of K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> (cm <sup>3</sup> )	Volume of H <sub>2</sub> O (cm <sup>3</sup> )	Volume of starch (cm <sup>3</sup> )	Time (s or min)
1						
2						
3						
4						
5						

- All measurements of volumes and time to be recorded (headings only) **[1 mark]**
- Units match data recorded (recorded data may not be complete but a minimum of volume of KI and time is required) **[1 mark]**

(d) Possible answers:

- Graph of 1/time against volume of KI (or vice versa). Straight line graph with a positive gradient.
- Graph of lg (1/time) against lg (volume of KI). Straight line graph with gradient = 1.
- Calculate volume of KI x time. Constant value obtained for all experiments.
- Compare 2 experiments where volume of KI has been doubled. Time taken should be halved.

**[1 mark for any correct answer]**

(e) Possible answers:

- Less reliable because initial rate is not being measured.
- Less reliable because thiosulfate may cease to be the limiting reagent and blue colour will never appear.
- More reliable because time taken for blue colour to appear is longer, hence smaller error due to human reaction time.

**[1 mark for any correct answer]**

**Comments:**

(a)

- Most students mentioned that thiosulfate would react with iodine but did not explain why the blue colour is eventually formed.
- There were students who wrongly believed that thiosulfate would react with starch, or that sodium iodide would be formed, or that the solution would be diluted affecting the rate of reaction, or that there was an equilibrium present that would be affected.

(b)

- Many students did not get the sequence correct, mixing KI and peroxodisulfate together

first before adding starch and thiosulfate.

- Many students did not give a clear description of the steps taken. They mentioned measurement of volumes of solutions but did not indicate where or when additions are made.
- Students placed the beaker of solution on top of “an insert with the words ‘stop timing if you cannot read these words’”. They were confused with the sulfur-forming reaction carried out during the practical in Term 4.

(c)

- Students did not record down the headings for the volumes of starch, H<sub>2</sub>O and thiosulfate.
- 1/time was improperly labeled as “rate of reaction” (1/time is PROPORTIONAL to the rate of reaction, i.e. it measures the RELATIVE rate) – penalized under units (rate does not have units of s<sup>-1</sup>!)

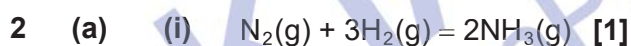
(d)

- Many incorrect answers involved plotting a concentration versus time graph and to look for a constant half-life. Students did not read the question carefully as the question asked them to use their results.

(e)

- Incorrect answers mostly involved stating that the rate of reaction would or would not be affected.

**Marker: Loy HC (All)**

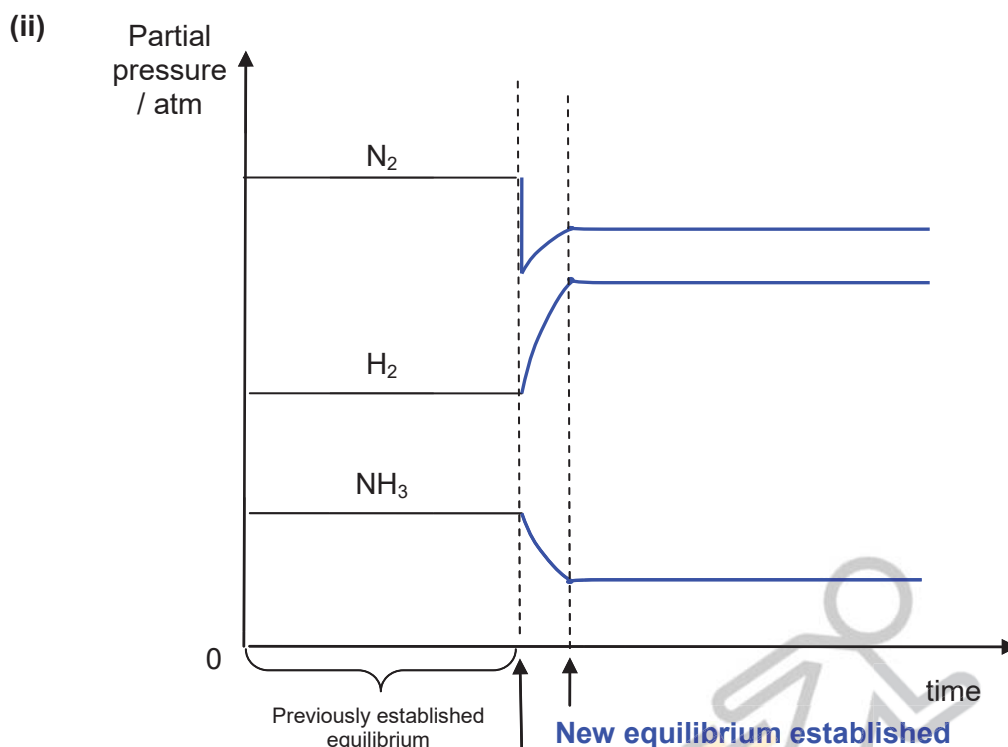


(ii) A large amount of energy is required to break the strong N≡N triple bond in N<sub>2</sub>. [1]

(iii) Advantage 1: The forward reaction involves a reduction in the number of moles of gas. By Le Chatelier's Principle, a high pressure would shift the position of equilibrium to the right and gives a higher yield of ammonia. [1]

Advantage 2: A high pressure also increases the rate of reaction as the molecules also collide with higher frequency, leading to higher number of effective collisions. [1]

(b) (i) Dynamic equilibrium refers to a state of balance in a reversible reaction in which the rate of forward reaction and the rate of backward reaction are equal. The concentrations of the reactants and products remain constant but the reaction continues to occur in both directions. [1]



Marking points:

- sharp decrease in partial pressure of  $N_2$ , followed by increase to attain new equilibrium (but does not rise above original partial pressure) [1]
- increase in partial pressure of  $H_2$  and decrease in partial pressure of  $NH_3$  to attain new equilibrium (must indicate new equilibrium on sketch) [1]

(For information: Ratio of change of partial pressures of  $N_2:H_2:NH_3$  to attain new equilibrium is 1:3:2.)

(c) No. of molecules of  $N_2 = \frac{1.25}{28.0} \times 6.02 \times 10^{23} \times 1 \times 10^6 = 2.69 \times 10^{28}$  [1]

#### Comments:

- (a)(i) Zero mark for the following cases: double headed arrow = not used, no state symbols, incorrect state symbols e.g.  $NH_3(aq)$ .
- (a)(ii) Zero mark for the following cases:
  - A vague statement like "energy is needed to break bonds", students must specify the bond of concern (which is the strong  $N \equiv N$  triple covalent bond in  $N_2$ ).
  - Explanation in terms of intermolecular forces, this is not relevant. Intermolecular attractions between gas molecules are weak and are unlikely to affect chemical reactions.
  - Explanation in terms of endothermic or exothermic nature of the reaction or in terms of entropy or  $\Delta G$ . Not accepted.  $\Delta H$ ,  $\Delta S$  and  $\Delta G$  --- these are Energetics/ Thermodynamics concepts, they do not give information about Kinetics or whether a reaction has high or low activation energy. Students should also be aware that the reaction is exothermic --- i.e.,



total energy released during bond forming > total energy needed for bond breaking.

- Some students explained that the reaction requires a collision between one  $N_2$  molecule and three  $H_2$  molecules and that is very difficult. Not accepted. The equation in **(a)(i)** is an *overall equation* which does not give information about the molecularity of the *rate-determining step*.
- Terms like "bonds between  $N_2$  and  $H_2$  molecules", "bond energy between  $N_2$  and  $H_2$ ". The bond of concern is the *strong  $N \equiv N$  triple bond in  $N_2$  molecule*. Some students wrote about "breaking bonds between N and H atoms", incorrect  $\therefore$  isn't that the N–H bonds to be *formed* in the  $NH_3$  molecules?!

- **(a)(iii)** Students are required to give the advantages and their correct reasoning to gain the marks --- higher yield of  $NH_3$   $\therefore$  by le Chatelier's principle, high pressure favours the forward reaction as that gives less number of moles of gas; higher rate of production of  $NH_3$   $\therefore$  high pressure forces the gas molecules more closely together or increases the number of molecules per unit volume (not area)  $\Rightarrow$  increases frequency of collisions  $\Rightarrow$  increases rate of reaction.
  - Some students started their answers with "At high temperature..." but the question states high pressure!
  - Some students linked le Chatelier's principle/shift in position of equilibrium/extent of forward reaction to rate of reaction. This is not appropriate.
  - High pressure probably does not affect/improve the orientation for collision between reactant molecules. High pressure does not affect/increase the fraction of reactant molecules with kinetic energy  $\geq E_a$ . High pressure probably does not increase the kinetic energies of the reactant molecules. The effect of pressure on reaction rate for a gas-phase reaction is like the effect of concentration.
  - The gas molecules are forced closely together --- this is a better description than the terms "pack" and "packing" used by many candidates. The terms "pack" and "packing" are more appropriate for solid lattices.
  - Some students explained that high pressure is used so that it becomes easier to liquefy and remove the product  $NH_3$  --- not given full mark  $\therefore$  liquefaction of  $NH_3$  *by cooling* is carried out at a later stage of the manufacturing process. Here, the temperature is  $450^\circ C$ ,  $NH_3$  is unlikely to liquefy.
  - Explanation in terms of ideal gas behaviour (at high pressure) is not relevant.

- **(b)(i)** Use the word "equal" rather than "equivalent".

Some students stated that the "forward and backward reactions are equal". Incorrect, the forward and backward reactions are different reactions, they cannot become equal!

Some students stated that the concentrations of the reactants and products are equal, this may not be true.

- **(b)(ii)** Draw the curved-part of the profiles as shown in the suggested answers.

Some students showed that there are small sudden increases in  $P_{H_2}$  and  $P_{NH_3}$  at the time of disturbance. This may be true but we are not required to show that. Show only the sudden decrease in  $P_{N_2}$  since it was only  $N_2$  that was suddenly removed from the previously established equilibrium. Some students showed that the sudden increases in  $P_{H_2}$  and  $P_{NH_3}$  are larger than the sudden decrease in  $P_{N_2}$ , this is incorrect and penalised.

Students are also penalised for the following errors:

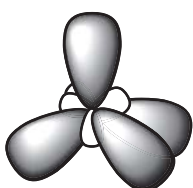
- The lines do not go horizontal at the same time (which means a new state of equilibrium is attained at that time). Please use a **ruler** to draw the horizontal line.
- New equilibrium partial pressure of  $N_2 \geq$  previous equilibrium value.
- (c) Many students stopped after determining the number of moles of  $N_2$  (44643 mol); the question asked for the number of  $N_2$  molecules!

Students who calculated an incorrect number of moles (e.g. due to incorrect  $M_r$ ) and hence an incorrect number of molecules are given zero mark, no ecf mark is given for this 1 mark question.

Students should work from the  $1.25 \text{ g dm}^{-3}$  density and  $1 \times 10^6 \text{ dm}^3$  reactor volume given in this question part --- it may be a different reactor from the one in (a). Students who used  $pV = nRT$  substituting 250 atm and  $450^\circ\text{C}$  taken from (a) hence obtaining a different answer, are given zero mark.

Marker: Li JX (11S60 – 11S69; 11S6B – 11S75); Ching MY (11S6A; 11S76 – 11S7N)

2 (d)  $sp^3$  hybridization [1]

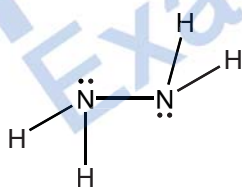


[1]

- must show small lobes
- hybrid orbitals must point in tetrahedral direction

[no ecf if type of hybridization predicted wrongly]

(e) (i)



[1]

- (ii) Hydrazine is **soluble in water** since its molecule can form **hydrogen bonds with water.** [1] **(Soluble alone no mark!)**

(f) (i)  $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$  [1]

(ii)  $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$

4x N-H (4x390)    O=O (496)    N≡N (994)    4 O-H (4x460)  
1 x N-N (1x160)

$$\Delta H = \Sigma \text{B.E. (bonds broken)} - \Sigma \text{B.E. (bonds formed)}$$

$$= (1560 + 160) - (994 + 1840)$$



$$= 2216 - 2834$$

$$= -618 \text{ kJ mol}^{-1}$$

correct working [1]  
 correct answer and units [1]  
 e.c.f from (e)(i) and (f)(i)

- (iii) Hydrazine is in liquid state in this reaction. To use bond energy values from the Data Booklet, all the bonds have to be in gaseous state.

Or student has to identify specifically that the enthalpy change of vapourisation of hydrazine was left out. [1]

- (iv) Any possible reason to the same effect [1]
- Ethane is in gaseous state while hydrazine is liquid. Thus hydrazine is easier to transport.
  - The by-products of combustion of hydrazine is water vapour and nitrogen which are harmless while ethane may produce carbon monoxide (if combustion is incomplete) or carbon dioxide.

- (v)  $\Delta G = \Delta H - T\Delta S$

Since  $\Delta H < 0$  and  $\Delta S > 0$ ,  $\Delta G$  is negative at all temperatures.

Reaction is feasible at all temperatures. [1]

[1/2] if student states how feasibility varies but not that it is feasible at all temperatures.

e.c.f. from (f)(ii)

#### Comments:

- Q2d) The most common error is that students gave  $sp^2$  hybridisation as the answer. They failed to realize that ammonia has 3 bond pairs and 1 lone pair of electrons around it and that the 4 electron pairs have to distribute themselves in a tetrahedral manner, hence requiring that the central nitrogen atom to have  $sp^3$  hybridisation.

All 4 hybrid orbitals must be drawn. Many students also did not draw the hybrid orbital lone pair on the nitrogen exists in.

A number of students do not realize that each  $sp^3$  hybrid orbital consists of a large lobe and a small lobe and randomly draws the small lobe in a wrong orientation.

Some students do not realize that the lone pair of electrons on the nitrogen exists within one of the hybrid orbitals and leaves the 4<sup>th</sup> hybrid orbital out of the drawing

$sp^x$  hybridisation is written with superscript, not subscript

- Q2ei) Many students did not give the correct shape of the molecule which is trigonal pyramidal with respect to the two nitrogen atoms. Many also left out the lone pairs of electron on the nitrogen atoms.

Other common errors include using dot-cross diagram, double/triple bonds for the bond between the two nitrogen atoms.

Q2eii) Many students mention that hydrazine has lone pairs on the nitrogen hence allowing it to form hydrogen bonds with water. This is technically a false statement as simply having lone pairs does not allow a molecule to form hydrogen bonds. Also, having a lone pair does not automatically make a bond polar.

Many students also do not realize hydrazine itself is also able to form hydrogen bonds. Ammonia is not the only nitrogen containing compound that can form hydrogen bonds

Many students think that the N-H bond and O-H bonds are the hydrogen bonds. These are covalent bonds, not hydrogen bonds.

Students were able to identify hydrogen bonding within hydrazine and water and/or that the interactions between hydrazine and water are favourable but could not identify or did not state hydrogen bonding between hydrazine and water.

Some students have the wrong concept of the dissolution process. The molecule does not have to break up to dissolve.

Q2fi) Some students gave  $N_2H_2$  as the formula even though the formula is stated in the question. Some also wrote the wrong state symbol for steam. Please read carefully.

Q2fiii) Some students were unable to identify that bond energies involved gaseous reactants. Many also did not realize that the reaction would be more endothermic not more exothermic when the state of hydrazine is taken into account.

Some students were able to identify that certain enthalpy changes were left out but gave the wrong enthalpies such as enthalpy change of solution, hydration or atomization.

Q2fiv) Quite a number of students mentions overheating of the rocket engine or that the highly exothermic reaction would cause the rocket to explode or that the more endothermic reaction of hydrazine makes it safer which demonstrates that students do not understand how rockets work.

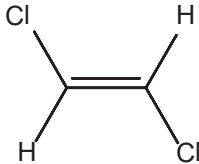
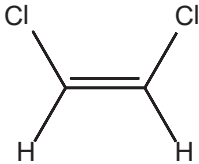
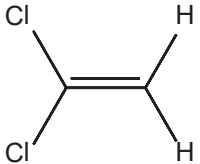
Some students still said that hydrazine gives a more exothermic reaction even though from their calculations, it clearly does not.

Q2fv) Many students did not realize the reaction is feasible at all temperatures.

Some students are still confused whether entropy increases or decreases when more gas particles are formed. And also whether feasibility increase or decrease with respect to changes in Gibb's Free Energy.

Some students attempted wrongly to answer the question using Le Chatelier's Principle or collision theory

3 (a) (i)

Isomer	A	B	C
Structure			
Cis or Trans Isomer	trans	cis	

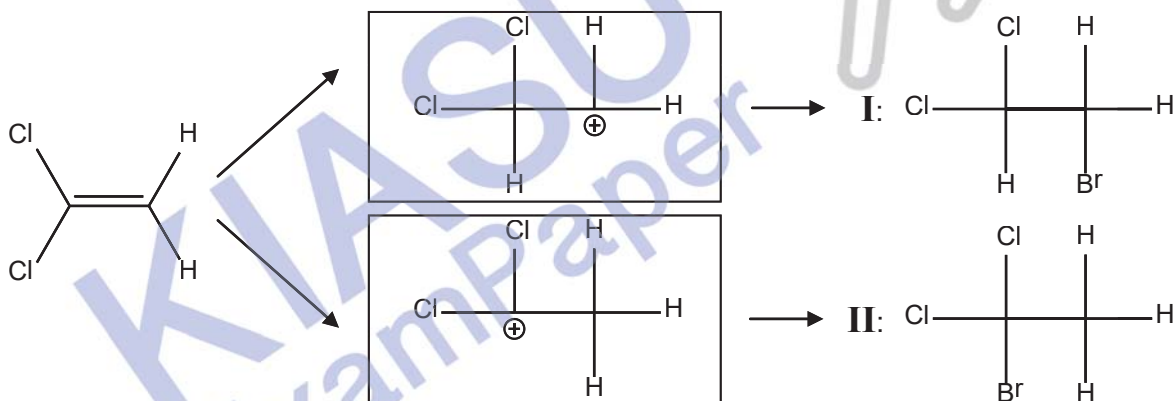
[1] for each structure

[1] for correct labeling of cis and trans

[-1] overall if students does not give 120° for drawing of structure

- (ii) [1] The presence of the pi bond restricts the rotation of the molecule and two different groups attached to each carbon of the C=C bond.

(b) (i)



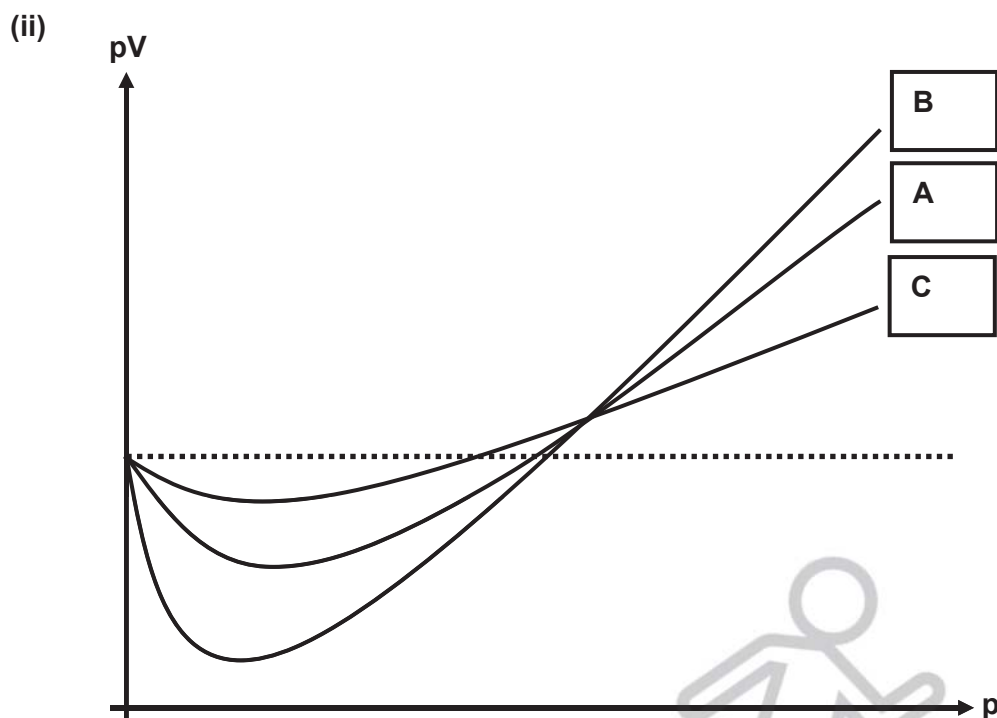
[1] for both intermediates. No penalty for wrong bond angle

- (ii) [1] The intermediate for I is more stable compared to II as the positively charged carbon is not destabilized by the 2 electron withdrawing chlorine substituents attached to the positively charged carbon. Hence I is the preferred product.  
Or words to the same effect including vice versa.

(c) (i) [1] The volume of the gas particles/molecules is negligible compared to the volume of the container.

[1] The forces of attractions and repulsion between gas particles/molecules are negligible.

**Answers using random motion or kinetic energy are not accepted.**



**[1] No marks awarded if no explanation offered. Award this mark if explanation is attempted**

**[1]** Greater boiling point implies greater overall intermolecular force and hence greater deviation from ideal gas behavior. (or words to the same effect)

Not sufficient if student just quotes boiling point. They must link to intermolecular force and deviation from ideal gas behavior.

#### Comments:

(a) (i)

- Well done.
- Many students did not read the question carefully and did not label cis and trans.
- Almost all the students remembered to draw the correct shape of the alkenes.

(a) (ii)

- Very badly done.
- Most students only mentioned the restricted rotation due to the pi bond and did not identify the condition of having geometric isomerism (2 different groups attached to each C of the C=C).
- Students should note that it is 2 different groups and not 2 different atoms attached to each C.

(b) (i)

- Well done.

(b) (ii)

- Not well attempted.
- Many answers were not clearly explained.
- Some students did not identify the intermediate they were discussing in their answers and lost the mark.
- One common misconception by students was using Markovnikoff's rule to explain which carbon was attacked by the electrophile.
- A few students referred chlorine as deactivating without realizing the term deactivating is used with benzene.
- Some students thought that H atom was electron donating!!

(c) (i)

- Answers were not as good as expected.
- "Volume of gas" was not accepted because it is equal to the volume of the container the gas occupies. [Volume of gas  $\neq$  volume of gas molecules]
- "Intermolecular forces of attraction between gases" was not accepted. (Gases may mean different gases)

(c) (ii)

- Very badly done.
- Majority compared the dipole moments instead of the boiling points.
- Any correct labelling of the gases without any explanation would not be awarded any marks.
- Students must compare the intermolecular forces using their boiling points.

**Marker: Fan YT (All)**

- 4 (a) (i)** When dissolved in water, the molecules will arrange themselves in such a way that the polar heads containing the carboxylic acid groups will face outside so as to be in contact with water where the polar heads are able to form hydrogen bonds with water molecules [1], whereas the non-polar long chain alkyl tails will face inwards where they will have favourable dispersion forces with one another. **[1]**

**(1 mark for stating hydrogen bonds between carboxylic acid and water; 1 mark for stating dispersion forces between the alkyl chains)**

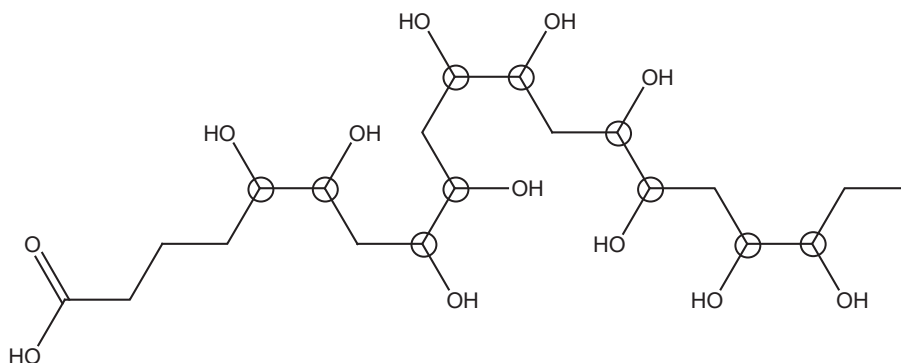
- (ii)** When EPA is dissolved in a non-polar solvent **[1]**

Accept other possible answers like: When EPA is dissolved in oil, tetrachloromethane etc.

Reject: organic solvents; very little or no water.

(b) (i) Cold dilute acidic  $\text{KMnO}_4$ . (Accept cold dilute alkaline  $\text{KMnO}_4$ ) [1]

(ii)



**[all 10 chiral carbons have to be identified to score 1 mark; ½ mark awarded if student used an asterisks to indicate the chiral centre; no mark if there is any chiral carbon not identified]**

(c) (i)  $n_{\text{bromine}}$  used for preparing solution =  $1.60/159.8 = 0.0100 \text{ mol}$

$$[\text{Br}_2] = 0.0100/0.200 = 0.0500 \text{ mol dm}^{-3} \text{ [1]}$$

(ii)  $n_{\text{bromine}} = 0.0500 \times 34.9 \times 0.001 = 1.745 \times 10^{-3} \text{ mol}$

Since bromine reacts with a double bond in a 1:1 ratio,

$$n_{\text{double bond}} = n_{\text{bromine}} = 1.75 \times 10^{-3} \text{ mol (3 s.f.) [1]}$$

(½ mark for calculating  $n_{\text{bromine}}$  without equating to  $n_{\text{double bond}}$ )

(iii) Since there are equal number of moles of DHA and EPA,

$$n_{\text{DHA}} = n_{\text{EPA}} = 0.100/(302+328) = 1.587 \times 10^{-4} \text{ mol [1]}$$

Let  $x$  be the number of double bonds per molecule of DHA.

$$\text{Total number of moles of double bonds} = 5 \times n_{\text{EPA}} + x \times n_{\text{DHA}}$$

$$1.745 \times 10^{-3} = 5(1.587 \times 10^{-4}) + x(1.587 \times 10^{-4})$$

$$x = 5.996 = 6 = \text{number of double bonds in DHA [1]}$$

### Comments:

(a)(i)

- Many candidates could identify and hence elaborated on the presence of hydrogen bonding between the carboxylic acid head and water molecules. However, most did not write about the existence of dispersion forces between the hydrocarbon tails.
- A lot of candidates wrote about the carboxylic head being 'hydrophilic' and hydrocarbon tail being 'hydrophobic' without explaining the intermolecular forces that are present.
- Some weaker candidates loosely used the word "react" (instead of "interact") and "bonds" (instead of intermolecular forces) in their explanations, ie. the hydrocarbon tail do not "react" with water to form 'bonds'.



**(a)(ii)**

- Many candidates could write that a non-polar solvent is used and/or name an example of such a solvent, eg. benzene, tetrachloromethane, hexane etc.
- Quite a number simply wrote the term “organic solvent”, without indicating whether the organic solvent is polar or non-polar, as they probably are not aware that organic solvents could also be polar.
- Some candidates thought that ethanol could be used, without realizing that it is also a polar solvent that can form hydrogen bonds with EPA.

**(b)(i)**

- Most candidates could identify that the reaction is mild oxidation, and were able to state the conditions for the reaction. However, the bulk of the candidates wrote that the reaction is to be done in an alkaline medium instead of the acidic medium (because a carboxylate salt would be formed in an alkaline medium), though no penalty was given.
- A few candidates wrote “room temperature” instead of “cold” and were given half credit.
- Some candidates wrote “potassium manganate solution” without indicating the oxidation state of the manganese, and were also given half credit.
- Quite a number of candidates are still confused over the differences in conditions between mild oxidation and oxidative cleavage.

**(b)(ii)**

- Very well done, though a few circled the carboxylic acid carbon.

**(c)(i)**

- Generally well done, though quite a number of candidates had calculation errors.
- Some candidates tend to write  $n_{\text{Br}}$  and  $[\text{Br}]$  instead of  $n_{\text{Br}_2}$  and  $[\text{Br}_2]$ , even though their calculation was for the latter, but was not penalized.
- A number of candidates wrongly divided the number of moles of  $\text{Br}_2$  by  $34.9\text{cm}^3$  instead of  $200\text{cm}^3$ .

**(c)(ii)**

- Very well done, except for a few mistakes in calculation.
- Some did not equate number of moles of double bond to number of moles of bromine.
- A large number of candidates calculated for the number of double bonds (11) instead of the number of moles of the double bond.

**(c)(iii)**

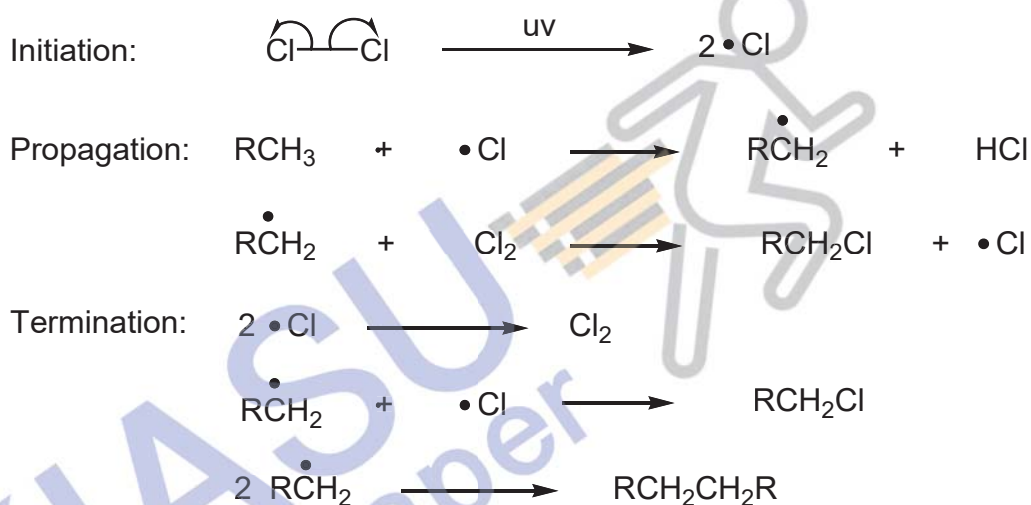
- Many candidates assumed that  $1.587 \times 10^{-4}$  is equivalent to the number of moles of DHA plus EPA, or the number of moles of sample (number of moles of the sample should be  $3.174 \times 10^{-4}$ ).
- Many did not attempt this part of the question due to lack of time.

## PAPER 2 SECTION B - FREE RESPONSE QUESTIONS

Marker: Sam Lee (11S60 – 11S69, 11S6B - 11S71); Sophie (11S6A, 11S72 – 11S7N)

- 1 (a)
- Order: pentane  $\rightarrow$  3,3-dimethylpentane  $\rightarrow$  heptane [1/2]
  - Pentane has the smallest no. of electrons/size of electron cloud, thus weakest dispersion forces. Less energy required to overcome these forces, hence it has the lowest boiling point. [1]
  - 3,3-dimethylpentane is a branched-chain hydrocarbon and thus has smaller surface area than heptane. It has weaker dispersion forces, thus lower boiling point than heptane. [1]
  - Separated by fractional distillation [1/2]

- (b) (i) Free radical substitution [1]



[½] initiation step  
[1] **both** propagation steps  
[½] termination steps

Penalties:

-½ for putting the unpaired radical on the incorrect atom



NO has a single unpaired electron which causes it to react with the radicals in the reaction. [1]

- (iii) In the first propagation,

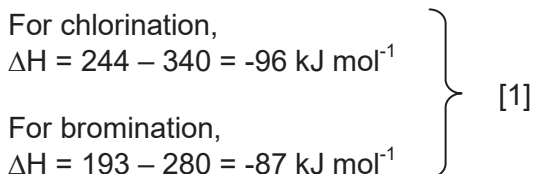
$$\left. \begin{array}{l} \text{For chlorination,} \\ \Delta H = 410 - 431 = -21 \text{ kJ mol}^{-1} \\ \text{For bromination,} \\ \Delta H = 410 - 366 = +44 \text{ kJ mol}^{-1} \end{array} \right\} [1]$$

Since the first step of bromination is endothermic, it occurs less readily as compared to chlorination. [1]

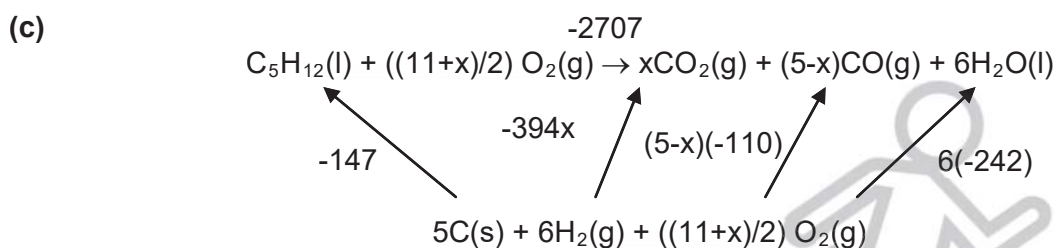


OR

In the second propagation,



In the second propagation step, chlorination is more exothermic than bromination, hence it occurs more readily. [1]



Correct method and application of Hess' Law and calculations [2]

Ratio of  $\text{CO}_2$ :  $\text{CO} = 3:2$  [1] (no e.c.f.)

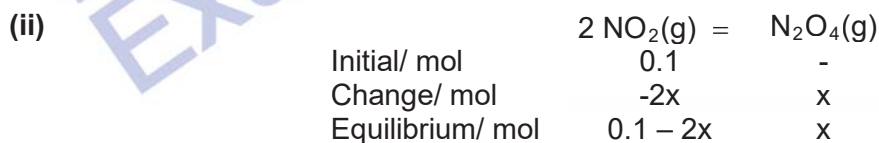
- (d)
- To minimize the production of carbon monoxide and nitrogen monoxide, the reverse exothermic reaction should be favoured. A low temperature should be used so as to absorb the excess heat given off by the reverse reaction. [1]
  - Pressure has to be high to minimize production of carbon monoxide as the reverse reaction has less gaseous molecules. [1]

(e) (i)

$$pV = nRT$$

$$(101 \times 10^3)(1.48 \times 10^{-3}) = n(8.31)(300)$$

No. of moles of gas = 0.05996 [1]



$$\begin{aligned} \text{Total} &= 0.1 - x = 0.05996 \\ x &= 0.04004 \end{aligned} [1]$$

$$\text{Percentage reacted} = (0.04004 \times 2) / 0.1 \times 100\% = 80.1\% [1]$$

(iii)

$$K_p = \frac{P_{\text{N}_2\text{O}_4}}{P_{\text{NO}_2}^2} = \frac{\left(\frac{0.04004}{0.05996} \times 1\right)}{\left(\frac{0.01992}{0.05996} \times 1\right)^2} [1]$$

$$= 6.05 \text{ atm}^{-1} [1] \text{ (answer must have correct units)}$$

Allow working and answer in Pa and kPa.

## Comments:

### (a)

- The question calls for a ranking in order of increasing boiling point. As such, answers with the opposite ranking (even though correct), or with no ranking, were penalized.
- Students should mention the size of the electron cloud, as it is the polarisability of the electron cloud that influences the strength of dispersion forces that exist between molecules, rather than the surface area.
- Many answers referred to intermolecular forces of attraction but did not mention what kind of forces these were.
- When attempting to compare the surface area of the electron clouds, candidates should compare hydrocarbons of the same molecular mass. Many candidates compared 3,3-dimethylpentane ( $C_7H_{16}$ ) with pentane ( $C_5H_{12}$ ) and incorrectly concluded that the unbranched pentane should have a higher b.p.
- It is irrelevant to talk about packing of molecules when comparing boiling points. Packing is relevant to a discussion on the melting point of compounds.

### (b)(i)

This question was generally well answered, however:

- Too many candidates omitted the name of the mechanism.
- Some forgot to label the names of the individual steps in the mechanism (i.e. initiation, propagation, termination)
- Some candidates did not show the fish-hook arrows in the homolytic fission of the Cl-Cl bond.
- Quite a number of students mis-labelled the position of the unpaired electron, particularly on the pentyl radical, placing it on the R group, rather than on the correct C.
- A large proportion of candidates formed " $RCH_2RCH_2$ " from the combination of two pentyl radicals, showing a weak understanding of the condensed structural formula notation.

### (b)(ii)

On the whole, most candidates were able to give the correct dot-and-cross diagram for NO.

- Some candidates placed more than 8 electrons around either N or O without realising that neither could have an expanded octet.
- A handful of candidates gave the Lewis structure rather than the dot-and-cross diagram.
- Legends should not be used for dot-and-cross diagrams.
- Most candidates realized that there was an unpaired electron on the NO molecule, but failed to refer to it appropriately, incorrectly calling to it as a 'radical', 'free electron', 'delocalised electron', 'very reactive electron', 'single electron'.

### (b)(iii)

This part was poorly answered.

- Many candidates referred to the initiation or termination steps in free radical substitution, when the question specifically asked for the propagation step.
- Candidates who did not quote any data from the Data Booklet were not awarded full credit.
- The majority of candidates referred to the bond-forming process, and in particular the

formation of a C-Cl bond being more exothermic than the formation of a C-Br bond. While this is true, they failed to consider the accompanied bond-breaking process, which is different in each case (as the former requires the breaking of a Cl-Cl bond, while the later requires the breaking of a Br-Br bond).

- Some candidates mixed up the two propagation steps, incorrectly combining the bond-breaking and bond-making processes.

**(c)**

In general, candidates either did very well or very poorly for this part.

- Candidates who solve this question by trial and error, or omitted crucial working steps were awarded little to no credit.
- Many candidates were unable to calculate anything, although they attempted to draw an appropriate energy cycle.

**(d)**

This question was very well answered by the majority of candidates.

- A handful of candidates confused their right and left. They are advised to use 'backward' and 'forward' instead.
- Ideally, candidates should make reference to Le Chatelier's Principle at least once.
- Candidates were expected to explain their choice of conditions. Answers with no explanation on why the equilibrium shifts in a particular direction were not awarded full credit.

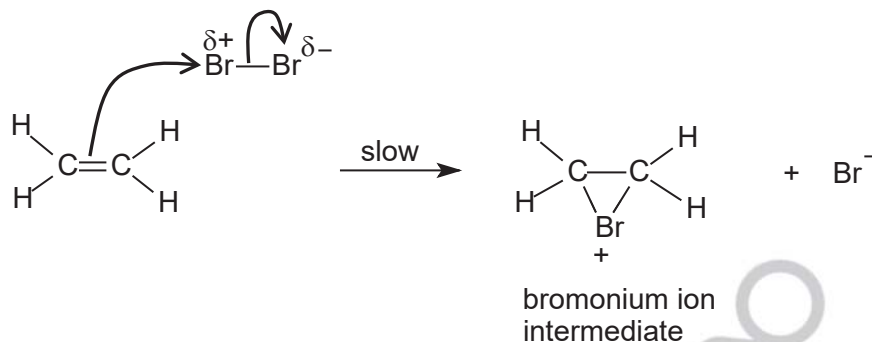
**(e) (i)/(ii)/(iii)**

Answers to this part were very disappointing, especially since it was very similar to a question discussed in Equilibrium Tutorial Q6(a).

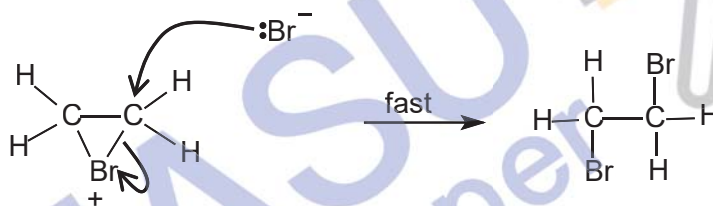
- Some candidates did not realize that the initial gas was not at r.t.p. and hence, that they could not use molar volume at r.t.p to find no. of moles of gas.
- Many candidates attempted to solve part (ii) without drawing an I-C-E table, and did not arrive at the correct answer. No marks were given for answers that did not have appropriate working shown.
- Some candidates confused  $K_c$  and  $K_p$ .
- Some candidates hedged their bets, and drew square brackets around the terms (e.g.  $[P(N_2O_4)]$ ).
- Most candidates who solve part (iii) expressed units correctly. But some failed to take the correct units when they tried to change from atm to Pa or kPa.

2(a) (i) [1] name of mechanism: electrophilic addition

[1] correct slow step: two correct arrows,  $\delta+$  &  $\delta-$  charges indicated on Br–Br, drawing of bromonium or carbocation intermediate, 'slow' indicated,  $\text{Br}^-$  formed  
[Give  $\frac{1}{2}$  mark if there is at least one correct item; 0 marks if more than 2 mistakes]



[1] correct fast step: two correct arrows (for bromonium ion intermediate) or one correct arrow (for carbocation intermediate), one arrow flows from lone pair on  $\text{Br}^-$ , drawing of product, 'fast' indicated  
[Give  $\frac{1}{2}$  mark if there is at least one correct item; 0 marks if more than 2 mistakes]



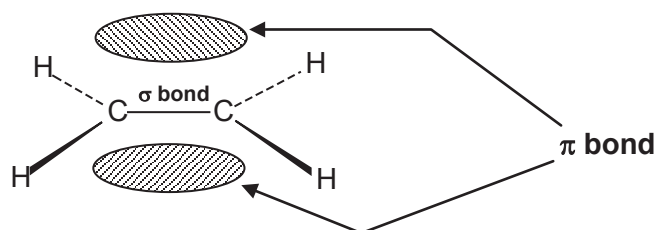
(ii) [1] The first step of the mechanism is rate-determining step.

*Possible reasoning:*

- first step requires the non-polar Br–Br to be polarised by the C=C double bond,  $\text{Br}^{\delta+}$  then "pulls" out a pair of electrons from C=C; while in the second step, there is an attraction between "fully-charged" positive and negative ions; so the first step is probably more difficult or slower to occur than the second
- (if carbocation is drawn as the intermediate) first step involves bond breaking (C=C to C–C and Br–Br) and forming, second step involves only bond forming, so the first step is probably more difficult or slower to occur than the second

[This mark is given only if a sensible reason is given to explain why the first step is rate-determining.]

(b) (i) [1]



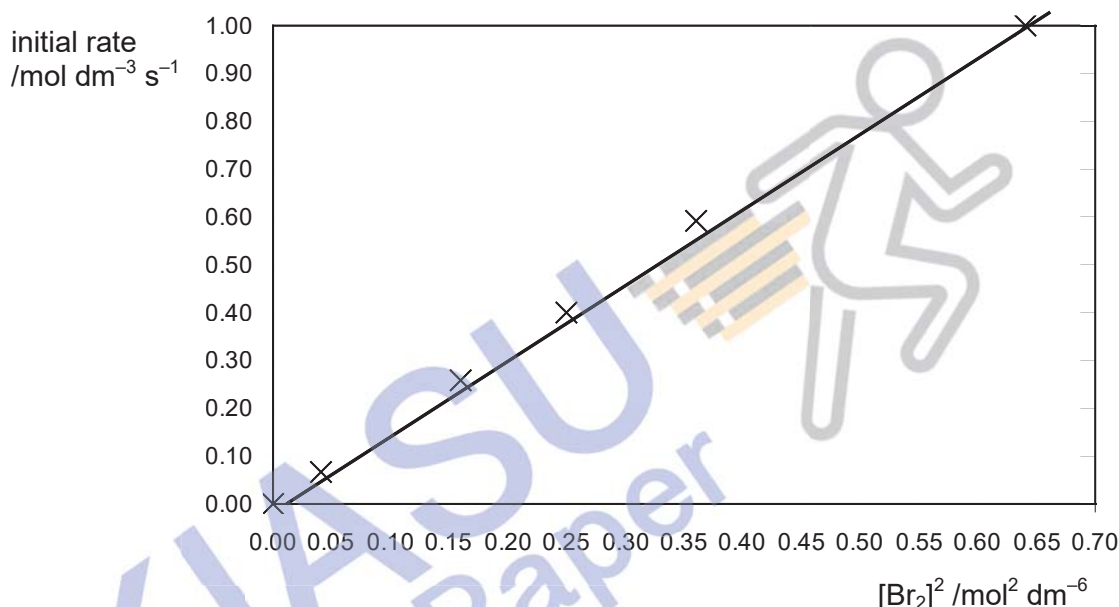
[1] As shown in the diagram, the  $\pi$  electrons are much more exposed or

available than those in the  $\sigma$  bond, therefore more vulnerable to attacking species particularly electrophiles. **[Accept other sensible reasoning e.g. higher electron density on top and bottom of the two carbon atoms.]**

- (ii) [1] Strength of  $\sigma$  bond = **+350 kJ mol<sup>-1</sup>**  
 Strength of  $\pi$  bond =  $+610 - 350 =$  **+260 kJ mol<sup>-1</sup>**  
 [½ mark each]

- [1]  $\sigma$  bond is stronger than  $\pi$  bond because  $\sigma$  bond is formed by head-to-head overlap between orbitals which gives a **larger region of overlap** compared to the side-to-side overlap for  $\pi$  bond.

- (c) (i) [1] Plot graph of initial rate against  $[\text{Br}_2]^2$



- [1] This gives a straight line that joins to (0, 0). Thus, rate  $\propto [\text{Br}_2]^2$ , order 2 with respect to  $\text{Br}_2$ . **[This mark is not given if there is no justification]**

- (ii) [1] Rate =  $k$  [propenyl ethanoate]  $[\text{Br}_2]^2$

- (iii) Using data from expt 1,

$$k = \frac{\text{initial rate}}{[\text{propenyl ethanoate}][\text{Br}_2]^2} = \frac{0.065}{0.02 \times (0.2)^2} = \mathbf{81.3 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}}$$

- [1] value of  $k$

- [1] Units

**[Students can use data from any of the experiments.]**

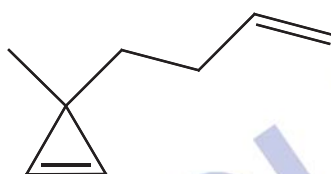
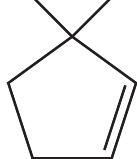
- (iv) [1] Decrease in [propenyl ethanoate] =  $\frac{1}{100} \times 0.02 = 2.00 \times 10^{-4} \text{ mol dm}^{-3}$

$$\text{Estimated time needed} = \frac{2.00 \times 10^{-4}}{0.065} = \mathbf{3.08 \times 10^{-3} \text{ s}}$$

*Remarks:* This is only an estimation because we have assumed that the rate of change for [propenyl ethanoate] remains constant at  $0.065 \text{ mol dm}^{-3} \text{ s}^{-1}$  during that time period of  $3.08 \times 10^{-3} \text{ s}$ .

- (v) [1] ▪ Decolourisation of orange Br<sub>2</sub>.
- (vi) [1] ▪ State the parameter to be monitored e.g. colour intensity of Br<sub>2</sub>.  
 ▪ State the instrument used to monitor this parameter e.g. colorimeter.
- (vii) [1] Any one possible reason:
- Ethanoic acid may be a **better solvent** than water as its hydrocarbon portion can form **dispersion forces** with Br<sub>2</sub> and propenyl ethanoate molecules. **[no marks for not stating that bromine does not dissolve in water]**
  - The rate of reaction would be too fast in water.
  - The ester might be hydrolysed in the presence of water.

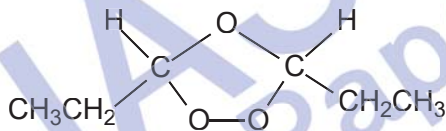
(d) (i) [1] A: CC1(C)C=CC=C1



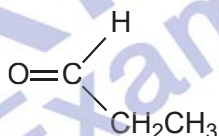
or

(note: this compound is highly unstable due to angle strain on the double bond in the cyclopropene ring)

(ii) [1] B:



[1] C:



#### Comments:

This question was generally poorly attempted with many students scoring less than 10 marks.

(a)(i):

- Most candidates were able to score at least 2 marks.
- Several candidates did not write the name of the mechanism.
- Some candidates failed to identify the mechanism as an electrophilic addition, and confused it with electrophilic substitution or even free radical substitution.
- Some candidates misread the question and drew the mechanism of the addition of hydrogen bromide instead of bromine.
- Many candidates drew the arrows wrongly, with the arrow originating from the bromine molecule instead of the double bond.



- Other common mistakes would be not writing in the “slow” step as well as the partial charges on the bromine molecule.

**(a)(ii):**

- A few candidates failed to identify the rate-determining step as the first step.
- Many candidates only identified the first step as the rate-determining step because it is the slow step, but did not discuss in terms of bonds broken.

**(b)(i):**

- Most candidates were unsure of what the question wanted and did not draw the  $\pi$  cloud above and below the alkene molecule. Instead, they drew a diagram showing all the hybridized and unhybridized orbitals in the molecule, which does not show why the  $\pi$  electrons are more exposed.
- Some candidates explained that the C=C double bonds are more vulnerable to attack because a  $\pi$  bond is weaker than a  $\sigma$  bond, which is not what the question wants.
- Some used the term “delocalized electrons” wrongly when discussing  $\pi$  bonds.

**(b)(ii):**

- Most candidates were able to correctly calculate the bond strength of the  $\sigma$  and  $\pi$  bonds.
- However, a few candidates used a triple bond to calculate the strength of the  $\pi$  bond, which cannot be accepted because the question asks for the strength of the  $\pi$  carbon-carbon bond in alkenes.
- A few candidates used C-H bond energy in their calculations instead of C-C bond energy.
- Most candidates mentioned that the head-on overlap of  $\sigma$  bond is stronger than side-on overlap of  $\pi$  bond without mentioning that this is because a head-on overlap gives a larger region of overlap as compared to side-on overlap, and were not awarded marks accordingly.

**(c)(i):**

- Most candidates plotted the wrong graph of initial rate vs  $[\text{Br}_2]$  instead of initial rate vs  $[\text{Br}_2]^2$ . As a result, they obtained a parabola, which cannot be used to conclude that the reaction is second order with respect to  $\text{Br}_2$ . Candidates need to recognize that the question gave the values of  $[\text{Br}_2]^2$  for a reason!
- Some candidates used their graphs to find half-life, which is impossible since neither of the axes drawn was a measurement of time.
- Some candidates concluded that the reaction is second order with respect to  $\text{Br}_2$  without using a graph, and so cannot be awarded any marks because the question specifically mentioned the word “hence”.
- Quite a number of candidates who plotted correctly lost marks because they were careless in the plotting or did not write in the units on the axes.
- Candidates who plotted the graph correctly but did not justify why the rate was second

order with respect to  $\text{Br}_2$  did not get full credit.

**(c)(ii):**

- Candidates who wrote the rate equation based on **(c)(i)** gets full credit regardless of the order of reaction with respect to  $\text{Br}_2$  that they had determined in **(c)(i)**.
- No marks were awarded if **(c)(i)** was not attempted at all.
- Some candidates omitted the order with respect to  $\text{Br}_2$  totally.

**(c)(iii):**

- Candidates who calculated the rate constant based on **(c)(ii)** receives full credit given that the calculations were correct.
- A number of candidates could not determine the units of the rate constant.
- Several candidates were very careless and substituted wrong data into their equation.

**(c)(iv):**

- Almost all candidates were unable to obtain the answer to this question.
- Candidates were unable to appreciate that because the time taken for 1% of propenyl ethanoate was short, the rate of change of [propenyl ethanoate] can be considered to be relatively constant.

**(c)(v):**

- Most candidates were able to state that the orange solution decolourised.
- A few candidates mentioned a white precipitate formed and white fumes being produced, which did not make sense.
- Some candidates mentioned that the colour of the solution fades, and only partial credit is given for that.
- Yet a few candidates stated that the solution turns orange as the reaction proceeds, which clearly shows a lack of understanding of the question.
- Some candidates mentioned that the brown/yellow/reddish brown solution decolourised. Candidates need to read the question carefully, it was stated that bromine is orange. Full credit is still awarded nonetheless.

**(c)(vi):**

- A number of candidates were able to suggest that the correct experimental technique to be used would involve the use of a colourimeter to measure the change in colour intensity as the reaction progressed.
- A number of candidates did not even attempt this question.

**(c)(vii):**

- A number of candidates were able to identify that the propenyl ethanoate does not dissolve well in water but dissolves better in ethanoic acid as it can form dispersion forces with it.



Partial credit was given if candidates mentioned that the propenyl ethanoate was non-polar and is hence insoluble in polar water.

- No mark is awarded if candidates mentioned that bromine is insoluble in water. This is not an entirely true statement as bromine dissolves to a certain extent in water.
- Several candidates suggested that hydrolysis of the ester might take place in water which was given full credit.
- A number of candidates mentioned that water can act as a nucleophile to give a bromoalcohol as the product. This answer is rejected because the focus of this question is not on synthesis. The purpose of this experiment is to measure the rate of the reaction and the product of the reaction does not matter if it does not affect the rate. The rate-determining step involves only bromine and propenyl ethanoate and does not involve water, hence the step involving water to form the bromoalcohol is the fast step does not have any impact on the rate of the reaction.

(d)(i):

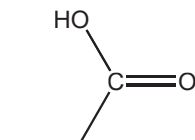
- Most students did not manage to get the correct structure and many did not even attempt this question.
- Two answers are accepted, however, it must be noted that the structure containing the cyclopropene ring is highly unstable as the angle strain in the ring ( $60^\circ$  in the ring vs  $120^\circ$  for a bond angle around a typical  $sp^2$  carbon) is too big.

(d)(ii):

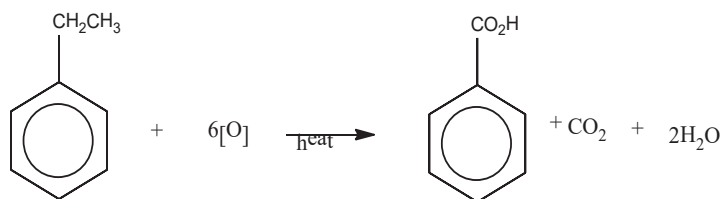
- Most students were able to get the structure of **B** correct. Half a mark was deducted if students drew the structure as follows:



- Most students managed to get the structure of **C** correct. However, a few candidates drew the carboxylic acid instead of the aldehyde that would be formed, as shown below:



3(a) (i) [1] for correct products formed and balancing equation



- (ii) [1] No. of moles of ethylbenzene is  $1.00/106 = 0.00943$  mol  
 mass of product is  $= 0.00943 \times 166 \times 0.8 = \underline{1.26 \text{ g}}$

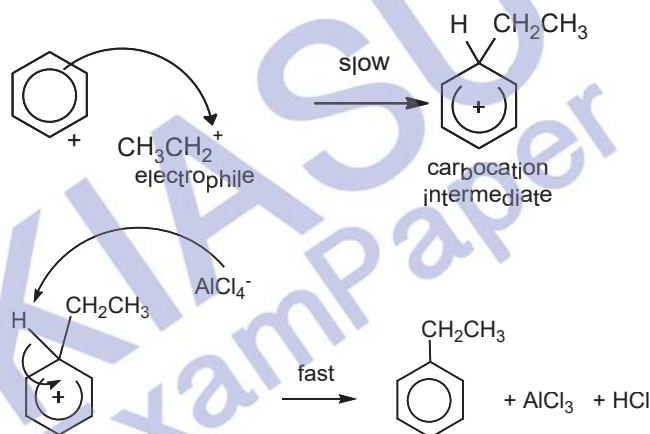
(allow ecf from (a)(i))

- (iii) I  $\text{AlCl}_3$  act as catalyst to form  $\text{CH}_3\text{CH}_2^+$  which is a strong electrophile. A stronger electrophile needs to be generated due to the stability of benzene. [1]

II Name of mechanism: Electrophilic substitution [1]



[2 marks for writing the mechanism. 1/2 mark will be deducted for each mistake]



(b) [1] To form ethylbenzene, the ethyl cation can only substitute the deuterium atom.

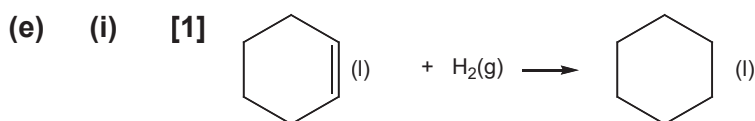
[1] To form 3-ethyldeuteriobenzene the ethyl cation can substitute the H atom from two possible identical positions. Statistically twice the amount of products are 3-ethyldeuteriobenzene. Thus the ratio 1:2

(c) [1] The rate determining step does not involve the breaking of C-D bond.

(d) [2] Any two suitable reagents and [2] observations

Reagents			
Adding liquid bromine (room temperature)	reddish brown $\text{Br}_2$ is	no decolourisation	no decolourisation

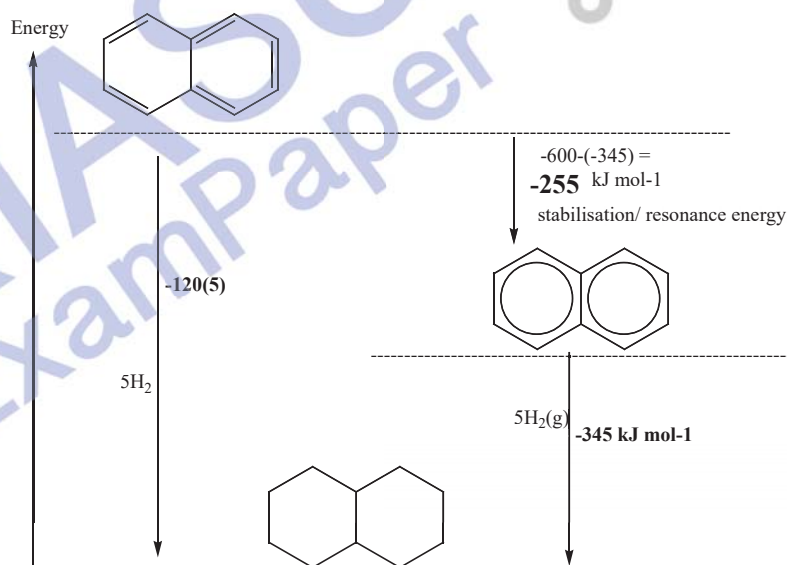
temperature; absence of light)	<b>decolourised</b>		
Adding liquid bromine (uv light)	<b>reddish brown Br<sub>2</sub> is decolourised</b>	no decolourisation	<b>reddish brown Br<sub>2</sub> is decolourised</b>
Adding KMnO <sub>4</sub> / H <sub>2</sub> SO <sub>4</sub> (aq) heat	<b>purple KMnO<sub>4</sub> is decolourised</b>	no decolourisation	<b>purple KMnO<sub>4</sub> is decolourised; formation of white ppt</b>
Concentrated HNO <sub>3</sub> and concentrated H <sub>2</sub> SO <sub>4</sub> (heat)	No yellow oil	<b>yellow oil of nitrobenzene</b>	<b>yellow oil</b>



[zero if no state symbols given. 1/2 mark deducted for wrong state symbols (except for cyclohexane) given]

(ii) [2] Correct energy level diagram (relative energy level correct) + working [1/2 mark deducted for any mistake]

[1] Correct answer of 255 kJ mol<sup>-1</sup> [1/2 mark deducted for wrong units]



stabilisation/ resonance energy is 255 kJ mol<sup>-1</sup>

(iii) [1] 

- Naphthalene is more stable than its hypothetical structure [1/2]
- due to the delocalization of the  $\pi$  electrons throughout the ring. [1/2]

 OR therefore naphthalene undergoes substitution rather than addition.

(iv) [1] Heat of hydrogenation =  $7(-120) + 3/2(255) = -457.5 \text{ kJ mol}^{-1}$

OR Heat of hydrogenation =  $7(-120) + 7/5(255) = -483 \text{ kJ mol}^{-1}$

[allow ecf]

**Comments:**

Overall, the markers noticed a lack of time to attempt this question as students have spent too much time on possibly Question 1. As a result, the question was often left incompleting or super bad handwriting was shown.

For (a)(i) and (ii):

- Many students have written the formula of ethylbenzene as " $\text{C}_6\text{H}_6\text{CH}_2\text{CH}_3$ " instead of the correct one which is " $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3$ ". This would be penalised in (i) but there will be error-carried-forward mark for (ii).
- While a handful of students may get to the correct final answer, no credit will be given once a wrong  $M_r$  is used for the calculation unless ecf from (i).

For (a)(iii):

- Some students have written down  $\text{AlCl}_3$  as a heterogeneous catalyst. While there is no penalty, they should note that it is actually a homogeneous catalyst.
- Common mistakes for writing the mechanism:
  - wrong direction for arrows (should be from electron-rich to electron-poor region)
  - the ethyl substituent should be drawn as " $-\text{CH}_2\text{CH}_3$ " and not " $-\text{CH}_3\text{CH}_2$ "
  - for the intermediate that is formed, delocalisation should be about the 5  $\text{sp}^2$  carbon atoms. There will be penalty if the delocalisation is shown to "touch" the  $\text{sp}^3$  carbon atom.
  - Lone pair on  $\text{AlCl}_4^-$  is often missed out.
  - $\text{AlCl}_3$  or  $\text{HCl}$  is often left out at the end of the mechanism.

For (b):

- Ambiguous answers such as "It is twice more likely for 3-ethyldeuteriobenzene to be formed than ethylbenzene" without mentioning about the probability of substitution will not be given any credit.

For (c):

- It is interesting to see that quite a large number of students think that C-D bond is not broken in the reaction, when the bond actually needs to be broken for substitution to occur.

For (d):

- Quite a handful of students like to use chlorine gas with uv light to distinguish the compounds. While no penalty is given, it is good to note that this is not a very good distinguishing test as the colour of chlorine gas is not very intense and thus difficult to observe the changes.
- Students are reminded to read the question carefully. The question states "the observation for **EACH** compound". Most only gave one observation, thus resulted in the mark for observations not being awarded.

- There are a few candidates who gave answers like "to distinguish cyclohexene from benzene...". The markers would like to remind these students that you were given 3 unknown compounds at the start. You have absolutely NO idea which samples are the ones that contain cyclohexene or benzene. You need to do the chemical tests to all 3 unknown samples.
- Answers with "heat under reflux" will be given zero for the reagents and conditions since the question asked for simple chemical tests.
- Answers stating using "concentrated  $\text{KMnO}_4$  with concentrated sulfuric acid" will have 1/2 mark deducted as these 2 reagents may react together. Typically, dilute sulfuric acid is used.

For (e):

- State symbols should be given since this is an energetics question. The state symbol of cyclohexene is given in the question itself. Any wrong state symbols for cyclohexane is not penalised, though it should be liquid.
- Students seem to be confused with the "cause-and-effect" of stabilisation energy. Do take note that it is the delocalization of  $\pi$  electrons throughout the ring that CAUSES naphthalene to be more stable than its hypothetical structure which RESULTS in stabilisation energy. Answers which suggest "Stabilisation energy confers/causes stability to naphthalene" will earn no credit.
- Common mistakes for the energy level diagram:
  - Naphthalene is shown to be at a higher energy level than the hypothetical polyalkene!
  - zero shown for the energy level of decalin. Do take note that decalin is not an element at standard states.
  - omission of the  $+5\text{H}_2$



**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**12S**

**CHEMISTRY**

**9647/01**

Paper 1 Multiple Choice

**1 October 2012**

**40 min**

Additional Materials: Multiple Choice Answer Sheet  
Data Booklet.

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Complete the information on the Multiple Choice Answer Sheet as shown below.

1. Enter your NAME ( as in NRIC ). \_\_\_\_\_

Write your **name**

2. Enter the SUBJECT TITLE. \_\_\_\_\_

3. Enter the PAPER NUMBER. \_\_\_\_\_

Write your **CT group**

4. Enter your CT GROUP. \_\_\_\_\_

5. Date. \_\_\_\_\_

6. Enter your NRIC NUMBER or  
FIN NUMBER.

7. Now SHADE the corresponding  
lozenge in the grid for  
EACH DIGIT or LETTER

NRIC / FIN															
S	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E
F	1	1	1	1	1	1	1	1	1	1	B	L	M	N	O
G	2	2	2	2	2	2	2	2	2	2	C	M	N	O	P
T	3	3	3	3	3	3	3	3	3	3	D	N	O	P	Q
	4	4	4	4	4	4	4	4	4	4	E	O	P	Q	R
	5	5	5	5	5	5	5	5	5	5	F	P	Q	R	S
	6	6	6	6	6	6	6	6	6	6	G	Q	R	S	T
	7	7	7	7	7	7	7	7	7	7	H	R	S	T	U
	8	8	8	8	8	8	8	8	8	8	I	S	T	U	V
	9	9	9	9	9	9	9	9	9	9	J	T	U	V	W

Write and  
shade your  
NRIC  
or FIN number

There are **twenty five** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

## Section A

- 1 Methane hydrate, also known as 'methane ice', is solid methane trapped in ice found at the depths of the ocean in many parts of the world. It represents a potential source of fuel for the future as the amount of frozen methane stored in the depths of the oceans dwarfs the known combined reserves of all fossil fuel types currently known to man.

When a sample of methane hydrate was brought to room temperature and pressure,  $160 \text{ cm}^3$  of methane and  $1000 \text{ cm}^3$  of water were produced.

What is the number of moles of water associated with each mole of methane in methane hydrate? (Density of water is  $1 \text{ g cm}^{-3}$ .)

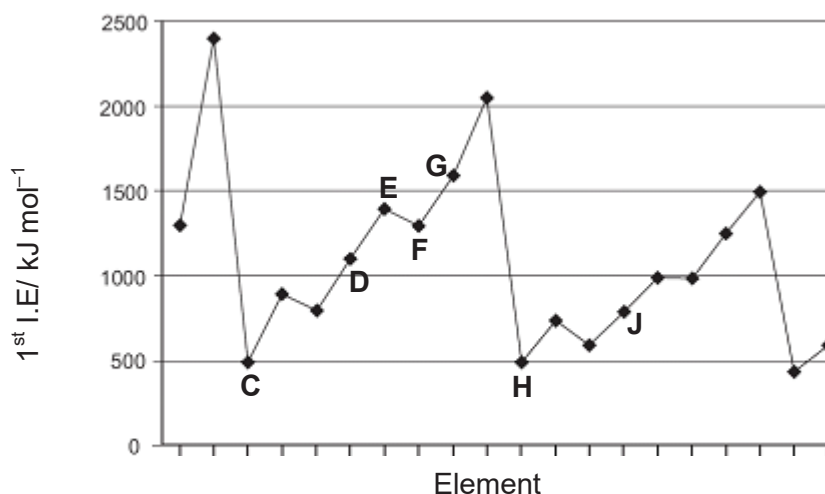
- A 0.12                      B 6.25                      C 150                      D 8300

- 2 Which of the following represents the correct electronic configuration for  $\text{Cr}^{3+}$ ?

- A  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$   
 B  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$   
 C  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$   
 D  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$

- 3 *Use of the Data Booklet is relevant to this question.*

The first ionisation energies of successive elements in the Periodic Table are represented in the graph.



Which of the following statements about elements **C** to **J** is **incorrect**?

- A **E** and **J** have half-filled p subshell.  
 B **H** has a larger atomic radius than **C**.  
 C **G** is the most electronegative element.  
 D **D** and **F** form compounds with the formulae **DF** and **DF<sub>2</sub>**.



4 In which one of the following pairs do the species have similar shapes?

- A  $\text{SO}_2$  and  $\text{CO}_2$
- B  $\text{PH}_3$  and  $\text{SO}_3$
- C  $\text{H}_2\text{O}$  and  $\text{BrF}_2^-$
- D  $\text{XeF}_4$  and  $\text{ICl}_4^-$

5 Use of the Data Booklet is relevant to this question.

**K** and **M** are elements in Period 3. The following statements describe their physical properties.

- Both **K** and **M** are good electrical conductors in the solid state.
- The melting point of **K** is higher than that of **M**.
- The first ionisation energy of **K** is higher than that of **M**.

What is the identity of element **M**?

- |             |             |
|-------------|-------------|
| A Sodium    | C Aluminium |
| B Magnesium | D Silicon   |

6 During a space expedition, a small space shuttle of capacity  $10 \text{ m}^3$  is connected to another of capacity  $30 \text{ m}^3$ . Before connection, the pressure inside the smaller shuttle is 50 kPa and that inside the larger is 100 kPa.

If all measurements are made at the same temperature, what is the pressure in the combined arrangement after connection?

- A 75.0 kPa
- B 87.5 kPa
- C 100 kPa
- D 150 kPa

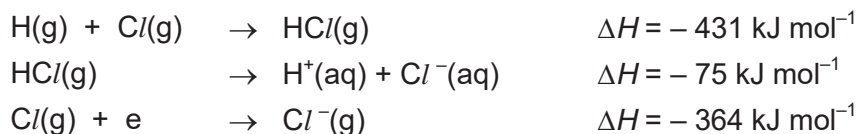
7 Which of the following exerts the highest pressure?

- A 1 mol of  $\text{H}_2\text{O}$  at  $27^\circ\text{C}$  in  $1 \text{ dm}^3$
- B 1 mol of  $\text{CH}_4$  at  $0^\circ\text{C}$  in  $22.4 \text{ dm}^3$
- C 1 mol of  $\text{N}_2$  at  $0^\circ\text{C}$  in  $11.2 \text{ dm}^3$
- D 1 mol of  $\text{N}_2$  at  $27^\circ\text{C}$  in  $22.4 \text{ dm}^3$

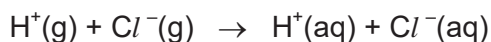


- 8 Use of the Data Booklet is relevant to this question.

The enthalpy changes for some reactions are given below.



What is the enthalpy change for the reaction given below?



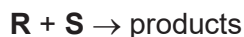
- A**  $-142 \text{ kJ mol}^{-1}$   
**B**  $+590 \text{ kJ mol}^{-1}$   
**C**  $-1302 \text{ kJ mol}^{-1}$   
**D**  $-1452 \text{ kJ mol}^{-1}$
- 9 A radioactive element has two isotopes, **P** and **Q**, with half-lives 2 h and 3 h respectively. A sample containing **P** and **Q** was analyzed 12 h after radioactive decay has taken place. It was found that the amount of **P** equals to that of **Q**.

Radioactive decay is a first order reaction.

What is the mole ratio of **P** and **Q** in the sample before radioactive decay started?

	<b>P</b>	<b>Q</b>
<b>A</b>	1	4
<b>B</b>	2	3
<b>C</b>	3	2
<b>D</b>	4	1

- 10 Consider the following reaction which is catalyzed by light.



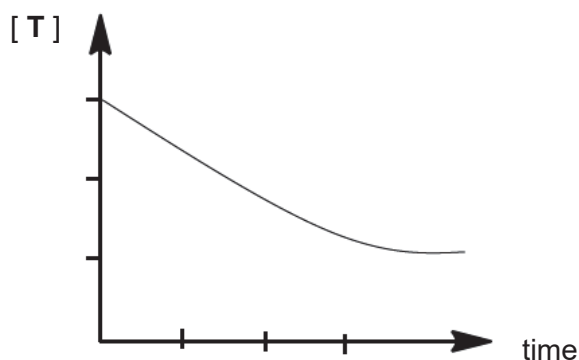
<b>[R]</b> / mol dm <sup>-3</sup>	<b>[S]</b> / mol dm <sup>-3</sup>	Relative light intensity	Initial rate
0.1	0.1	1	r
0.2	0.1	4	4r
0.2	0.2	1	2r
0.3	0.3	16	x

It was found that the rate of reaction is proportional to  $\sqrt{\text{light intensity}}$ .

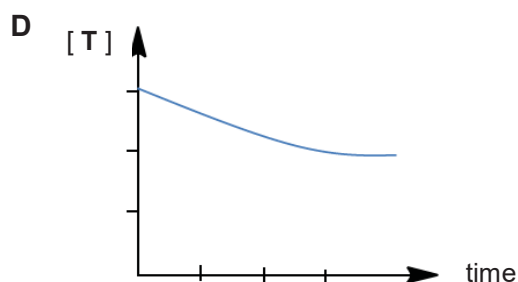
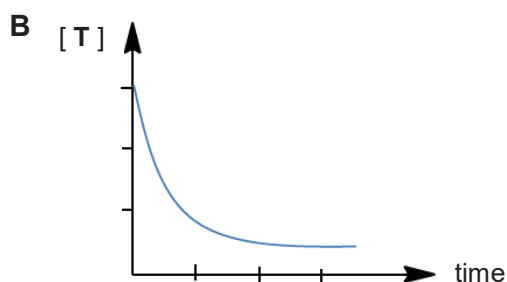
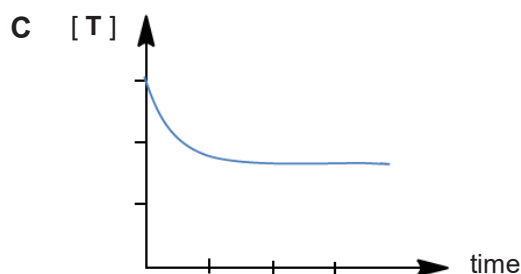
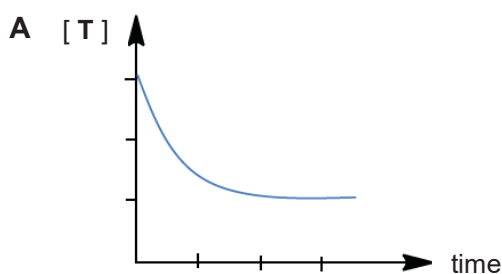
What is the value of x?

- A** 3r                      **B** 12r                      **C** 24r                      **D** 36r

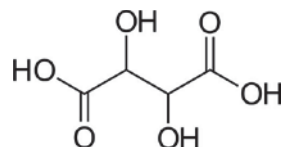
- 11 The concentration of a reactant, **T**, was plotted against time as it reacted exothermically with **U** to reach equilibrium. The graph shows the results.



Which of the following graphs could be obtained if the reaction were repeated at a higher temperature but with the same initial concentrations of **T** and **U**?



- 12 Tartaric acid has led the scientists to the discovery of chirality.



Based on the structure shown above, which of the following statements is correct about the structure?

- A** Tartaric acid can exist as four different stereoisomers.
- B** The molecular formula is  $C_4H_6O_6$ .
- C** It has four trigonal planar carbon centers.
- D** It can undergo electrophilic addition with  $H-X$ .

- 13 Which of the following statements does **not** illustrate the general inertness of alkanes?
- A The use of octanes in car petrol.
  - B Their unreactivity towards strong acids and bases.
  - C The use of hexane as solvent in organic synthesis.
  - D The use of fractional distillation to obtain alkanes of different carbon number.

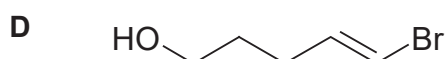
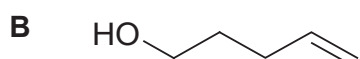
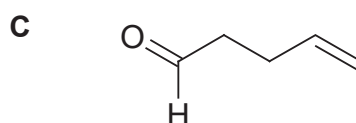
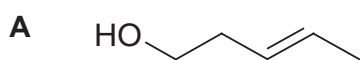
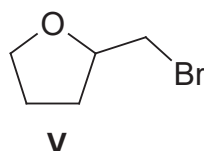
- 14 An example of a three-way honeycomb type catalytic converter is shown below.



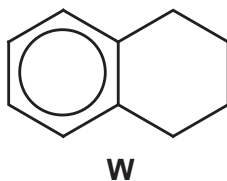
The catalytic converter goes through three stages. In the first stage,  $\text{NO}_x$  gases get reduced; in the second stage, unburnt hydrocarbon and carbon monoxide are completely oxidized; the third stage is a control system that monitors the exhaust stream and adjust the air-to-fuel ratio.

Which of the following equations does **not** represent the reactions that took place in the car engine?

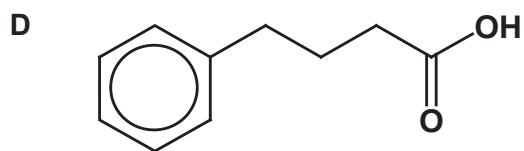
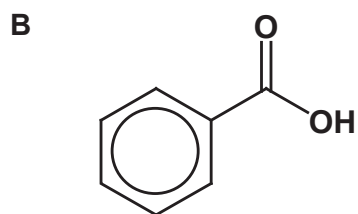
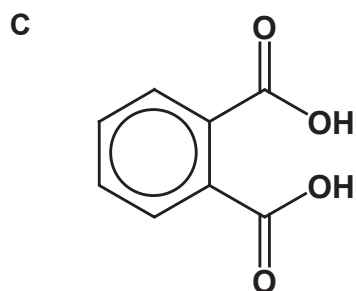
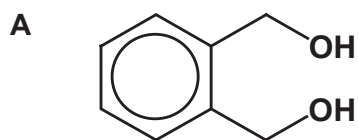
- A  $2\text{CO(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)}$
  - B  $2\text{C}_8\text{H}_{18}\text{(g)} + 25\text{O}_2\text{(g)} \rightarrow 16\text{CO}_2\text{(g)} + 18\text{H}_2\text{O(g)}$
  - C  $\text{C(g)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$
  - D  $2\text{NO(g)} + 2\text{CO(g)} \rightarrow \text{N}_2\text{(g)} + 2\text{CO}_2\text{(g)}$
- 15 Which one of the organic compounds below reacts with liquid bromine to give the following product **V**?



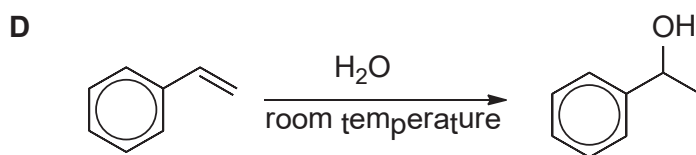
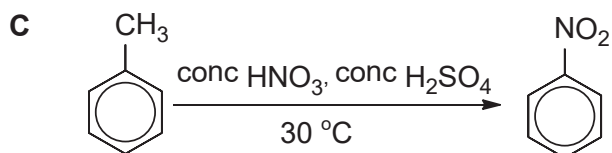
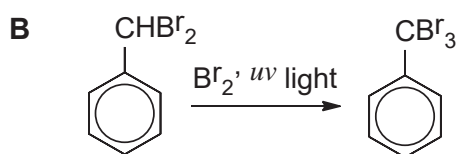
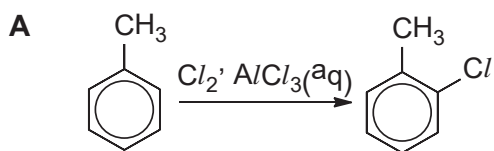
- 16 When compound **W** was heated with acidified  $\text{KMnO}_4$ , compound **X** was obtained.



Which of the following could be the structure of **X**?



- 17 Which synthesis readily yields the product shown?



## Section B

For questions **18** to **25**, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct. (You may find it useful to put a tick against the statements that you consider to be correct.)

The response **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

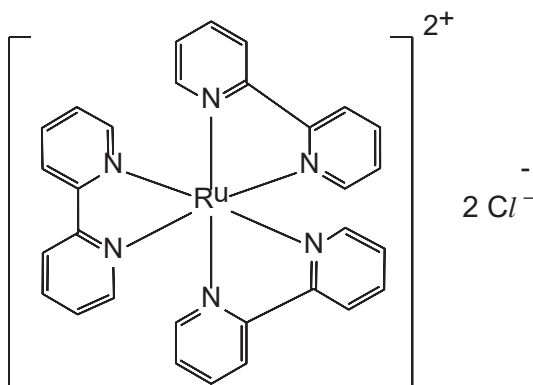
No other combination of statements is used as a correct response.

- 18** Most elements contain more than one isotope, atoms that have the same chemical properties but different masses.

Which expressions correctly define the term *relative atomic mass* of an element?

- 1** The mass of one mole of atoms relative to the mass of one mole of  $^{12}\text{C}$  atoms.
- 2** The average mass of one atom relative to one-twelfth the mass of one atom of  $^{12}\text{C}$ .
- 3** The mass of one atom relative to the mass of one atom of  $^{12}\text{C}$ .

- 19** In 2002, a ruthenium compound, known as tris(bipyridine)ruthenium(II) chloride was discovered. The structure is shown below.



Which of the following statements are true about this compound?

- 1** Its aqueous solution can conduct electricity as there are mobile charge carriers.
- 2** The compound is soluble in water as it forms ion–dipole interaction with water molecules.
- 3** The shape around Ru is octahedral.

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

**20** Which statements about the properties of a catalyst are correct?

- 1 A catalyst increases the rate of the reverse reaction.
- 2 A catalyst increases the yield of a reaction.
- 3 A catalyst increases the average kinetic energy of the reacting particles.

**21** When an equilibrium is established in a reversible reaction, the standard Gibbs free energy,  $\Delta G^\ominus_{\text{eq}}$ , is related to the equilibrium constant,  $K_{\text{eq}}$ , by the following equation.

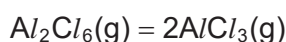
$$\Delta G^\ominus_{\text{eq}} = -2.303 RT \log K_{\text{eq}}$$

where R is the gas constant and T is the temperature in Kelvin.

Which of the following statements are correct?

- 1 At constant temperature, a shift in position of equilibrium to the right results in the same value of  $\Delta G^\ominus_{\text{eq}}$ .
- 2 The reaction is spontaneous for all values of  $K_{\text{eq}}$ .
- 3 Adding a catalyst makes  $\Delta G^\ominus_{\text{eq}}$  more negative.

**22** At 500 K, an equilibrium exists for the dissociation of  $\text{Al}_2\text{Cl}_6$  gas.



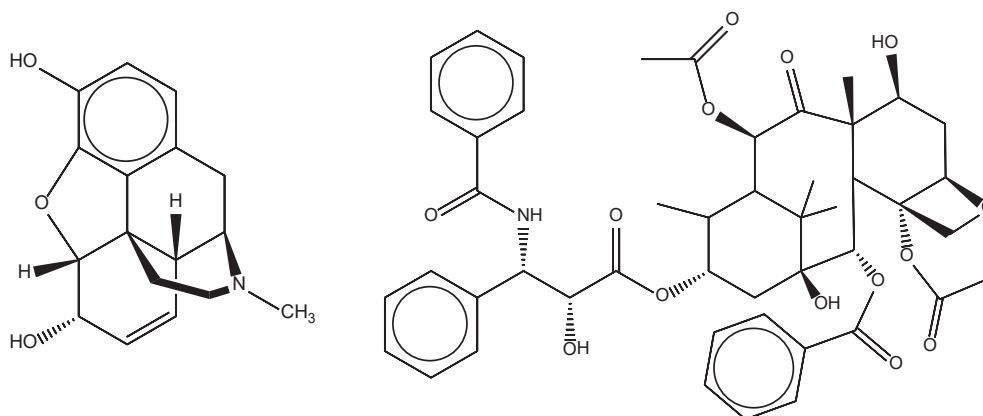
A sample of  $\text{Al}_2\text{Cl}_6$  gas at a pressure of 0.72 atm was placed in an empty container and allowed to reach equilibrium at 500 K. The total pressure at equilibrium was 1.20 atm.

Which of the following statements are true of the equilibrium?

- 1 The degree of dissociation  $\alpha$  is 0.67.
- 2 The forward reaction is endothermic.
- 3 When volume is halved, the position of equilibrium will shift to the left.

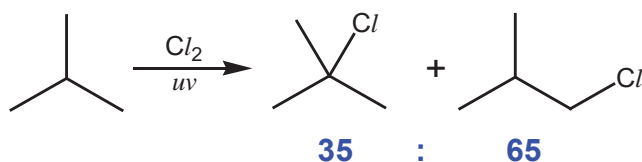
A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

23 What functional groups are present in **both** skeletal structures shown below?



- 1 Secondary alcohol
- 2 Alkene
- 3 Carboxylic acid

24 2-methylpropane reacts with chlorine under *uv* to yield two monochlorinated products as shown in the reaction below.



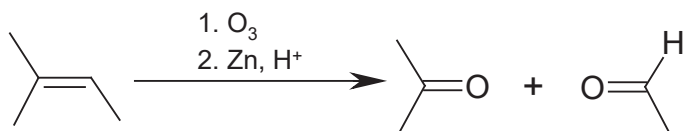
The product ratio was given to be 35 : 65 as illustrated above.

Which of the following statements might explain the resultant product ratio?

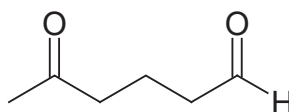
- 1 There are more primary hydrogen atoms than tertiary hydrogen atoms.
- 2 The intermediate tertiary radical is more stable.
- 3 The  $\text{H}\bullet$  radical is not formed in the reaction mechanism.

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

- 25 The double bond in alkenes may undergo oxidative cleavage with ozone in a process known as ozonolysis. For example,

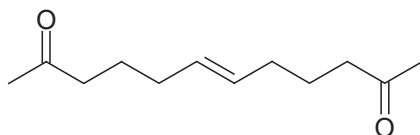


Which of the following gives **Y** as the only organic product upon ozonolysis?

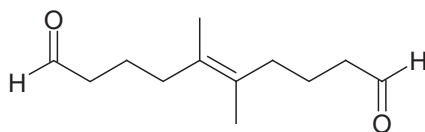


**Y**

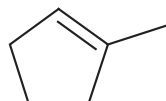
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2



3





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**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

CANDIDATE  
NAME

CT GROUP

12S

**CHEMISTRY**

**9647/01**

Paper 1 Multiple Choice

**1 October 2012**

**40 min**

Additional Materials: Multiple Choice Answer Sheet  
Data Booklet.

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Complete the information on the Multiple Choice Answer Sheet as shown below.

1. Enter your NAME ( as in NRIC ).

Write your **name**

2. Enter the SUBJECT TITLE.

3. Enter the PAPER NUMBER.

Write your **CT group**

4. Enter your CT GROUP.

5. Date.

6. Enter your NRIC NUMBER or  
FIN NUMBER.

7. Now SHADE the corresponding  
lozenge in the grid for  
EACH DIGIT or LETTER

NRIC / FIN															
S	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E
F	1	1	1	1	1	1	1	1	1	1	B	L	M	N	O
G	2	2	2	2	2	2	2	2	2	2	C	M	N	O	P
T	3	3	3	3	3	3	3	3	3	3	D	N	O	P	Q
	4	4	4	4	4	4	4	4	4	4	E	O	P	Q	R
	5	5	5	5	5	5	5	5	5	5	F	P	Q	R	S
	6	6	6	6	6	6	6	6	6	6	G	Q	R	S	T
	7	7	7	7	7	7	7	7	7	7	H	R	S	T	U
	8	8	8	8	8	8	8	8	8	8	I	S	T	U	V
	9	9	9	9	9	9	9	9	9	9	J	T	U	V	W

Write and  
shade your  
NRIC  
or FIN number

There are **twenty five** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

## Section A

- MB 1** Methane hydrate, also known as 'methane ice', is solid methane trapped in ice found at the depths of the ocean in many parts of the world. It represents a potential source of fuel for the future as the amount of frozen methane stored in the depths of the oceans dwarfs the known combined reserves of all fossil fuel types currently known to man.

When a sample of methane hydrate was brought to room temperature and pressure, 160 cm<sup>3</sup> of methane and 1000 cm<sup>3</sup> of water were produced.

What is the number of moles of water associated with each mole of methane in methane hydrate? (Density of water is 1 g cm<sup>-3</sup>.)

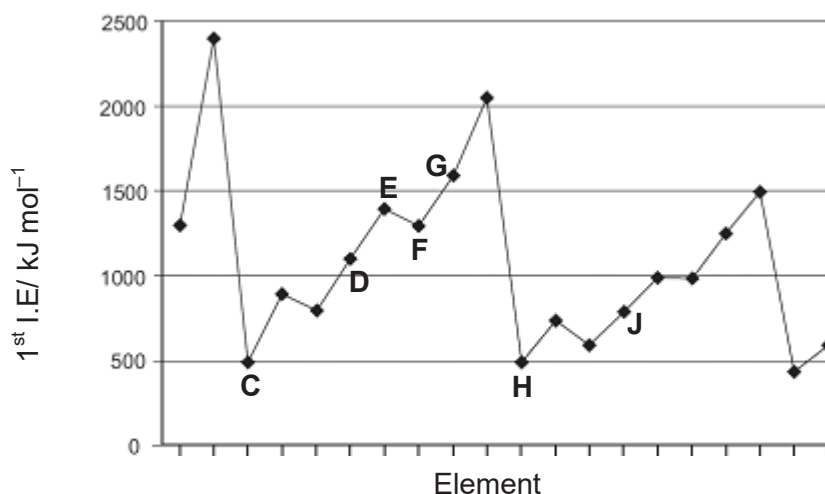
- A** 0.12                      **B** 6.25                      **C** 150                      **D** 8300

- EA 2** Which of the following represents the correct electronic configuration for Cr<sup>3+</sup>?

- A** 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>3s<sup>2</sup>3p<sup>6</sup>3d<sup>5</sup>4s<sup>1</sup>  
**B** 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>3s<sup>2</sup>3p<sup>6</sup>3d<sup>4</sup>4s<sup>2</sup>  
**C** 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>3s<sup>2</sup>3p<sup>6</sup>3d<sup>3</sup>  
**D** 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>3s<sup>2</sup>3p<sup>6</sup>3d<sup>4</sup>

- MB 3** *Use of the Data Booklet is relevant to this question.*

The first ionisation energies of successive elements in the Periodic Table are represented in the graph.



Which of the following statements about elements **C** to **J** is **incorrect**?

- A** **E** and **J** have half-filled p subshell.  
**B** **H** has a larger atomic radius than **C**.  
**C** **G** is the most electronegative element.  
**D** **D** and **F** form compounds with the formulae **DF** and **DF<sub>2</sub>**.

**MB** 4 In which one of the following pairs do the species have similar shapes?

- A**  $\text{SO}_2$  and  $\text{CO}_2$
- B**  $\text{PH}_3$  and  $\text{SO}_3$
- C**  $\text{H}_2\text{O}$  and  $\text{BrF}_2^-$
- D**  $\text{XeF}_4$  and  $\text{ICl}_4^-$

**MB** 5 *Use of the Data Booklet is relevant to this question.*

**K** and **M** are elements in Period 3. The following statements describe their physical properties.

- Both **K** and **M** are good electrical conductors in the solid state.
- The melting point of **K** is higher than that of **M**.
- The first ionisation energy of **K** is higher than that of **M**.

What is the identity of element **M**?

- |                    |                    |
|--------------------|--------------------|
| <b>A</b> Sodium    | <b>C</b> Aluminium |
| <b>B</b> Magnesium | <b>D</b> Silicon   |

**EB** 6 During a space expedition, a small space shuttle of capacity  $10 \text{ m}^3$  is connected to another of capacity  $30 \text{ m}^3$ . Before connection, the pressure inside the smaller shuttle is 50 kPa and that inside the larger is 100 kPa.

If all measurements are made at the same temperature, what is the pressure in the combined arrangement after connection?

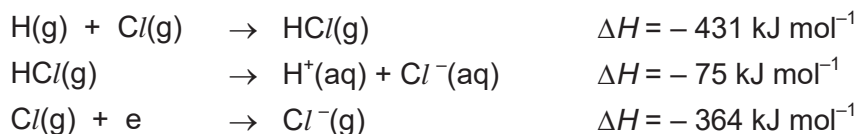
- A** 75.0 kPa
- B** 87.5 kPa
- C** 100 kPa
- D** 150 kPa

**MB** 7 Which of the following exerts the highest pressure?

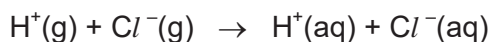
- A** 1 mol of  $\text{H}_2\text{O}$  at  $27^\circ\text{C}$  in  $1 \text{ dm}^3$
- B** 1 mol of  $\text{CH}_4$  at  $0^\circ\text{C}$  in  $22.4 \text{ dm}^3$
- C** 1 mol of  $\text{N}_2$  at  $0^\circ\text{C}$  in  $11.2 \text{ dm}^3$
- D** 1 mol of  $\text{N}_2$  at  $27^\circ\text{C}$  in  $22.4 \text{ dm}^3$

- MB 8** Use of the Data Booklet is relevant to this question.

The enthalpy changes for some reactions are given below.



What is the enthalpy change for the reaction given below?



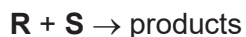
- A**  $-142 \text{ kJ mol}^{-1}$   
**B**  $+590 \text{ kJ mol}^{-1}$   
**C**  $-1302 \text{ kJ mol}^{-1}$   
**D**  $-1452 \text{ kJ mol}^{-1}$
- MB 9** A radioactive element has two isotopes, **P** and **Q**, with half-lives 2 h and 3 h respectively. A sample containing **P** and **Q** was analyzed 12 h after radioactive decay has taken place. It was found that the amount of **P** equals to that of **Q**.

Radioactive decay is a first order reaction.

What is the mole ratio of **P** and **Q** in the sample before radioactive decay started?

	<b>P</b>	<b>Q</b>
<b>A</b>	1	4
<b>B</b>	2	3
<b>C</b>	3	2
<b>D</b>	4	1

- MB 10** Consider the following reaction which is catalyzed by light.



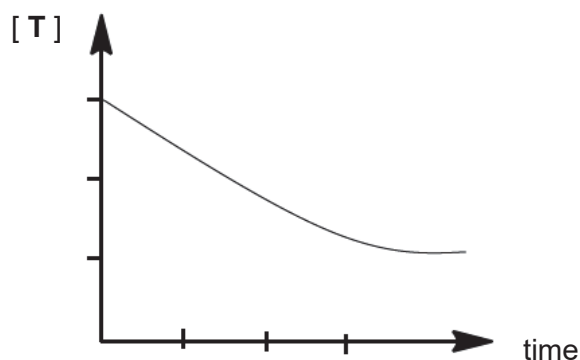
<b>[R]</b> / mol dm <sup>-3</sup>	<b>[S]</b> / mol dm <sup>-3</sup>	Relative light intensity	Initial rate
0.1	0.1	1	r
0.2	0.1	4	4r
0.2	0.2	1	2r
0.3	0.3	16	x

It was found that the rate of reaction is proportional to  $\sqrt{\text{light intensity}}$ .

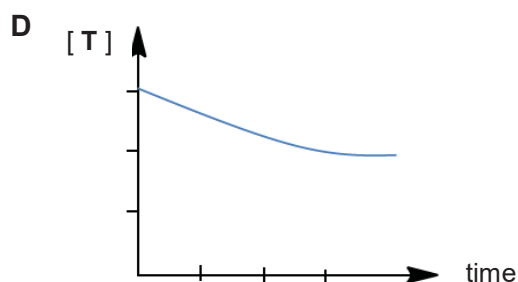
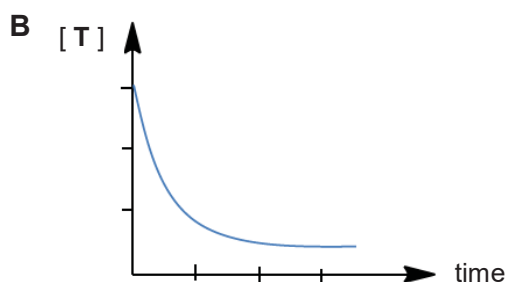
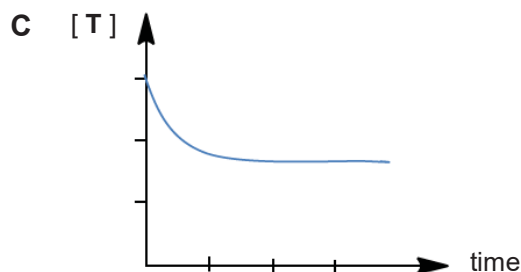
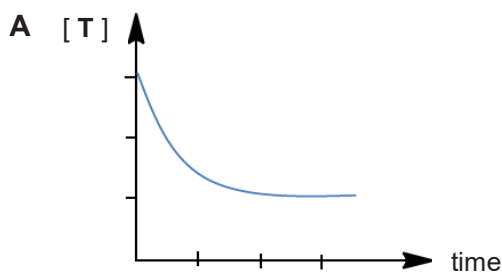
What is the value of x?

- A** 3r                      **B** 12r                      **C** 24r                      **D** 36r

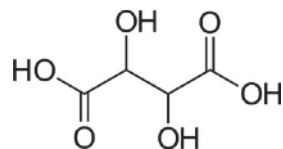
- MB 11** The concentration of a reactant, **T**, was plotted against time as it reacted exothermically with **U** to reach equilibrium. The graph shows the results.



Which of the following graphs could be obtained if the reaction were repeated at a higher temperature but with the same initial concentrations of **T** and **U**?



- DB 12** Tartaric acid has led the scientists to the discovery of chirality.



Based on the structure shown above, which of the following statements is correct about the structure?

- A** Tartaric acid can exist as four different stereoisomers.
- B** The molecular formula is  $C_4H_6O_6$ .
- C** It has four trigonal planar carbon centers.
- D** It can undergo electrophilic addition with  $H-X$ .

- EA 13** Which of the following statements does **not** illustrate the general inertness of alkanes?
- A** The use of octanes in car petrol.
  - B** Their unreactivity towards strong acids and bases.
  - C** The use of hexane as solvent in organic synthesis.
  - D** The use of fractional distillation to obtain alkanes of different carbon number.

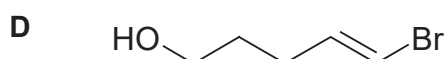
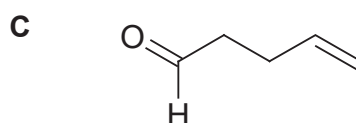
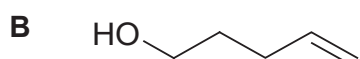
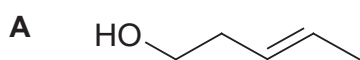
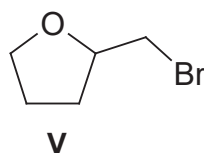
- EB 14** An example of a three-way honeycomb type catalytic converter is shown below.



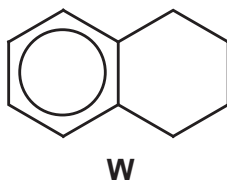
The catalytic converter goes through three stages. In the first stage,  $\text{NO}_x$  gases get reduced; in the second stage, unburnt hydrocarbon and carbon monoxide are completely oxidized; the third stage is a control system that monitors the exhaust stream and adjust the air-to-fuel ratio.

Which of the following equations does **not** represent the reactions that took place in the car engine?

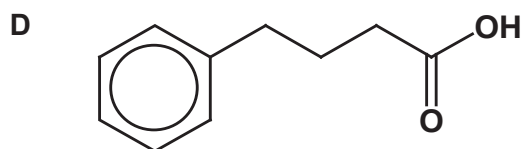
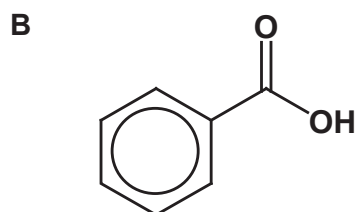
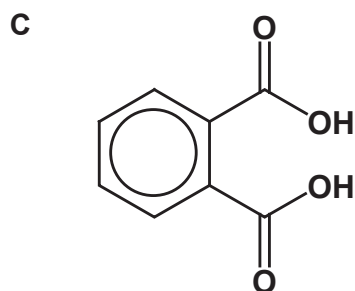
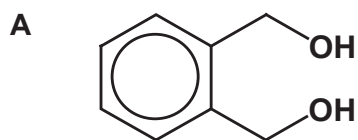
- A**  $2\text{CO(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)}$
  - B**  $2\text{C}_8\text{H}_{18}\text{(g)} + 25\text{O}_2\text{(g)} \rightarrow 16\text{CO}_2\text{(g)} + 18\text{H}_2\text{O(g)}$
  - C**  $\text{C(g)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$
  - D**  $2\text{NO(g)} + 2\text{CO(g)} \rightarrow \text{N}_2\text{(g)} + 2\text{CO}_2\text{(g)}$
- DB 15** Which one of the organic compounds below reacts with liquid bromine to give the following product **V**?



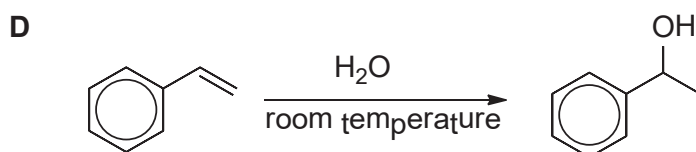
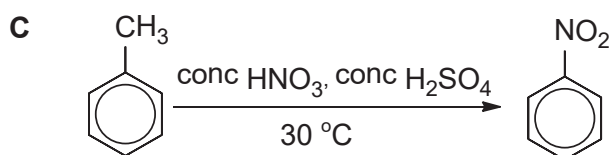
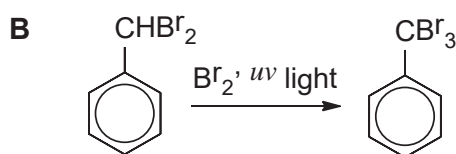
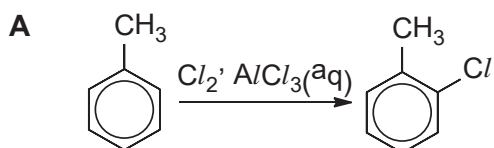
- MB 16** When compound **W** was heated with acidified  $\text{KMnO}_4$ , compound **X** was obtained.



Which of the following could be the structure of **X**?



- MB 17** Which synthesis readily yields the product shown?





## Section B

For questions **18** to **25**, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct. (You may find it useful to put a tick against the statements that you consider to be correct.)

The response **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

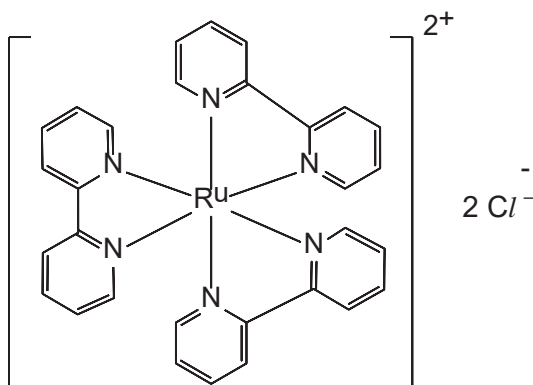
No other combination of statements is used as a correct response.

- MA 18** Most elements contain more than one isotope, atoms that have the same chemical properties but different masses.

Which expressions correctly define the term *relative atomic mass* of an element?

- 1** The mass of one mole of atoms relative to the mass of one mole of  $^{12}\text{C}$  atoms.
- 2** The average mass of one atom relative to one-twelfth the mass of one atom of  $^{12}\text{C}$ .
- 3** The mass of one atom relative to the mass of one atom of  $^{12}\text{C}$ .

- MB 19** In 2002, a ruthenium compound, known as tris(bipyridine)ruthenium(II) chloride was discovered. The structure is shown below.



Which of the following statements are true about this compound?

- 1** Its aqueous solution can conduct electricity as there are mobile charge carriers.
- 2** The compound is soluble in water as it forms ion-dipole interaction with water molecules.
- 3** The shape around Ru is octahedral.

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

**EA 20** Which statements about the properties of a catalyst are correct?

- 1 A catalyst increases the rate of the reverse reaction.
- 2 A catalyst increases the yield of a reaction.
- 3 A catalyst increases the average kinetic energy of the reacting particles.

**DB 21** When an equilibrium is established in a reversible reaction, the standard Gibbs free energy,  $\Delta G^\ominus_{\text{eq}}$ , is related to the equilibrium constant,  $K_{\text{eq}}$ , by the following equation.

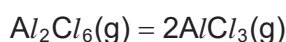
$$\Delta G^\ominus_{\text{eq}} = -2.303 RT \log K_{\text{eq}}$$

where R is the gas constant and T is the temperature in Kelvin.

Which of the following statements are correct?

- 1 At constant temperature, a shift in position of equilibrium to the right results in the same value of  $\Delta G^\ominus_{\text{eq}}$ .
- 2 The reaction is spontaneous for all values of  $K_{\text{eq}}$ .
- 3 Adding a catalyst makes  $\Delta G^\ominus_{\text{eq}}$  more negative.

**MB 22** At 500 K, an equilibrium exists for the dissociation of  $\text{Al}_2\text{Cl}_6$  gas.



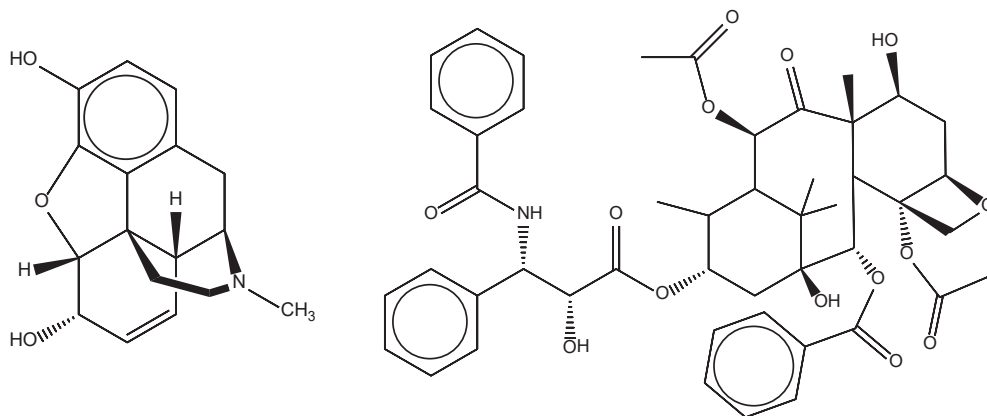
A sample of  $\text{Al}_2\text{Cl}_6$  gas at a pressure of 0.72 atm was placed in an empty container and allowed to reach equilibrium at 500 K. The total pressure at equilibrium was 1.20 atm.

Which of the following statements are true of the equilibrium?

- 1 The degree of dissociation  $\alpha$  is 0.67.
- 2 The forward reaction is endothermic.
- 3 When volume is halved, the position of equilibrium will shift to the left.

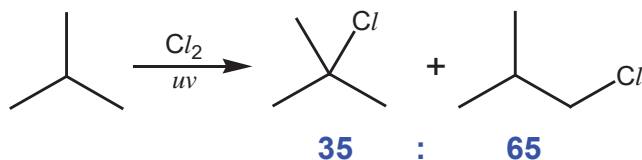
A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

**EA 23** What functional groups are present in **both** skeletal structures shown below?



- 1 Secondary alcohol
- 2 Alkene
- 3 Carboxylic acid

**MB 24** 2-methylpropane reacts with chlorine under  $uv$  to yield two monochlorinated products as shown in the reaction below.



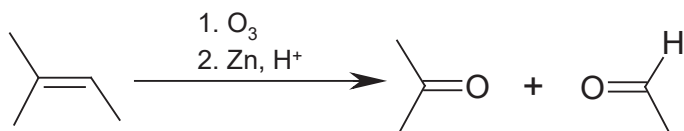
The product ratio was given to be 35 : 65 as illustrated above.

Which of the following statements might explain the resultant product ratio?

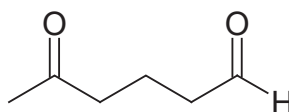
- 1 There are more primary hydrogen atoms than tertiary hydrogen atoms.
- 2 The intermediate tertiary radical is more stable.
- 3 The  $H\bullet$  radical is not formed in the reaction mechanism.

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

- DB 25** The double bond in alkenes may undergo oxidative cleavage with ozone in a process known as ozonolysis. For example,

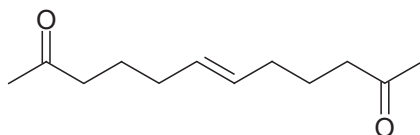


Which of the following gives **Y** as the only organic product upon ozonolysis?

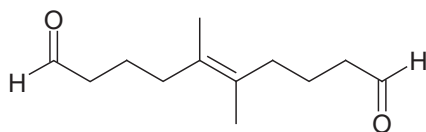


**Y**

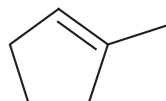
**1**



**2**



**3**



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### Answer Key

1	D	6	B	11	C	16	C	21	D
2	C	7	C	12	B	17	B	22	A
3	A	8	D	13	D	18	B	23	D
4	D	9	D	14	C	19	A	24	B
5	A	10	B	15	B	20	D	25	A

**A – 5      B – 7      C – 5      D – 8**

### **Tally table:**

Difficulty	Marks
E (easy, $\geq 80\%$ )	6
M (moderate, $80\% <$ and $> 30\%$ )	15
D (difficult, $< 30\%$ )	4
<b>EMD ratio =</b>	<b>2.4 : 6 : 1.6</b>

Note: target EMD ratio is 2:6:2

Type	Marks
A (knowledge with understanding, basic application)	5
B (higher order thinking, application, synthesis, evaluation etc.)	20
<b>AB ratio =</b>	<b>1 : 4</b>

Note: target AB ratio is 4:6

## 2012 C1 H2 Chemistry Promotional Examination Paper 1 Mark Scheme

1	D	6	B	11	C	16	C	21	D
2	C	7	C	12	B	17	B	22	A
3	A	8	D	13	D	18	B	23	D
4	D	9	D	14	C	19	A	24	B
5	A	10	B	15	B	20	D	25	A

## 2012 C1 H2 Chemistry Promotional Examination Paper 2 Mark Scheme

- 1 (a) (i)  $\Delta H_{\text{sol}} = \Delta H_{\text{hyd}} - \text{lattice energy}$  [1m]

Generally well done.

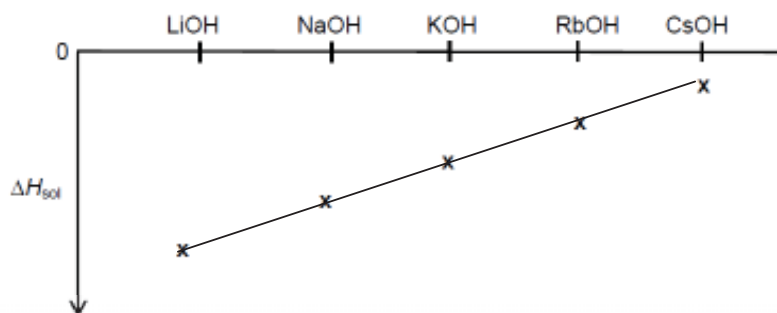
- (ii)  $\text{LE} \propto \frac{q^+ \times q^-}{r^+ + r^-}$ , down the group, **the sum of the ionic radius increases/ the ionic radius of the cation increases** thus LE will be **less exothermic**. [1m]  
(do not accept charge density discussion)

Lattice energy is directly proportional to the product of ionic charge and inversely proportional to sum of ionic radii. Hence, charge density of the cations should not be compared. The answer should include a clear link to an increase in ionic radius of the cation down the group that leads to an increase in sum of ionic radii.

- (iii) Down the group, **cationic radius increases/charge density of the cations decreases**, hence the cations are less strongly attracted to the water molecules and hydration enthalpy change for the cation becomes less exothermic. Since the hydration enthalpy change of the anion is the same for all Group I hydroxides, the **sum** of hydration enthalpy becomes less exothermic. [1m]

It is incorrect to deduce the trend in  $\Delta H_{\text{hyd}}$  based on the trend in lattice energy since the trend in  $\Delta H_{\text{sol}}$  is not known. In addition, the more important factor that affects the strength of the ion-dipole interaction between the cation and water molecules is the charge density of the cation and not the number of water molecules that can surround the cation.

(iv) **Correct trend [1m]**



Students should predict a trend based on the answer in (a)(iii).

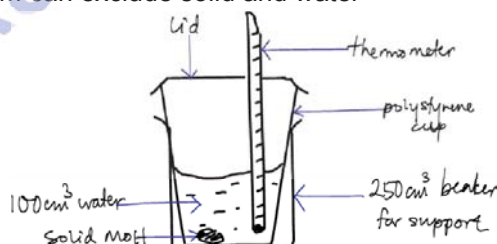
- (b) (i) independent variable type of MOH } [1m]  
 dependent variable temperature change/rise  
 controlled variable volume of water / mass of solid hydroxide [1m]

Identification of independent and dependent variable were generally well done. However, for controlled variable, which is a factor that is kept constant in the experiment, students should suggest a property that can be measured, i.e., mass of solid metal hydroxide instead of number of moles of solid metal hydroxide. The apparatus used such as thermometer and polystyrene cup are assumed to be the same and will not be accepted in this case.

(ii) **[1m] labelled diagram including thermometer, insulated container and support**

Note:

1. Either polystyrene cup or insulated calorimeter can be used as the container.
2. Either retort stand/beaker can be used for support
3. Diagram can exclude solid and water



A common mistake is the lack of support for the polystyrene cup. It should be stabilized by standing it in a beaker or by clamping it to a retort stand. Nesting the polystyrene cup in another polystyrene cup is done to provide better insulation (not for support). Student should also remember to label the apparatus in their diagrams.



(c)  $Q = \text{Heat change} = y \times 4.3 \times \Delta T \times 10^{-3} \text{ kJ [1m]}$

$$\Delta H_{\text{sol}} \text{ of KOH} = - \frac{y \times 4.3 \times \Delta T \times 10^{-3}}{\frac{x}{56.1}} \text{ kJ mol}^{-1} \text{ [1m]}$$

**Note: accept expression in J mol<sup>-1</sup>**

Most students were able to calculate the heat change. When calculating  $\Delta H_{\text{sol}}$ , the sign should be given. Students should also remember to round their numerical answers to 3 significant figures should they decide to compute their answers.

- (d) **Solid KOH absorbs water vapour. Actual mass of KOH is less than expected, thus heat evolved will be less than expected. Thus  $\Delta H_{\text{sol}}$  less exothermic. [1m]**

Students should read the question carefully and identify an error based on the information given about Group I hydroxide. Any answer related to the insensitivity of the thermometer and heat capacity of the styrofoam cup is not accepted. A link to the mass of MOH is required. Students should explain clearly in their answer whether they are referring to the measured mass of the sample containing MOH or the actual mass of MOH in the sample. The actual mass of MOH in the sample is less than expected. Since there is less MOH present in the sample, the heat given off from the dissolving of MOH is less than expected which leads to less exothermic  $\Delta H_{\text{sol}}$  calculated. Credit will not be given when the answer is not clear.

- 2 (a) (i) Since the **half-life of propene is constant** at 10s, the reaction is **first order with respect to propene**. [1m]

This question is well done and most students could correctly identify the order of reaction with respect to propene. Students should state the half-life of the reaction, although its omission was not penalized.

- (ii) **HCl is not present in large excess**. Therefore the overall reaction is not pseudo first order and the half-life of the reaction is not constant. [1m]

This question was well done as most students recognized that the hydrochloric acid is no longer in large excess and the reaction is no longer an overall first order reaction. Students who claimed that the hydrochloric acid is now the limiting reagent were penalized as they have drawn the incorrect conclusion from the data, which clearly shows a 1:1 mole ratio between the two reactants. Students who alluded to the lower partial pressure slowing the rate of effective collisions and hence the rate of reaction were also penalized.

- (iii) Rate =  $k (P_{\text{propene}})(P_{\text{HCl}})$  [1m]

This question is well done. However, students who lost this mark confused the rate constant with the  $K_p$  expression, or expressed rate in terms of concentration (via square brackets).

- (iv) In the pseudo 1<sup>st</sup> order reaction,  $k' = kP_{\text{HCl}}$   
 $k' = \ln 2 / 10 = 0.0693$   
 $k = 0.0693 / 300 = 2.31 \times 10^{-4} \text{ (kPa)}^{-1} \text{ s}^{-1}$  [1m]

This question was poorly done despite the fact that many students realized that the reaction is a pseudo first order reaction. As such, many students incorrectly used  $t_{1/2} = \ln 2 / k'$  to solve for  $k'$  thinking that  $k'$  and  $k$  is the same, while  $k'$  is actually  $kP_{\text{HCl}}$ .

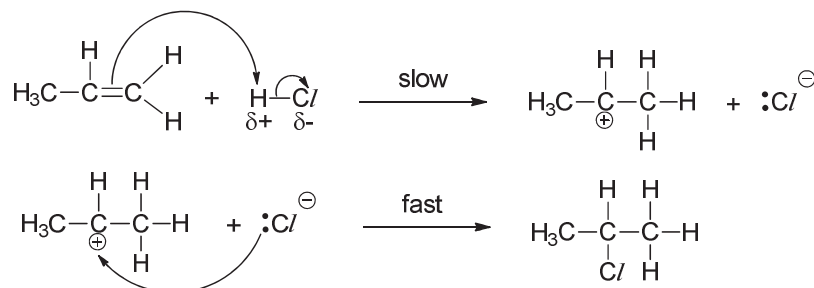
- (v) Since  $t_{1/2} = \ln 2 / k'$  where  $k' = kP_{\text{HCl}}$ . When  $P_{\text{HCl}}$  is halved,  $k'$  is halved and  $t_{1/2}$  is doubled to 20 s. [1m]

OR

When  $P_{\text{HCl}}$  is halved, rate is halved. Therefore the time taken to consume half of the propene is doubled to 20 s.

Few students obtained credit for this question as it depends on their understanding of a pseudo first-order reaction. Students who did manage to obtain credit typically used a qualitative approach to solve the problem. Regardless of the method used, students have to demonstrate a clear link between what was given and their conclusion. An answer such as "because  $P_{\text{HCl}}$  is halved, therefore new half-life is  $10 \times 2 = 20\text{s}$ " is not acceptable.

(b) Electrophilic Addition [1m]

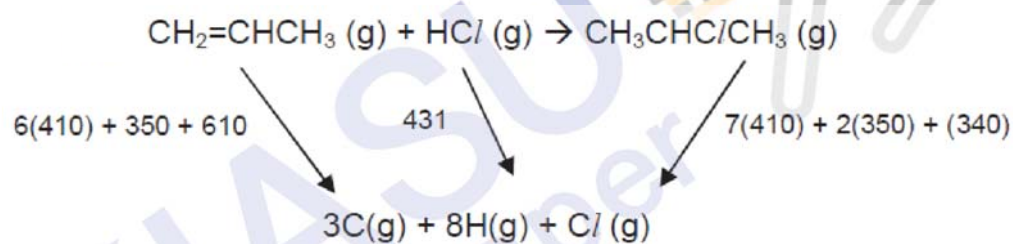


[1m] for each step, half mark deducted for every mistake

[Total: 2m]

This question was well attempted and most students earned full credit for the mechanistic drawings. However, a small number of students drew a cyclic chloronium or hydronium ion as an intermediate which reflects a grave misunderstanding of the mechanism.

(c)

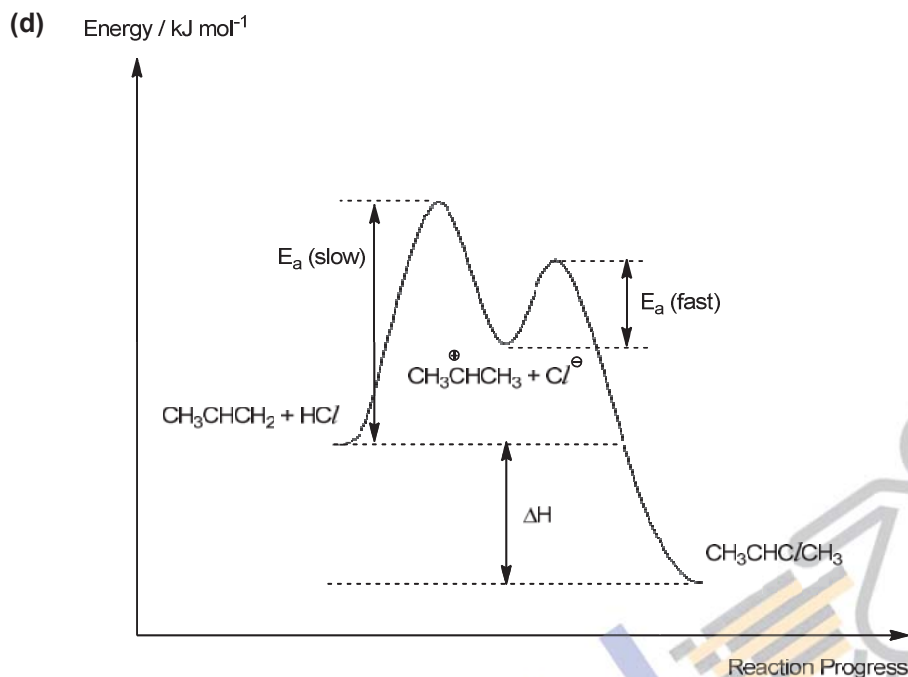


Applying Hess's Law,

$$\Delta H = 6(410) + 350 + 610 + 431 - 7(410) - 2(350) - 340$$
$$= \underline{-59 \text{ kJ mol}^{-1}}$$

[1m] Enthalpy changes  
[1m] Equation and expression  
[1m] Application of Hess Law  
Ignore state symbols

This question was poorly attempted and reflects many issues and misconceptions. This question was meant to be attempted independently of the previous parts of the question, but many students drew Hess Cycles based on the mechanism and incorrectly incorporated heterolytic bond breaking into their Hess Cycle and drew ions as intermediates. They are then penalized because Bond Energy is defined as a homolytic bond breaking process.



- Correct axes [0.5m]
- Correct shape [0.5m]
- Correct labels for reactants, intermediate, products [0.5m]
- Correct labels for  $E_a(\text{slow})$  and  $\Delta H$  [0.5m]

The energy profile diagram was poorly drawn as most students drew diagrams that reflected a single step mechanism. Many did not label their axes and the intermediates as well.

- (e) **Optically inactive**, as there is **no chiral carbon/ the molecule is symmetrical**. [1m]

This question was well done.

- (f) The formation of 1-chloropropane **requires the formation of the less stable  $1^\circ$  carbocation**, thus it is not produced in the reaction. [1m]

This question was relatively well done. For students who were penalized, they failed to answer the question directly, often commenting on the secondary carbocation with no reference to the primary carbocation or its relationship to 1-chloropropane. Students are also penalized for not stating the type of intermediate or whether it is a primary or secondary carbocation. This is of particular importance as it is the minimum requirement in accounting for the relative stability of each carbocation.

Any student who referenced Markovnikov's Rule as an explanation needs to realize that the rule is a statement that predicts the outcome of such a reaction. It does not explain why the outcome occurs in the described manner.

- 3 (a) (i)  $N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$  [1m]

Balancing the overall equation is generally well done. Common mistakes include forgetting to include the state symbols and writing the reversible ( $\rightleftharpoons$ ) arrow.

(ii) 
$$K_{c(\text{overall})} = \frac{[NO_2]^2}{[N_2][O_2]^2} \text{ mol}^{-1} \text{ dm}^3$$

[1m] with units

Students should note that  $K_c$  is derived from concentration and  $K_p$  from pressure. When in doubt, some students chose to write two expressions for the equilibrium constant – one in terms of concentration and one in terms of partial pressures. Students who have attempted this are penalized as they have not demonstrated that they have a clear understanding of the requirements of the question.

Students should also exercise more care in writing the units of the expression. Many were either providing wrong units or had neglected units entirely despite being asked to state them. The numerical value was not required for this part of the question.

(iii) 
$$K_{c1} \times K_{c2} = \frac{\cancel{[NO]}^2}{[N_2][O_2]} \times \frac{[NO_2]^2}{\cancel{[NO]}^2[O_2]}$$

$$= \frac{[NO_2]^2}{[N_2][O_2]^2} = K_{c(\text{Overall})}$$

[1m] working

Students should note that they need to provide mathematical proof instead of simply stating the expressions for  $K_{c1}$  and  $K_{c2}$ . It is also not sufficient to write  $K_{c1} \times K_{c2} = K_{c(\text{overall})}$ ; that is merely repeating the stem of the question.

(iv)  $K_{c(\text{overall})} = 0.013 \times 7.0 \times 10^5 = 9100 \text{ mol}^{-1}\text{dm}^3$  [1m] numerical answer

$$9100 = \frac{\left(\frac{10}{5}\right)^2}{[N_2]\left(\frac{1}{5}\right)^2}$$

$[N_2] = 0.0110 \text{ mol dm}^{-3}$   
Amount of  $N_2$  at eqm = 0.0549 mol

[1m] Expression and substitution  
[1m] amount of  $N_2$  with units

This part was poorly done. Students should only answer the question in the designated spaces. As such, if the numerical value for  $K_C$  was solved for in part (a)(ii) or (iii) but not used in the (a)(iv), no mark will be awarded for it.

Students should also recognize the fact that not all equilibria questions require the use of the 'ICE table'. This question had provided equilibrium concentrations that can be directly substituted into the overall  $K_C$  expression.

Common mistakes include the following:

- Assuming that a stoichiometric ratio of  $N_2$  and  $O_2$  were used. NO mark was awarded even if students arrived at the correct numerical value
- Forgetting to calculate the number of moles of  $N_2$  after obtaining the  $[N_2]$
- Forgetting to write the units (mol, not mols) for the number of moles of  $N_2$  at equilibrium
- Very poor presentation of answers

(v) No change.  $K_{c(\text{overall})}$  is not affected by changes in pressure/concentration.  
**OR**  $K_{c(\text{overall})}$  is only affected by temperature. [1m]

This question was badly done. Students failed to recognize that amount of reactants do not affect the  $K_C$  value, since the disturbance to the equilibrium will eventually cause the ratio between the numerator and denominator to become constant when the new equilibrium is reached. The value of  $K_C$  is only affected by temperature.

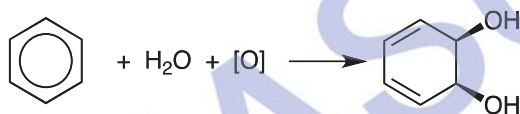
- (b) (i) Na has an **additional principle quantum shell** compared to Ne, hence the electron to be lost is **further away** and experiences less attraction from the nucleus. [1m]

Students should note that the explanation of the difference in ionization energy between elements in different periods involve the distance between the valence electron and the nucleus. Explanations involving greater effective nuclear charge or shielding are not relevant to this question and should not be used. Many students referenced the stability of the octet configuration, which is irrelevant and does not answer the question. Other misconceptions include mentioning that Na has an additional quantum shell (not orbital!) compared to Ne.

- (ii) Sodium is in the **solid state** and has to be **vapourised** first before the atoms can be ionised. [1m]

This part is very poorly done. Few students recognized the need to vaporize the sodium metal, even though the question provided the equation for the first ionization energy of Na(g). Answers that just described the intermolecular forces between Ne and the metallic bonding in Na are not sufficient. In addition, neon is monoatomic and does not exist as a molecule!

4 (a)



[1m]

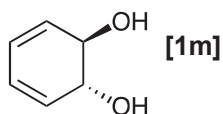
A large majority of students balanced the oxidation equation wrongly. Common mistakes include counting the number of hydrogens in the product wrongly and balancing hydrogen with H<sub>2</sub> or H<sup>+</sup>.

- (b) No, compound **R** is not optically active because it has a **plane of symmetry** (or is a **meso compound**). [1m]

The answer required "plane/line of symmetry". Students who gave a wrong explanation even if they said that **R** was not optically active received no credit. Some students wrongly thought that **R** has no chiral carbons.



(c)



Less than half of the students answered this correctly. Structures which did not use wedge/dash bonds were not awarded a mark if it was not completely clear which way the OH groups were pointing. Many students drew an -OH group pointing into the ring, showing that they did not fully understand what was meant by "on the same/opposite side of the plane of the ring".

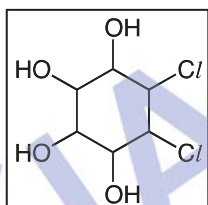
(d) (i) (nucleophilic) substitution [1m]

Neither "electrophilic substitution" nor "free radical substitution" was accepted.

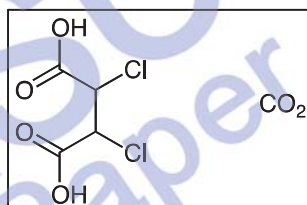
(ii)  $\text{H}_2(\text{g})$ , nickel catalyst, high temperature and pressure [1m]

The reagent, hydrogen gas, was frequently left out of answers. Other students failed to mention (the right) catalyst and/or high temperature and/or high pressure necessary for the hydrogenation reaction.

(iii)



[1m]



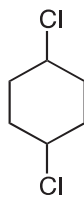
[1m]

[1m]

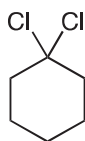
The product of mild oxidation was well answered, though some students wrongly substituted the chlorine atoms with alcohol groups as well. For oxidative cleavage, many students drew the dicarboxylic acid (ethanedioic acid) instead of carbon dioxide. This was not awarded a mark. Many students drew  $\text{CO}_2$  wrongly as bent instead of linear. As only carbon-containing products are required, water should not be included; students are reminded to be careful.



(iv)



OR



[1m]

This was well done, although some students suggested answers which were not cyclohexanes. Students should read the question carefully.

(v) Add aqueous bromine at room temperature. [1m]

Compound **T**: yellow/orange bromine turns colourless.

Compound **U**: aqueous bromine remains yellow/orange (or does not decolourize).

[1m]

OR

Add  $\text{KMnO}_4$  with dilute  $\text{H}_2\text{SO}_4$  and heat. [1m]

Compound **T**: Purple  $\text{KMnO}_4$  turns colourless.

Effervescence of  $\text{CO}_2$  which gives white ppt with limewater.

Compound **U**: Purple  $\text{KMnO}_4$  did not decolorize. No effervescence.

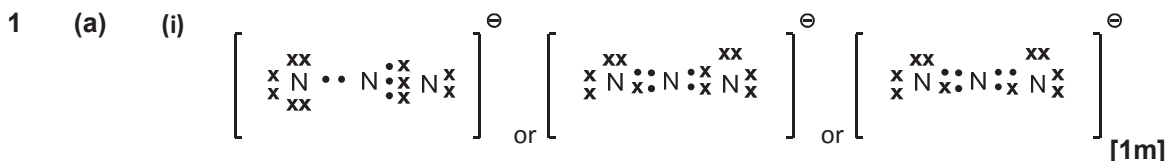
[1m]

(Accept test using cold  $\text{KMnO}_4$  with dilute  $\text{NaOH}$ )

Most students suggested using aqueous or liquid bromine. Note that the correct colour must be specified, i.e. yellow-orange for  $\text{Br}_2(\text{aq})$  and reddish-brown for  $\text{Br}_2(l)$  or  $\text{Br}_2/\text{CCl}_4$ . Students must not warm/heat for this test. Students are reminded that the expected observation for both compounds **T** and **U** are required. The observation for the negative test should not be written as "no reaction", "no change" or "no observation" etc.

An alternative test is using  $\text{KMnO}_4$  with dilute  $\text{H}_2\text{SO}_4$  and heat. In this case other than the decolourisation of purple  $\text{KMnO}_4$ , students must include the liberation of carbon dioxide gas.

## 2012 C1 H2 Chemistry Promotional Examination Paper 3 Mark Scheme



Too many students forgot that N belongs to Period 2 and hence unable to expand its octet. There were an alarming number of students who drew fantastic structures involving three-membered nitrogen rings without consideration for the unfavourable ring strain.

Students are reminded to use only dots (•) and crosses (x) for their diagrams and to remember to indicate the charge on the ion.

- (ii) No. of moles of  $\text{I}_2$  (excess)  
 $= \frac{1}{2} \times 0.30 \times 26.80/1000 = 4.02 \times 10^{-3} \text{ mol}$  [1m]
- No. of moles of  $\text{I}_2$  (reacted) =  $[0.60 \times 25.0/1000] - 4.02 \times 10^{-3}$   
 $= 1.098 \times 10^{-2} \text{ mol}$  [1m]
- No. of moles of  $\text{NaN}_3 = 1.098 \times 10^{-2} \times 2 = 2.196 \times 10^{-2} \text{ mol}$  [1m]
- Mass of  $\text{NaN}_3 = 2.196 \times 10^{-2} \times (23.0 + 3(14.0)) = 1.43 \text{ g}$
- % purity of  $\text{NaN}_3 = 1.43 / 1.80 \times 100\% = 79.4\%$  [1m]

This part was very well done with most students obtaining the full marks. Common mistakes included forgetting to add the mass of Na to the  $M_r$  of the salt in order to obtain the mass of the pure  $\text{NaN}_3$  or failing to divide the number of moles of thiosulfate by two to obtain the number of moles of iodine in excess. Another serious error was to calculate the % purity using the number of 'moles' of impure salt. It must be noted here that calculation of 'number of moles' of a substance implies calculating the amount of a pure compound. It cannot be applied to mixtures or substances containing impurities.

- (iii) For the decomposition of  $\text{HN}_3$ ,  $\Delta S > 0$ , since there is an increase in the number of gaseous molecules, thus there are more ways to distribute energy in the system. [1m]

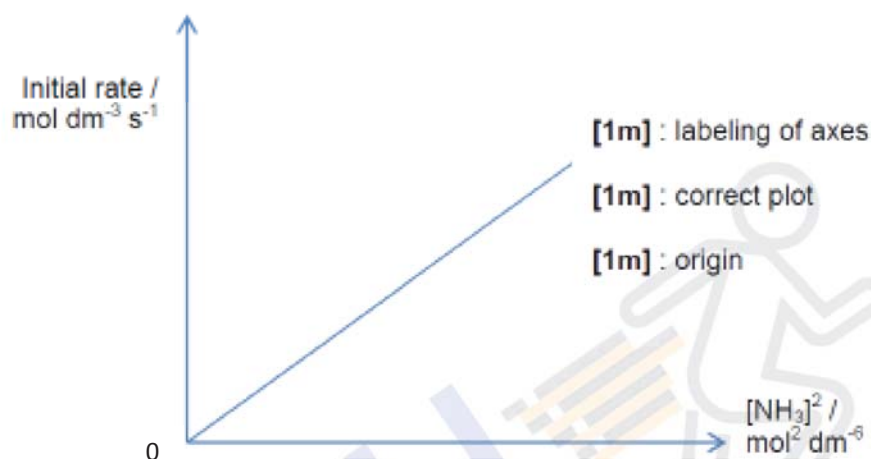
Hence, since  $\Delta H < 0$  &  $\Delta S > 0$ ,  $\Delta G = \Delta H - T\Delta S$ , will always be negative, whatever the temperature. [1m]

This question was also very well done. Common mistakes included writing S instead of  $\Delta S$  or G instead of  $\Delta G$ . Also some students wrote 'the entropy is positive'. Note that entropy is first of all, always positive, and secondly, it is not possible to calculate the absolute entropy. All computations within the A level syllabus deal only with the change in entropy. The same point applies to similar calculations and references to enthalpy and the Gibbs free energy.

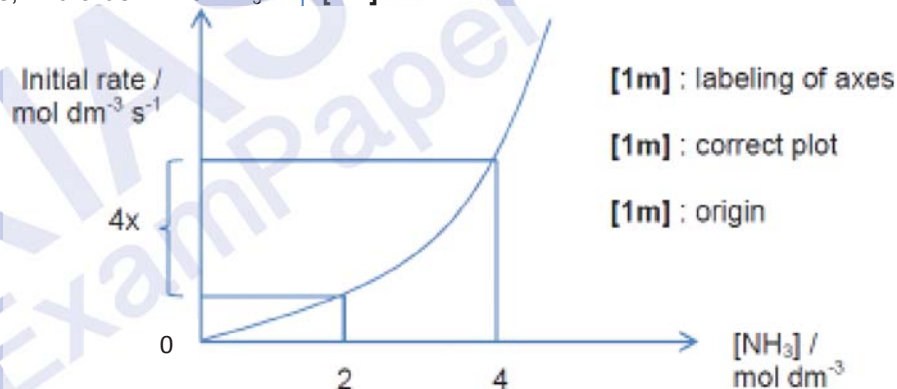
The correct explanation to why  $\Delta S$  is positive is that the reaction results in an

increase in the number of gaseous molecules. Note that a reaction is not considered a phase change, which refers to the same substance changing from say the liquid state to the gaseous state. Students who said that there are more moles of products than reactants, without the word 'gaseous' were penalized.

(b) (i)



Initial rate  $\propto$  [NH<sub>3</sub>]<sup>2</sup>,  
hence, 2nd order w.r.t. NH<sub>3</sub> } [1m]  
OR



When [NH<sub>3</sub>] is doubled, the initial rate is increased by 4 times  
Hence, 2nd order w.r.t. NH<sub>3</sub>. } [1m]

Generally the graph was well-drawn. However, many students failed to appreciate that in plotting rate against [NH<sub>3</sub>]<sup>2</sup>, the straight line should pass through the origin, costing them a mark. On the other hand, a small group of students attempted to force a straight line when plotting rate against [NH<sub>3</sub>] when it was clear from the spread of data points that they fit a curve. The presence of values for both [NH<sub>3</sub>] and [NH<sub>3</sub>]<sup>2</sup> in the table should have alerted students to the possibility that the order of reaction might be second order.

Students who plotted initial rate against [NH<sub>3</sub>]<sup>2</sup> has a much easier task to show the reaction is second order with respect to NH<sub>3</sub>. Those who plotted initial rate

against  $[\text{NH}_3]$  had to use their graph to show that when  $[\text{NH}_3]$  is doubled, rate increases by four times. The answer 'since the graph is not a straight line the reaction must be second order with respect to  $\text{NH}_3$ ' was not accepted.

Students who plotted both sets of data on the same axes without clear labels were penalized.

(ii) 1<sup>st</sup> order w.r.t.  $\text{O}_2$  [1m]

Gradient of the graph (for rate versus  $[\text{NH}_3]^2$ ) is the **change in the rate of reaction**. When the concentration of  $\text{O}_2$  is halved, the gradient is halved. Hence the change in the rate of reaction is half. This implies that the rate of reaction at each value of  $[\text{NH}_3]^2$  is half of the original value in the original graph. Hence halving the concentration of  $\text{O}_2$  halves the rate of reaction. [1m]

or

When rate is plotted against  $[\text{NH}_3]^2$ ,

rate =  $k [\text{O}_2]^n [\text{NH}_3]^2$  where gradient =  $k [\text{O}_2]^n$

Given that when  $[\text{O}_2]$  is halved, gradient is halved,

$k (\frac{1}{2}[\text{O}_2])^n = \frac{1}{2} k [\text{O}_2]^n$

$(\frac{1}{2})^n = \frac{1}{2} \Rightarrow n = \text{order w.r.t. } \text{O}_2 = 1$

This part was very poorly done. A vast majority of students interpreted the question to mean plotting a graph of concentration of oxygen against time. Students will do well to read the question carefully. In addition, for those who were aware that the plot referred to was rate against  $[\text{NH}_3]^2$ , there was an abject failure to realize that the gradient of the graph was not the rate of reaction but rather the change in rate of reaction. This is in part due to lack of familiarity with handling rate versus concentration graph as the more common graph is the concentration-time graph.

To get the marks, students must make a clear link between the change in rate of reaction and the change in gradient of the graph. Statements like '... when  $[\text{O}_2]$  is halved, gradient is halved hence rate is halved...' did not meet the mark.

(iii) Rate =  $k [\text{NH}_3]^2 [\text{O}_2]$  [1m, ecf allowed]

This part was not satisfactorily done for a large number of students. There were many who came up with a rate equation without having completed parts (b)(i) or (ii). No credit was given in this case.

(iv)  $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$  [1m, ecf allowed]

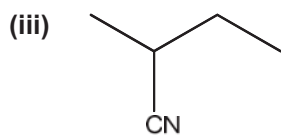
This part was badly done by too many students. This group of students had little clue how to work out the dimensions for the rate constant. A common mistake was to leave out the ' $\text{s}^{-1}$ ' in the unit.

- (c) (i) The chain reaction is self-sustaining, as the **•CN radical is regenerated** in the propagation step. Hence, only a flash of light is needed to produce **some •CN radicals to initiate the reaction**. [1m]

This question highlighted students' general failure to appreciate the fact that in reference to 'a flash of light and not prolonged irradiation', there were two parts to their answers that was required. The first being the reason for the brevity of irradiation. And the second being to explain why irradiation was in fact required. Some laxity was given in this question and yet too many students still lost this mark unnecessarily.

- (ii) **Use butane in excess (or use limited amount of (CN)<sub>2</sub>)**. [1m] (The probability of •CN radicals reacting with butane is higher than the probability of •CN radical reacting with monosubstituted butane.)

This part was generally well-done except for a handful of students who clearly were not familiar with the finer points of free radical substitution. Many irrelevant answers were given which included temperature. Another popular if completely irrelevant answer was *uv* light which does not affect the type and proportion of product formed.



[1m]

This part was generally well-done.

- (iv)  $\bullet\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \bullet\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \rightarrow \text{CH}_3(\text{CH}_2)_6\text{CH}_3$   
 Alternatives where radicals are coupled at different positions are also accepted. [1m]

The number of students who misread this question was quite unacceptable. The question was framed in the context of excess butane. This meant that the mono-substituted product was the major product. Hence the multiple substitutions using cyanogen to achieve products with 8 carbon atoms were not accepted.

- (v) Chlorine monoxide, being an **odd electron species** can **react readily with the radicals** in the reaction to decrease its' concentration and slow down the reaction. [1m]

Most students who got this part wrong failed to recognize that the chlorine oxide is also a radical species itself. Other students who recognized it as a radical erroneously thought that it would compete with the cyanogen radical for the butane and hence slow down the reaction. The competition would result in the formation of by-products, not a slower reaction. It is the reduction in the concentration of radicals that results in the slowdown in rate of reaction. This is achieved when the radicals collide with each other.

Many students also missed the point when they tried to suggest that C/O would breakdown to give C/ radicals.

Note that the  $\bullet\text{CN}$  radical is called a nitrile radical (not cyanogen radical) and  $\bullet\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$  is called a butyl radical (not butane radical). In addition, note that the unpaired electron in C/O is on the C/ atom, not the O atom.

- 2 (a) (i) Ox:  $\text{C}_6\text{H}_5\text{CH}_3 + 2\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_5\text{CO}_2\text{H} + 6\text{H}^+ + 6\text{e}^-$   
Red:  $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$   
Overall:  $5\text{C}_6\text{H}_5\text{CH}_3 + 6\text{MnO}_4^- + 18\text{H}^+ \rightarrow 5\text{C}_6\text{H}_5\text{CO}_2\text{H} + 6\text{Mn}^{2+} + 14\text{H}_2\text{O}$   
Answer: **5:6**

OR

Oxidation state of carbon changes from  $-3$  to  $+3$ , thus 6 electrons are transferred.

Oxidation state of manganese changes from  $+7$  to  $+2$ , thus 5 electrons are transferred.

Total number of electrons transferred must be 30 electrons, thus the ratio of methylbenzene to potassium permanganate is **5:6**.

[1m]

Most candidates could work out the ratio of **5:6**, with appropriate working shown to gain credit. The species undergoing oxidation is  $\text{C}_6\text{H}_5\text{CH}_3$ , not " $\text{C}^{3-}$ " or " $\text{CH}_3$ ". The molecular/structural formula should be written in the **overall** balanced equation.

- (ii) C1: Tetrahedral,  $\text{sp}^3$   
C2: Trigonal planar,  $\text{sp}^2$

[1m] both shapes correct  
OR [1m] both hybridization correct  
OR [1m] 1 pair of shape and hybridization  
OR [2m] all correct

This part was well answered. It is important to specify the molecular geometry about **C2** as **trigonal** planar. Merely saying that it is planar could mean it is square planar or trigonal planar. For hybridization, write  $\text{sp}^3$  instead of  $\text{sp}_3$  or  $\text{sp}3$ .

- (iii) Potassium benzoate will be found in water while methylbenzene will be found in hexane. [1m]

Potassium benzoate is an ionic salt that forms **ion-dipole interactions with water**. Thus it is soluble in water. [1m]

Methylbenzene and hexane are both non-polar molecules. Thus **dispersion forces occur between both molecules** and methylbenzene is thus soluble in hexane. [1m]



Methylbenzene undergoes side-chain oxidation with potassium manganate(VII) to form benzoic acid and  $\text{Mn}^{2+}$ . As manganate(VII) is the limiting reagent, excess methylbenzene will remain in the mixture. When excess  $\text{KOH}$  (aq) was added, benzoic acid will react with  $\text{KOH}$  (*neutralisation* reaction) to form potassium **benzoate**  $[\text{C}_6\text{H}_5\text{CO}_2]^- [\text{K}]^+$  which forms ion-dipole interactions **with** water molecules. Hence, benzoic acid is no longer present.

It is essential to point out clearly the **solute-solvent** interactions, for instance, dispersion forces **between** the solute methylbenzene and the solvent hexane, instead of just saying dispersion forces are present.

A lengthy explanation of the solute-solute, solvent-solvent interactions is **not** required.

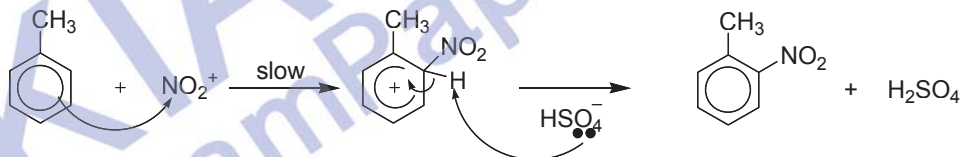
- (b) (i) Reagents:  
Concentrated nitric acid and concentrated sulfuric acid (catalyst)  
Conditions: heat at  $30^\circ\text{C}$

[1m]

Reagents must be **concentrated**  $\text{HNO}_3$  and **concentrated**  $\text{H}_2\text{SO}_4$ . Usage of dilute or aqueous  $\text{HNO}_3$  and/or  $\text{H}_2\text{SO}_4$  is wrong.

Since the methyl ( $\text{CH}_3$ ) substituent is an **activating** group, it activates the benzene ring towards electrophilic substitution. Hence a milder temperature between  **$30^\circ\text{C}$  to  $55^\circ\text{C}$**  is required.

- (ii) Electrophilic Substitution [1m]



[3m]

–1/2m for every mistake

Generation of the  $\text{NO}_2^+$  electrophile involves **two** molecules of concentrated  $\text{H}_2\text{SO}_4$ , forming  $\text{H}_3\text{O}^+$  as one of the products.

The slow step involves the electrophilic attack of the **nitrogen** of  $\text{NO}_2^+$  (arrow *must* start from the delocalized electron cloud of the aromatic benzene ring and point clearly towards the “N” of  $\text{NO}_2^+$ ) to result in the formation of a C-N bond. In the fast step, the arrow must start from the lone pair on **O** of  $\text{HSO}_4^-$  and point clearly towards the **H** atom to be substituted. Lastly the C-H bond cleaves, restoring the aromaticity of the benzene ring.

- (iii) The **methyl substituent is 2, 4-directing** while the **nitro substituent is 3-directing**. [1m]

Both the methyl and nitro substituents direct the incoming electrophile to the same carbon positions (2<sup>nd</sup> or 4<sup>th</sup> position with regards to the methyl group). Hence compound A, which has the incoming electrophile substituted at neither of these positions, is not favourably formed. [1m]

Note that one considers which substituent will “win out” **only** in cases where the substituents direct to **different** positions on the ring.

- (iv) The reactant in Step 3 (2,4-dinitromethyl benzene) has **one more deactivating NO<sub>2</sub> group**. Therefore, it is **more deactivated/less reactive/more stable** towards electrophilic attack. **More** rigorous conditions would hence be necessary to carry out electrophilic substitution. [1m]

Candidates must consider why Step 3 is **more** rigorous than Step 2 to gain credit.

- (c) (i)  $2\text{C}_7\text{H}_5\text{N}_3\text{O}_6(\text{s}) \rightarrow 3\text{N}_2(\text{g}) + 5\text{H}_2\text{O}(\text{g}) + 7\text{CO}(\text{g}) + 7\text{C}(\text{s})$

[1m]

At 400 °C, water should be present as steam: H<sub>2</sub>O (g). For the balanced equation, write “C<sub>7</sub>H<sub>5</sub>N<sub>3</sub>O<sub>6</sub>” instead of ‘TNT’. **State symbols** are essential in the equation (read the question).

- (ii)  $\Delta H_{\text{rxn}}^\ominus = [7(-111) + 5(-241)] - 2(-65.5) = -1850 \text{ kJ mol}^{-1}$  (3 s.f.)

Accept answer depending on coefficients of equation in (c)(i)

[1m] Statement of Hess’ Law

[1m] Answer

Note that the **standard** enthalpy change of formation of N<sub>2</sub>(g) and C(s) is **zero**.

- (iii)  $n(\text{TNT}) = 10.0 \div 227.0 = 0.0441 \text{ mol}$   
 Total amount of gas =  $0.0441 \div 2 \times 15 = 0.331 \text{ mol}$  [1m] (ecf allowed)  
 $pV = nRT$   
 $(101000)V = (0.331)(8.31)(400 + 273)$  [1m]  
 $V = 1.83 \times 10^{-2} \text{ m}^3$

This part was not well answered. Candidates must use the stoichiometric coefficients in their balanced equation from (c)(i) to calculate the **total number of moles of gases produced** by 10 g of TNT, **before** substituting into the ideal gas equation.



- (iv) The enthalpy change of reaction is highly exothermic, and a large amount of gas is produced per mole of TNT. The **heat evolved will cause rapid expansion** of the large amount of gases causing the explosive effect of TNT. [1m]

To obtain credit, candidates must first recognise, from (c)(i)-(iii), that a lot of heat is produced **and** a large volume of gases is produced, and then put these two ideas together: the **heat evolved** will cause the **further and rapid expansion of gases**.

- 3 (a) (i) An **ideal gas** is a hypothetical gas whose pressure-volume-temperature behaviour can be completely accounted for by the ideal gas equation  $pV = nRT$ . [1m]

Common mistakes:

- Students stating the assumption of ideal gas – some made errors while stating the assumptions e.g. gas (instead of gas **particles**) occupy negligible volume compared to volume of container. Wrong concepts would have negated the mark for correct definition of an ideal gas.
- No credit was given for simply stating that the gas obeys the ideal gas equation. Students must explicitly write out the equation as  $PV=nRT$ .

- (ii) At moderately high pressure, the gas molecules are close together. There are **intermolecular forces of attraction** [1m] between the gas particles which results in **lower than expected pressure when they collide with the walls** [1m] of the container, causing the factor  $pV/RT < 1$ , giving negative deviation. (OR relate to volume)

Most students scored the 1<sup>st</sup> mark for recognizing that intermolecular forces become significant at moderately high pressure as the particles are closer together, but they failed to get the 2<sup>nd</sup> mark, and merely stated the 2 assumptions of kinetic theory on negligible intermolecular forces of attraction between particles and gas particles have negligible volume compared to volume of container – both of which do NOT explain the **negative** deviation.

- (iii) X is steam [1m] (and Y is nitrogen). As the hydrogen bonding in steam is much stronger than the dispersion forces in nitrogen, the negative deviation is greater for steam than nitrogen. [1m]

Some students failed to identify hydrogen bonding in steam. Instead they commented that steam is polar, thus permanent dipole-permanent dipole interaction (wrong) is stronger than dispersion forces in nitrogen molecules. There were some students who thought that steam is a larger molecule (**not true**) than nitrogen and hence the steam molecules occupy a larger volume /more significant volume compared to the volume of container and leading to a greater deviation – again this will negate the mark for correctly stating the hydrogen bonding and dispersion forces in steam and nitrogen respectively.

- (b) (i) Le Chatelier's principle states that when a system in equilibrium is subjected to a change in conditions which disturb the equilibrium, the position of equilibrium will shift in a way so as to reduce that change. [1m]

Common mistakes:

- Students failed to mention that the changes in conditions is done on a system "in equilibrium"
- "Counteract the changes" is used rather than "position of equilibrium will shift"
- Some students wrote that "system will shift to offset the changes". It is necessary that students state that position of equilibrium will shift and not the system.

- (ii) Too high a pressure will **increase the cost** of production for ammonia. [1m]  
 Low temperature increase the production of ammonia but the **rate** of ammonia production is **very slow**. [1m]  
 Thus, moderate pressure (any value between 150 – 1000 atm) is used to save cost and a moderate temperature (any value between 400 – 500 °C) is used to speed up the rate of reaction. [1m]

Common mistakes:

- Some students cannot quote the correct conditions (both temp and pressure must be correct to get the mark) for the Haber Process.
- Some students mentioned high cost due to low temperature and high pressure. It is expected that students state clearly that high pressure leads to high cost and low temperature leads to slow rate.

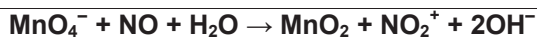
- (iii) Iron is used as a catalyst [1m] to speed up the rate of reaction.

- Students need to recognize that iron is a (heterogeneous) catalyst for Haber Process. Some mentioned that iron is used to remove impurity.
- Many students continued to describe that the catalyst lowers the activation energy of the reaction. This is not an accurate description! **It should be "a catalyst provides an alternative reaction pathway with lower activation energy".**
- Please also note that the catalyst will **not** increase the **yield** of ammonia.

- (c) No of moles of NO =  $5 \times 10^{-4}$   
 No of moles of  $\text{MnO}_4^-$  =  $5 \times 10^{-4}$   
 NO :  $\text{MnO}_4^-$  = 1 : 1  
 1  $\text{MnO}_4^-$  gains 3 e to form  $\text{MnO}_2$ , hence 1 NO loses 3 e. } [1m]  
 Final oxidation number of N in the product is **+5**. [1m]  
 Possible formula of product is  **$\text{NO}_3^-$**  or  **$\text{KNO}_3$**  [1m]  
 Balanced equation  
 $\text{MnO}_4^- + \text{NO} \rightarrow \text{MnO}_2 + \text{NO}_3^-$  [1m]

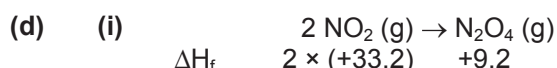
**$\text{NO}_2^+$**  is also an acceptable answer in addition to  $\text{NO}_3^-$ .

If students identified  $\text{NO}_2^+$  as the answer, then the corresponding equation will be:



Common mistakes:

- Students failed to realize the redox reaction occurred in an alkaline medium and consequently used the wrong half equation for reduction of  $\text{MnO}_4^-$ .
- $\text{HNO}_3$  not accepted as the reaction condition is basic.
- $\text{N}_2\text{O}_5$  is a commonly suggested identity but was rejected as question states clearly that the product is ionic.

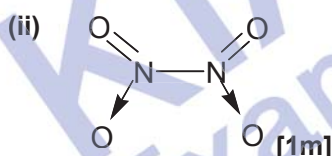


$$\Delta H_{\text{rxn}} = (+9.2) - (+66.4) = -57.2 \text{ kJ mol}^{-1}$$

The N–N bond is formed in this reaction, hence the bond energy of N–N =  $+57.2 \text{ kJ mol}^{-1}$  [1m]

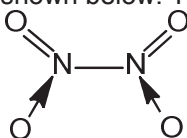
Common mistakes:

- Students failed to link the enthalpy change of reaction to bond energy of N–N. Quite a number of students cannot get the correct enthalpy change of reaction.
- Many did not put the (+) sign for bond energy and hence did not get the mark. The + sign for bond energy is critical in scoring the credit for this question.
- No marks awarded if students presented  $\Delta H = -57.2 \text{ kJ mol}^{-1}$  as the final answer. Since question asked for bond energy, it is expected that students present the final answer as bond energy of N–N =  $+57.2 \text{ kJ mol}^{-1}$ . This is a case whereby students have to answer in the context of the question.



Common mistakes:

- Some students drew 'dot-and-cross' diagram, instead of answering the question which asked for 'structure' of the molecule which typically refers to the Lewis structure.
- Many students drew the dative bond from the O atom to N atom as shown below. This is **not acceptable**.



- It is good practice that students incorporate the correct shape in drawing the structure of the molecule in this context. However, no marks were deducted for wrong shape in this case.

- (iii) In the  $\text{N}_2\text{O}_4$  molecule, the N–N bond is weak so the bond breaks easily when heated. The C–C bond in the  $\text{C}_2\text{O}_4^{2-}$  ion is a strong covalent bond. [1m]

Most students received credit for this question. When it is possible to quote from the data booklet to substantiate answers, it should be done. In this case, students who gave good quality answers would quote the bond energy values of N–N bond and C–C bond and comment that the C–C bond is stronger than the N–N bond.

- (e) (i) S is nitrogen [1m]. W is in Group I as it has the highest 2<sup>nd</sup> IE. Counting backwards, S is identified as a Group V element. [1m]

Some students who correctly identified S to be nitrogen were not able to explain their reasons clearly. Any element/elements in the graph can be used as the reference point. It is not necessary to use W.

- (ii) Nitrogen does not have available d orbitals to expand its octet, whereas P has available 3d orbitals. [1m]

Students have to mention the availability of **d-orbitals** in the explanation, not just vacant orbitals/larger size/more quantum shell/expand octet.

Some students used the wrong orbital (e.g. p orbital) for expansion of octet.



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**CANDIDATE  
NAME**

**CT GROUP**

**13S**

**CHEMISTRY**

**9647/01**

Paper 1 Multiple Choice

**3 October 2013**

**40 min**

Additional Materials: Multiple Choice Answer Sheet  
Data Booklet.

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Complete the information on the Multiple Choice Answer Sheet as shown below.

1. Enter your NAME ( as in NRIC ). \_\_\_\_\_

Write your **name**

2. Enter the SUBJECT TITLE. \_\_\_\_\_

3. Enter the PAPER NUMBER. \_\_\_\_\_

4. Enter your CT GROUP. \_\_\_\_\_

Write your **CT group**

5. Date. \_\_\_\_\_

6. Enter your NRIC NUMBER or  
FIN NUMBER.

7. Now SHADE the corresponding  
lozenge in the grid for  
EACH DIGIT or LETTER

NRIC / FIN															
S	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E
F	1	1	1	1	1	1	1	1	1	1	B	L	M	N	O
G	2	2	2	2	2	2	2	2	2	2	C	M	N	O	P
T	3	3	3	3	3	3	3	3	3	3	D	N	O	P	Q
	4	4	4	4	4	4	4	4	4	4	E	O	P	Q	R
	5	5	5	5	5	5	5	5	5	5	F	P	Q	R	S
	6	6	6	6	6	6	6	6	6	6	G	Q	R	S	T
	7	7	7	7	7	7	7	7	7	7	H	R	S	T	U
	8	8	8	8	8	8	8	8	8	8	I	S	T	U	V
	9	9	9	9	9	9	9	9	9	9	J	T	U	V	W

Write **and**  
**shade** your  
**NRIC**  
or **FIN** number

There are **twenty five** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

## SECTION A

- 1 Chlorine is a severe irritant to the eyes and respiratory system. The maximum safe toleration level of chlorine gas in air is  $0.005 \text{ mg dm}^{-3}$ .

How many molecules of chlorine gas are present in  $1 \text{ dm}^3$  of air at this toleration level?

- A  $\frac{0.005}{1000} \times \frac{1}{71} \times 6 \times 10^{23}$
- B  $\frac{0.005}{1000} \times 71 \times 6 \times 10^{23}$
- C  $\frac{0.005}{71} \times 6 \times 10^{23}$
- D  $\frac{0.005}{6 \times 10^{23}} \times 71$

- 2 Which particle would, on losing an electron, have a half-filled set of p orbitals?

- A  ${}_{13}\text{Al}^+$                       B  ${}_{14}\text{Si}^-$                       C  ${}_{15}\text{P}^-$                       D  ${}_{16}\text{S}^+$

- 3 Which statement correctly describes a physical property of the Period 3 elements?

- A The ionic radius of  $\text{Na}^+$  is greater than that of  $\text{Cl}^-$ .
- B The  $\text{S}^{2-}$  ion contains the same number of electrons as the  $\text{K}^+$  ion.
- C The electronegativity of phosphorus is greater than that of nitrogen.
- D The first ionisation energy of magnesium is less than that of aluminium.

- 4  $\text{SF}_4$  reacts with  $(\text{CH}_3)_4\text{NF}$  to form  $(\text{CH}_3)_4\text{N}^+\text{SF}_5^-$ .

Which combination correctly describes the shape of the ions in the product?

- |   | Shape of cation with respect to N atom | Shape of anion       |
|---|--|----------------------|
| A | trigonal pyramidal                     | square planar        |
| B | square planar                          | trigonal bipyramidal |
| C | tetrahedral                            | octahedral           |
| D | tetrahedral                            | square pyramidal     |

- 5 The boiling points of hydrogen chloride, carbon dioxide and ammonia are given below.

Gas	Boiling point/ °C
HCl	-85
CO <sub>2</sub>	-78
NH <sub>3</sub>	-33

Which statement best explains the data above?

- A** CO<sub>2</sub> has a higher boiling point than HCl because the dispersion forces in CO<sub>2</sub> are stronger than the hydrogen bonding in HCl.
- B** NH<sub>3</sub> has a higher boiling point than HCl because the hydrogen bonding in NH<sub>3</sub> is stronger than the permanent dipole-permanent dipole interactions in HCl.
- C** NH<sub>3</sub> has a higher boiling point than CO<sub>2</sub> because the permanent dipole-permanent dipole interactions in NH<sub>3</sub> are stronger than the permanent dipole-permanent dipole interactions in CO<sub>2</sub>.
- D** CO<sub>2</sub> has a higher boiling point than HCl because the permanent dipole-permanent dipole interactions in CO<sub>2</sub> are stronger than the permanent dipole-permanent dipole interactions in HCl.
- 6 Measured values of the pressure, volume and temperature of a known mass of a gaseous compound are to be substituted into the equation

$$pV = nRT$$

in order to calculate the relative molecular mass,  $M_r$ , of the compound.

Which conditions of pressure and temperature would give the most accurate value of  $M_r$ ?

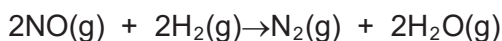
	pressure	temperature
<b>A</b>	high	high
<b>B</b>	high	low
<b>C</b>	low	low
<b>D</b>	low	high

- 7 When  $25 \text{ cm}^3$  of  $0.5 \text{ mol dm}^{-3}$  hydrochloric acid is reacted with an equal volume of  $0.5 \text{ mol dm}^{-3}$  potassium hydroxide, the temperature of the mixture rose by  $3.4^\circ\text{C}$ .

What will be the temperature change if  $50 \text{ cm}^3$  of  $1 \text{ mol dm}^{-3}$  hydrochloric acid is mixed with an equal volume of  $1 \text{ mol dm}^{-3}$  potassium hydroxide?

- A  $1.7^\circ\text{C}$
- B  $3.4^\circ\text{C}$
- C  $6.8^\circ\text{C}$
- D  $13.6^\circ\text{C}$

- 8 The reaction of nitrogen monoxide and hydrogen gas



is thought to involve the following steps:

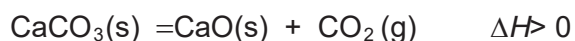
- I  $\text{NO} + \text{NO} \rightleftharpoons \text{N}_2\text{O}_2$  (fast)
- II  $\text{N}_2\text{O}_2 + \text{H}_2 \rightarrow \text{H}_2\text{O} + \text{N}_2\text{O}$  (slow)
- III  $\text{N}_2\text{O} + \text{H}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O}$  (fast)

What conclusion can be drawn from this information?

- A  $\text{H}_2$  acts as the catalyst.
  - B The overall order of the reaction is 3.
  - C The rate equation for the reaction is  $\text{rate} = k [\text{N}_2\text{O}_2] [\text{H}_2]$ .
  - D Increasing the concentration of NO does not change the rate of reaction.
- 9 Which statement about the effect of a catalyst on a reversible reaction is correct?
- A It increases the yield of the product at equilibrium.
  - B It increases the equilibrium constant for the forward reaction.
  - C It increases the rate constant for the forward reaction, but not that of the reverse reaction.
  - D It increases the rate constant for both the forward reaction and the reverse reaction.

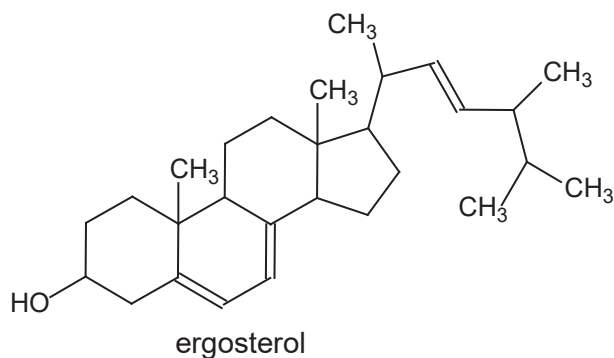


- 10 An equilibrium is represented by the following equation.



Which statement correctly describes the equilibrium?

- A** The position of equilibrium shifts to the right when the temperature is decreased.
- B** The value of the equilibrium constant,  $K_p$ , decreases when the temperature is increased.
- C** The position of equilibrium shifts to the right when the total pressure is decreased.
- D** The value of the equilibrium constant,  $K_p$ , increases when less  $\text{CaCO}_3(\text{s})$  is present at equilibrium.
- 11 How many aromatic isomers are possible for  $\text{C}_7\text{H}_7\text{Br}$ ?
- A** 3
- B** 4
- C** 5
- D** 6
- 12 The molecule shown below is ergosterol, a precursor of vitamin D.

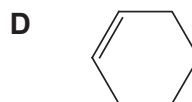
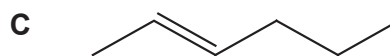


How many chiral centres are present in one ergosterol molecule?

- A** 6                      **B** 7                      **C** 8                      **D** 9

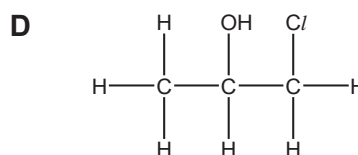
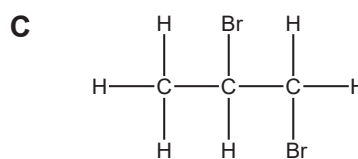
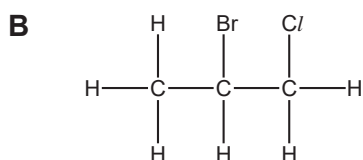
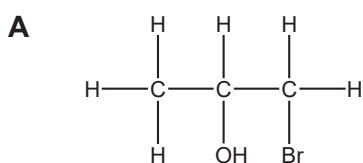
- 13 When a sample of a hydrocarbon was burnt in excess oxygen, 0.33 g of carbon dioxide and 0.18 g of water were formed.

What is a possible structure of the hydrocarbon?



- 14 Propene is shaken with an aqueous solution of bromine and sodium chloride.

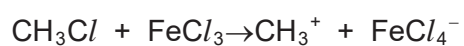
Which compound will **not** be formed?



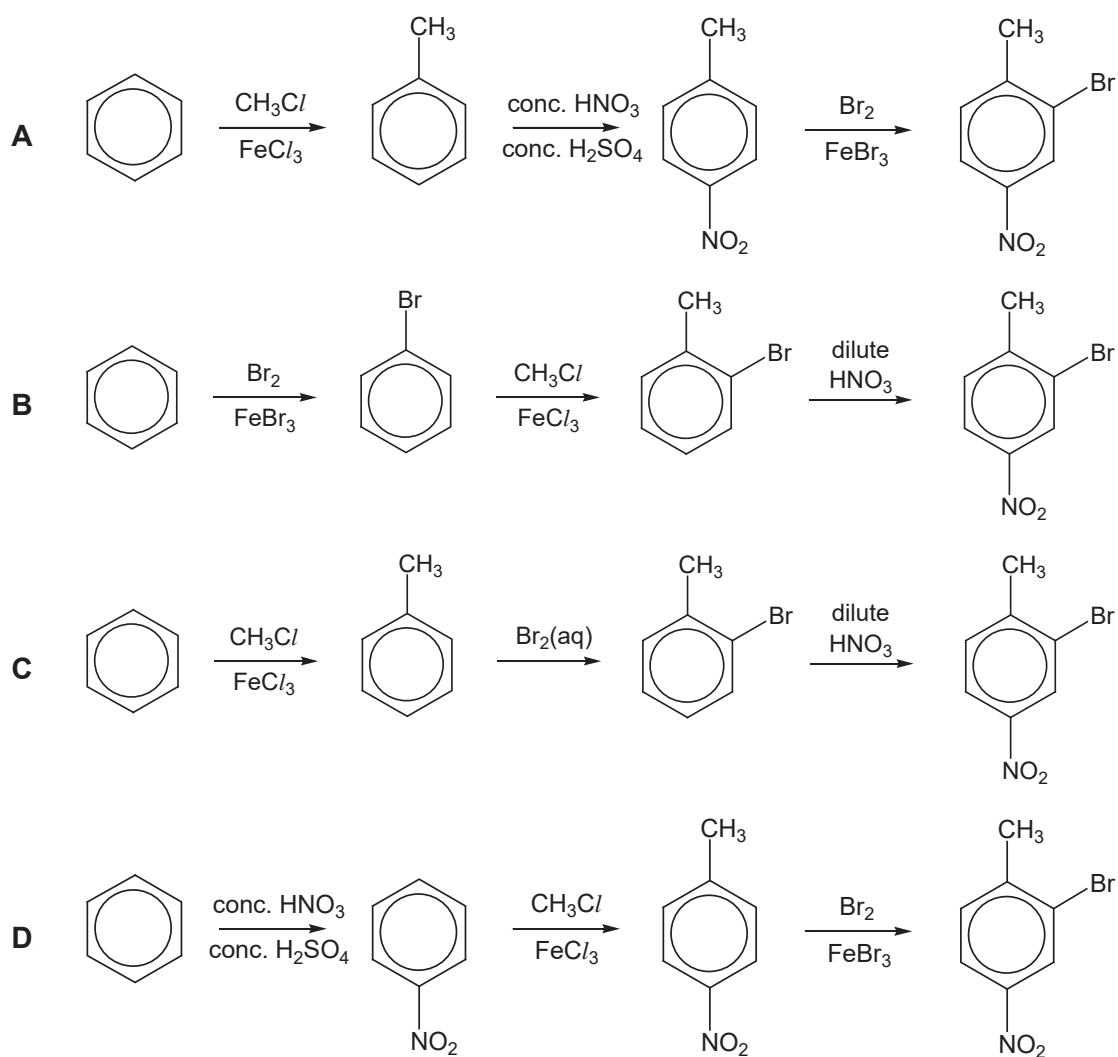
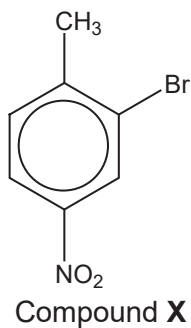
- 15 Which statement about the nitration of benzene is **incorrect**?

- A The intermediate contains 5 delocalised electrons.
- B  $\text{H}_2\text{SO}_4$  donates  $\text{H}^+$  to  $\text{HNO}_3$ , thus forming  $\text{NO}_2^+$  ions.
- C The reaction involves heterolytic fission of a C–H bond.
- D The geometry of the carbon undergoing substitution changes from planar to tetrahedral and back to planar.

16 Chloromethane reacts with iron(III) chloride as follows:



Which is the correct sequence of reactions to convert benzene to compound **X**?



- 17** Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere.

Which compound can be used as a replacement for CFCs?

- A**  $\text{CH}_2\text{F}_2$  **C**  $\text{CF}_3\text{CH}_2\text{Br}$   
**B**  $\text{CHBr}_3$  **D**  $\text{CH}_3\text{CH}_2\text{CH}(\text{CF}_3)$

## SECTION B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

No other combination of statements is used as a correct response.

- 18** Which statements about the complete combustion of an alkene,  $C_nH_{2n}$ , in oxygen are correct?

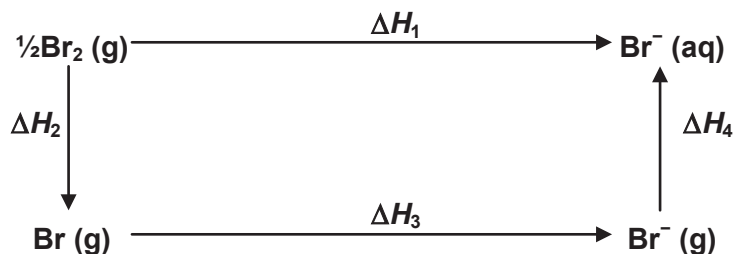
- 1 The volume of oxygen required is directly proportional to the number of carbon atoms present in the molecule.
- 2 The volume of gas produced at 25 °C is the same as for the complete combustion of an alkane with the same number of carbon atoms per molecule.
- 3 At 120 °C, the volume of steam produced is always twice the volume of carbon dioxide.

- 19** Which pairs of substances have similar types of structure and bonding?

- |          |                            |                         |
|----------|----------------------------|-------------------------|
| <b>1</b> | $\text{BF}_3$              | $\text{AlF}_3$          |
| <b>2</b> | $\text{PH}_3$              | $\text{SiCl}_3\text{H}$ |
| <b>3</b> | $\text{C}(\text{diamond})$ | $\text{SiC}$            |

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

20 Consider the energy cycle for bromine below.



Given that the bond energy of Br–Br is  $194 \text{ kJ mol}^{-1}$ , which statements are correct for the energy cycle for bromine?

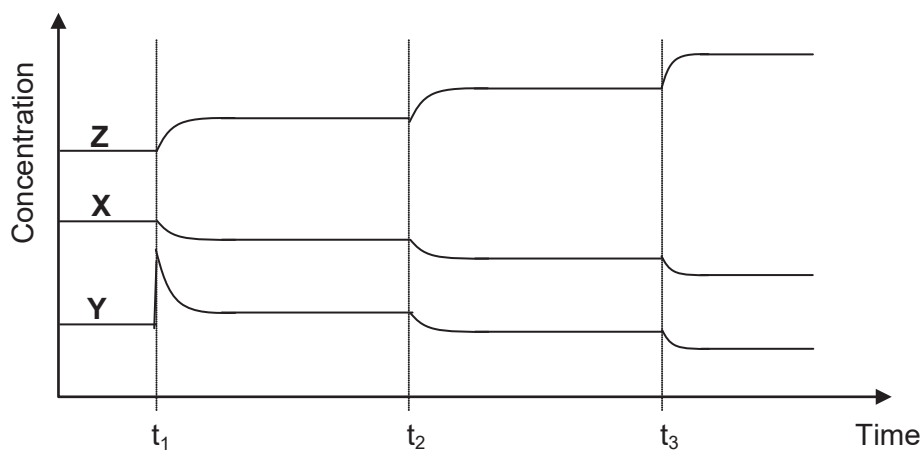
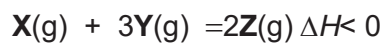
- 1  $\Delta H_4$  is the enthalpy change of hydration of bromide ion.
- 2 The value of  $\Delta H_2$  is  $-97 \text{ kJ mol}^{-1}$ .
- 3  $\Delta H_3$  is the first ionisation energy of bromine.

21 Which would always affect the rate of a reaction?

- 1 concentration of reactants
- 2 temperature
- 3 catalyst

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

22 The graph shows how the concentrations of **X**, **Y** and **Z** changes with time.

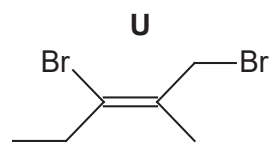
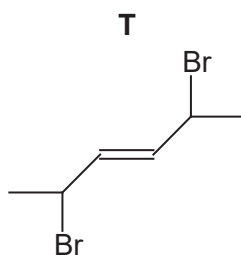
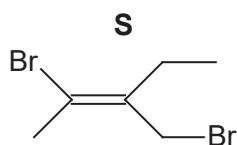
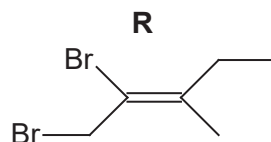
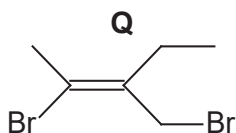
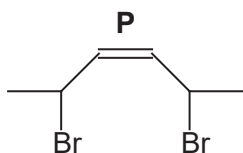


Which statements correctly explain the graph?

- 1 At time  $t_1$ , more **Y** was added.
- 2 At time  $t_2$ , the mixture was cooled.
- 3 At time  $t_3$ , a catalyst was added.

A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

**23** Six isomers of  $C_6H_{10}Br_2$  are shown below.



Which pairs of compounds are geometric isomers of each other?

- 1 **P** and **T**
- 2 **Q** and **S**
- 3 **R** and **U**

**24** Ethene gas undergoes two different reactions with  $KMnO_4(aq)$  under different conditions. For one reaction, a liquid product is formed. For another reaction, a gaseous product is formed.

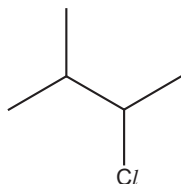
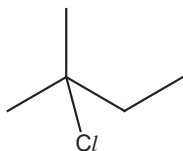
Which statements are correct?

- 1 For the reaction that forms a gaseous product, 2.8 g of ethene forms 4.4 g of the gaseous product.
- 2 The liquid product is optically inactive.
- 3 Temperature differences can result in the formation of different products.

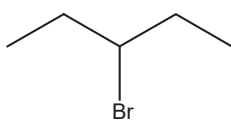
A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

**25** Which pairs of isomers give the same number of different alkenes on treatment with hot ethanolic sodium hydroxide?

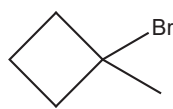
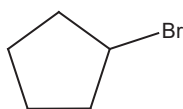
**1**



**2**



**3**



**END OF PAPER**





**HWA CHONG INSTITUTION**  
**C1Promotional Examination**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**13S**

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**CHEMISTRY**

**9647/02**

Paper 2 Structured Questions

**3 October 2013**

**1 h 15 min**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet.

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**INSTRUCTIONS TO CANDIDATES**

- 1) Write your **name** and **CT class** clearly in the spaces at the top of this page.
- 2) Answer **all** questions in the spaces provided in this Question Booklet.

**INFORMATION FOR CANDIDATES**

The number of marks is given in brackets [ ] at the end of each question or part question.

You may use a calculator.

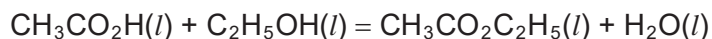
You are reminded of the need for good English and clear presentation in your answers.

**FOR EXAMINERS' USE ONLY**

Paper 1	Paper 2	Paper 3	TOTAL
Multiple Choice	Structured	Free Response	
	Q1 / 10	Q1 / 20	
	Q2 / 10	Q2 / 20	
	Q3 / 9	Q3 / 20	
	Q4 / 16		
/ 25	Subtotal / 45	Subtotal / 40	<b>110</b>

## 1 Planning (P)

Ethyl ethanoate is an important solvent used in the laboratory. One way of preparing it is through the esterification between ethanoic acid and ethanol, as shown by the following equation:



The reaction is reversible and it takes a long time for equilibrium to be reached. However, when an acid catalyst such as hydrochloric acid is added, the rates of both forward and reverse reactions increase so that equilibrium can be reached in a much shorter time. The catalyst will not affect the equilibrium composition of the reaction mixture.

- (a) Write an expression for the equilibrium constant,  $K_c$ , for the above esterification.

[1]

To determine the value of  $K_c$  for the above esterification, a conical flask, **A**, with different initial concentrations of the various reactants was set up as shown below.

Conical flask	Volume/ $\text{cm}^3$				
	HCl (1 mol $\text{dm}^{-3}$ )	$\text{CH}_3\text{CO}_2\text{H}$	$\text{C}_2\text{H}_5\text{OH}$	$\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$	$\text{H}_2\text{O}$
<b>A</b>	5.00	15.00	15.00	15.00	0.00

The conical flask was stoppered and placed in a thermostatically-controlled water bath for one week.

After a week had passed, the reaction in the conical flask was quenched. The quenching was done by transferring 25.0  $\text{cm}^3$  of the mixture from the flask and making up to 250  $\text{cm}^3$  in a volumetric flask using deionised water.

The diluted quenched solution, **FA1**, was then titrated immediately against a standard solution of 0.50 mol  $\text{dm}^{-3}$  NaOH to determine the amount of acid present.

The  $K_c$  was then determined.

- (b) Explain why it was necessary to carry out the experiment in a thermostatically-controlled water bath.

.....  
.....

[1]

- (c) Explain how the large volume of water added quenches the reaction.

.....  
.....

[1]

- (d) Write a plan for the volumetric analysis of **FA1**. You may use the reagents and apparatus commonly found in a school or college laboratory.

In your plan, you should give the essential details of the titration procedure.

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[3]

- (e) State two important techniques for the titration procedure to ensure accuracy of the titre values obtained.

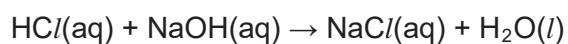
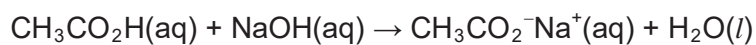
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[2]

- (f) The sodium hydroxide solution used in the titration neutralised both hydrochloric acid and ethanoic acid in the mixture.

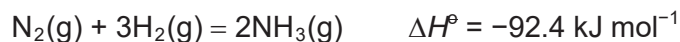


In a student's titration, it was found that  $p \text{ cm}^3$  of **FA1** reacted with exactly  $q \text{ cm}^3$  of  $0.50 \text{ mol dm}^{-3} \text{ NaOH}$ .

Outline how you would use the results to determine the amount of ethanoic acid present at equilibrium in conical flask **A**.

[2]  
[Total: 10 marks]

- 2 (a) The Haber process was founded by Fritz Haber and Carl Bosch and is known for the commercial synthesis of ammonia. The reaction is usually carried out at a pressure of 250 atm and a temperature of 450 °C.



- (i) Explain qualitatively what temperature and pressure (high or low) you would suggest to ensure a high yield of ammonia.

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- (ii) Explain why the conditions suggested in (a)(i) are not used industrially.

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- (iii) The standard entropy change,  $\Delta S^\ominus$ , for the Haber process is  $-198 \text{ J mol}^{-1} \text{ K}^{-1}$ .

Explain the significance of its sign.

.....

.....

- (iv) For any reaction,  $\Delta G^\ominus$ , in  $\text{J mol}^{-1}$ , and the equilibrium constant,  $K$ , are related according to the equation  $\Delta G^\ominus = -RT \ln K$ .

Use this equation to calculate a value of  $K$  for the Haber process at 298K and comment on the significance of its magnitude.

- (b) When an aqueous solution of ammonia is shaken with ether (a non-polar organic solvent which is immiscible with water), an equilibrium is established between aqueous ammonia and the organic layer at room temperature.

The distribution coefficient,  $K_D$ , is as shown:

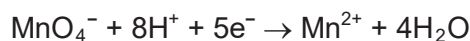
$$K_D = \frac{[\text{NH}_3(\text{ether})]}{[\text{NH}_3(\text{aq})]} = 8.0$$

In an experiment, 0.10 mol of ammonia in 120 cm<sup>3</sup> of water was shaken with 70 cm<sup>3</sup> of ether and allowed to reach equilibrium. Calculate the amount of ammonia present in ether at equilibrium.

[2]

[Total: 10 marks]

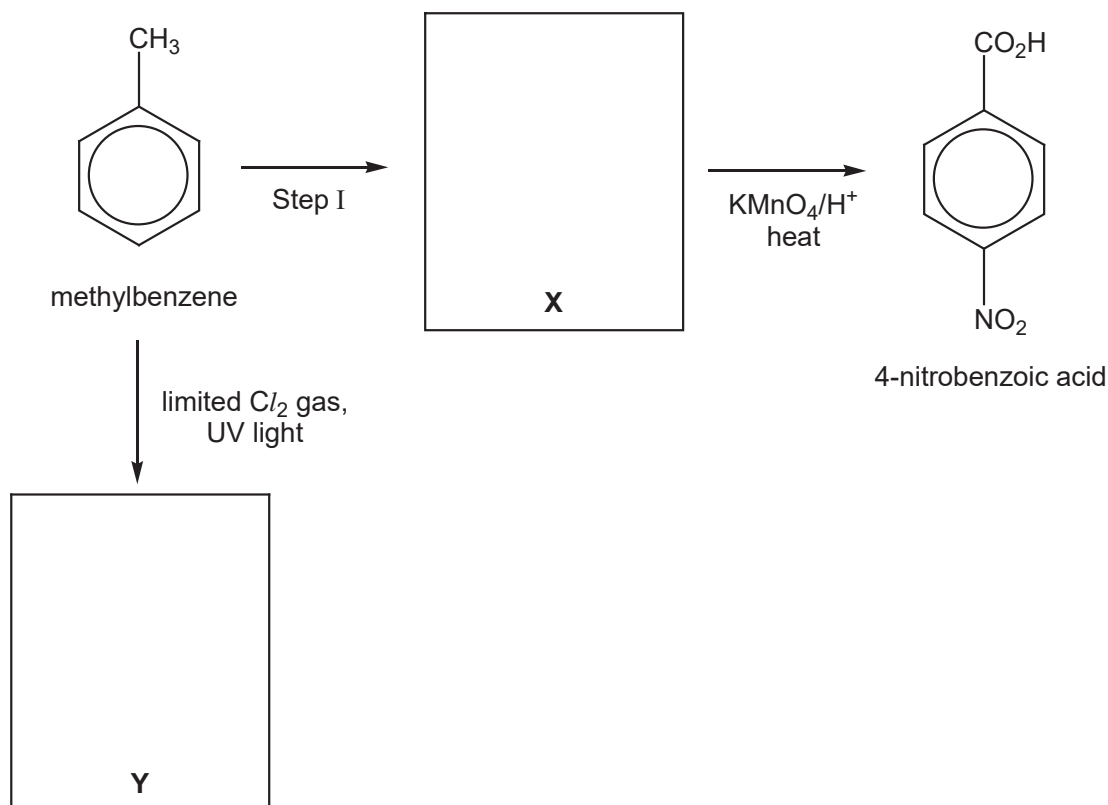
- 3 Potassium manganate(VII),  $\text{KMnO}_4$ , is a strong oxidising agent. In acidic conditions, it is reduced according to the following half-equation:



- (a) State the electronic configuration of  $\text{Mn}^{2+}$ .

[1]

- (b) The reaction scheme below shows some reactions of methylbenzene.



- (i) Draw the structural formulae of **X** and **Y** in the boxes above, and suggest the reagents and conditions used for step I.

Reagents and conditions:

- (ii) Write a balanced half-equation for the oxidation of methylbenzene,  $\text{C}_6\text{H}_5\text{CH}_3$  to benzoic acid,  $\text{C}_6\text{H}_5\text{CO}_2\text{H}$ . It is given that the oxidation number of the carbon that is oxidised in methylbenzene changes from  $-3$  to  $+3$ . Hence, write a balanced equation for the reaction between methylbenzene and acidified potassium manganate(VII).

[5]

- (c) The following is a method by which the reaction between iron(III) ions and hydroxylammonium chloride,  $\text{NH}_3\text{OH}^+\text{Cl}^-$ , may be investigated.

25.0  $\text{cm}^3$  of a solution containing 3.60  $\text{g dm}^{-3}$  of hydroxylammonium chloride was added to a solution containing an excess of  $\text{Fe}^{3+}$  ions and sulfuric acid. The  $\text{Fe}^{2+}$  ions formed required 25.90  $\text{cm}^3$  of 0.020  $\text{mol dm}^{-3}$  potassium manganate(VII) for complete reaction.

(5 mol of  $\text{Fe}^{2+}$  reacts with 1 mol of  $\text{MnO}_4^-$ )

- (i) Calculate the molar ratio  $\text{Fe}^{3+} / \text{NH}_3\text{OH}^+$  in the reaction.

- (ii) Determine the oxidation number of nitrogen in the product.

[3]

[Total: 9 marks]



4 This question concerns the reactions of some secondary alkyl halides.

(a) When samples of 2-chlorobutane, 2-bromobutane and 2-iodobutane were separately heated with aqueous NaOH, a product which rotated plane-polarised light was obtained.

(i) Arrange the three alkyl halides in order of increasing boiling points. Explain your answer.

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(ii) Name the mechanism for the reaction that had occurred.

.....

(iii) By quoting relevant data from the *Data Booklet*, explain which reaction is expected to be the fastest.

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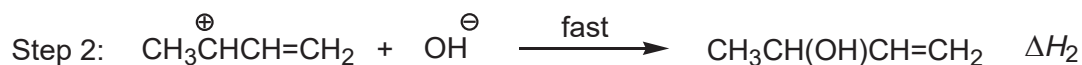
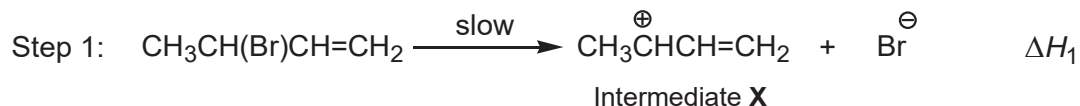
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[6]

- (b) Unlike the 2-halobutane compounds, when a sample of 3-bromobut-1-ene,  $\text{CH}_3\text{CH}(\text{Br})\text{CH}=\text{CH}_2$ , was heated with aqueous  $\text{NaOH}$ , no rotation of plane-polarised light was observed for the product mixture.

This reaction proceeds via the formation of intermediate **X** as shown by the mechanism below.



- (i) State the type of stereoisomerism exhibited by 3-bromobut-1-ene. Draw the structures of the two stereoisomers.

Type of stereoisomerism: .....



- (ii) Draw an energy profile diagram for the reaction between 3-bromobut-1-ene and aqueous  $\text{NaOH}$ .

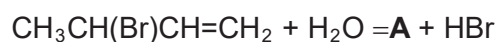
Indicate the activation energies, species involved and the enthalpy changes for each step of the reaction in your diagram.

- (c) The dielectric constant, which is a measure of solvent polarity, of some solvents is shown in **Table 1** below. A more polar solvent has a larger dielectric constant.

**Table 1**

Solvent	Dielectric constant
water	80.1
propanone, CH <sub>3</sub> COCH <sub>3</sub>	20.7
2-methylpropan-2-ol, (CH <sub>3</sub> ) <sub>3</sub> COH	10.0

A series of experiments was performed to determine the effect of solvent polarity on the rate of reaction between 3-bromobut-1-ene and water. This reaction is known to proceed via the same intermediate, **X** as shown in (b), and the overall balanced equation for the reaction is shown below.



The formation of HBr allows the rate of reaction to be followed by adding a fixed amount of NaOH(aq) and phenolphthalein indicator, and determining the time taken for the solution to turn colourless. The results of the experiment are shown in **Table 2** below.

**Table 2**

Solvent	Time taken / s
H <sub>2</sub> O	10
1:1 mixture of H <sub>2</sub> O and CH <sub>3</sub> COCH <sub>3</sub>	34
1:1 mixture of H <sub>2</sub> O and (CH <sub>3</sub> ) <sub>3</sub> COH	65

- (i) Draw the displayed formula of compound **A**.
- (ii) Draw a simple diagram to show how a molecule of (CH<sub>3</sub>)<sub>3</sub>COH can be attracted to an intermediate **X** cation. Label your diagram to show the type of interaction involved.

- (iii) By considering your answer to (c)(ii) and the results in **Table 2**, describe and explain the effect of solvent polarity on the rate of reaction.

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.....

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[5]  
[Total: 16 marks]

– End of paper –



**HWA CHONG INSTITUTION**  
**C1 PROMOTIONAL EXAMINATION**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**13S**

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**CHEMISTRY**

**9647/03**

Paper 3: Free Response

**3 October 2013**

**1 h**

Candidates answer on on separate paper.

Additional Materials: Answer Paper

Graph Paper

Data Booklet

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**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **any 2 of the 3** questions on the writing paper provided.

Begin each question on a **new piece of paper**.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

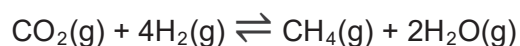
At the end of the examination, fasten all your work securely together.

**Write down** the question numbers for the questions that you have attempted on the **cover page** provided.

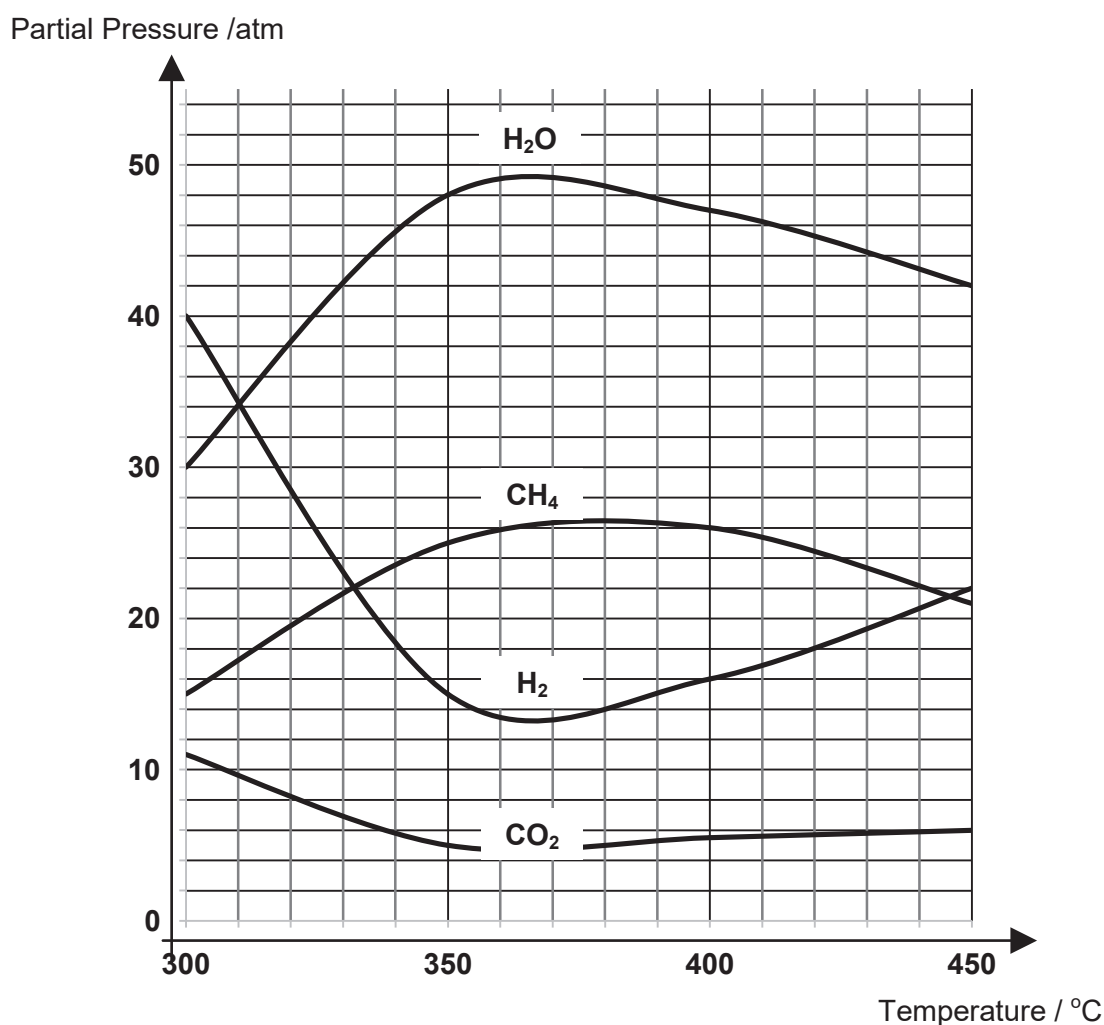
Answer any **two** questions.

- 1 With increasing focus on green energy, there is a push for carbon neutral fuels like hydrocarbons generated from carbon dioxide in the atmosphere. Methane is a prime candidate for such fuels as it can be used directly as a fuel and also to generate larger hydrocarbon molecules of interest.

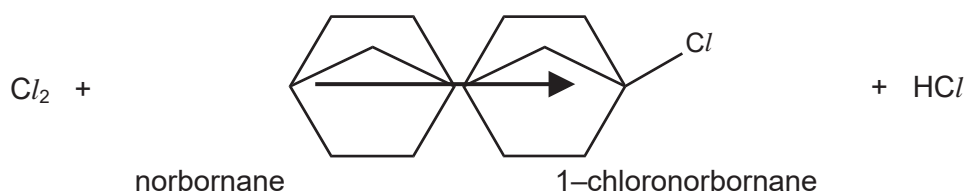
One of the proposed methods of generating methane is through the Sabatier reaction, which is catalysed by ruthenium metal. The chemical equation for the reaction is shown below.



- (a) State one environmental consequence of excessive carbon dioxide in the atmosphere. [1]
- (b) In order to optimise the process, a scientist performed a series of experiments by measuring the equilibrium partial pressure of each gas at various temperatures. The results are shown in the graphs below.



- (i) Write an expression for the equilibrium constant,  $K_p$ , for the Sabatier reaction and state its units.
- (ii) Calculate the value of  $K_p$  for the reaction at 300°C.
- (iii) Based on the data provided, suggest with reasoning the optimal temperature for the production of methane in the Sabatier reaction.
- (iv) Calculate the total pressure of the system at the temperature suggested in (b)(iii).
- (v) State one assumption of an ideal gas. Explain which gas in the system you would expect to deviate the most from ideality based on the assumption you have stated.
- (vi) Hence or otherwise, explain why the actual total pressure of the system is lower than that expected from an ideal system.
- [9]
- (c) (i) Describe the mode of action of the ruthenium catalyst as a heterogeneous catalyst in the Sabatier reaction.
- (ii) Explain why the ruthenium catalyst is usually spread over a highly porous support during the reaction.
- [3]
- (d) One particular hydrocarbon molecule of interest is norbornane,  $C_7H_{12}$ , which can be converted to 1-chloronorbornane using chlorine.



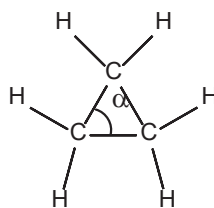
- (i) State the condition necessary for the reaction.
- (ii) Describe the mechanism for the reaction.
- (iii) Draw the structure of other possible monochlorinated norbornanes besides 1-chloronorbornane. Only structural isomers of 1-chloronorbornane need to be considered.

Predict the ratio of **all** the monochlorinated norbornanes obtained. You may assume reaction occurs at the same rate for every carbon atom.

[7]

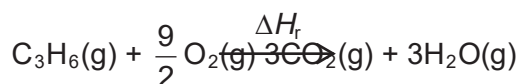
[Total: 20 marks]

- 2 (a) Cyclopropane,  $C_3H_6$ , is a cycloalkane. Its structure is shown below:



cyclopropane

- (i) Sketch the shapes of the hybrid orbitals around one of the carbon atoms in cyclopropane.
- (ii) Based on the structure shown, state the bond angle,  $\alpha$ , indicated in the diagram.
- (iii) Taking the bond energy of the C=O bond in  $CO_2$  to be  $805 \text{ kJ mol}^{-1}$ , and using other appropriate bond energies given in the *Data Booklet*, calculate a value for the enthalpy change for the following reaction,  $\Delta H_r$ .



cyclopropane

- (iv) The standard enthalpy change of vapourisation of water is  $+40.7 \text{ kJ mol}^{-1}$ . Using this value and your answer in (a)(iii), construct an energy cycle and use it to calculate the standard enthalpy change of combustion of cyclopropane.
- (v) The C-C bond energy in cyclopropane was found to be only  $272 \text{ kJ mol}^{-1}$ . With reference to your answers in (a)(i) and (a)(ii), suggest why the C-C bond energy in cyclopropane is so much lower than that quoted in the *Data Booklet*.

[8]

- (b) Propene is an alkene that is a structural isomer of cyclopropane.

Hydrogen halides, such as HCl and HBr, react readily with alkenes. Describe the mechanism for the reaction between propene and HBr.

[3]



- (c) The number of cyclic rings and pi bonds in a hydrocarbon can often be deduced using the following formula:

$$n = \text{number of rings} + \pi \text{ bonds} = C - \frac{H}{2} + 1$$

where  $C$  represents the number of carbon atoms in the hydrocarbon and  $H$  represents the number of hydrogen atoms in the hydrocarbon.

For instance, for a molecule with molecular formula  $C_3H_6$ ,  $n = 3 - 6/2 + 1 = 1$ .

We can therefore conclude that the molecule possesses either 1 ring or 1  $\pi$  bond. In this case, the molecule can only be either propene, with 1  $\pi$  bond, or cyclopropane, with 1 ring.

Compound **X** has the molecular formula of  $C_8H_{12}$ .

- (i) Calculate  $n$  for compound **X**.

When **X** is reacted with hot acidified  $KMnO_4$ , only one product, **Y**,  $C_4H_6O$ , is formed. **Y** does not contain any chiral centres.

- (ii) Name the type of reaction that occurred when **X** is converted to **Y**.  
(iii) Name the functional group that is present in **Y**.  
(iv) Suggest the structural formulae for **X** and **Y**.

[5]

- (d) A  $40.0 \text{ cm}^3$  sample of an unknown hydrocarbon,  $C_xH_y$ , was heated from  $25^\circ\text{C}$  to  $130^\circ\text{C}$  at a fixed pressure of 1 atm.

The hydrocarbon was then combusted in an excess of  $400 \text{ cm}^3$  of oxygen gas. On passing the residual gases over anhydrous calcium chloride (a drying agent) and potassium hydroxide, contractions of  $271 \text{ cm}^3$  and  $216 \text{ cm}^3$  were observed respectively. The volume of the gas that remained was  $48.4 \text{ cm}^3$ . The volumes of these gases were measured at  $130^\circ\text{C}$  and 1 atm.

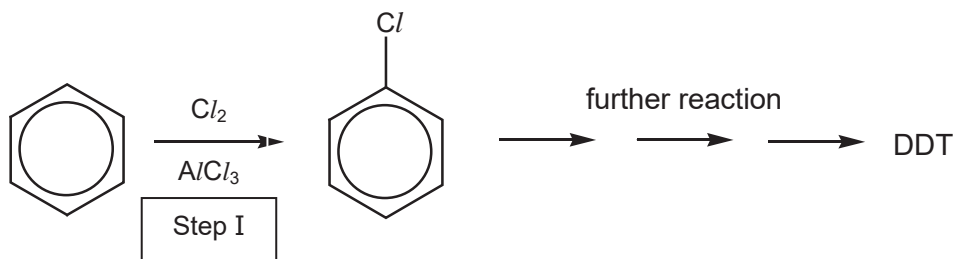
- (i) Determine the volume of the hydrocarbon at  $130^\circ\text{C}$  and 1 atm.  
(ii) State the volume of steam that was produced in the combustion reaction.  
(iii) Deduce the molecular formula of the unknown hydrocarbon.

[4]

[Total: 20 marks]

3 Benzene is widely used as a starting material to produce pesticides and synthetic plastics.

- (a) In the synthesis of the insecticide dichlorodiphenyltrichloroethane (DDT), benzene is first treated with chlorine to form chlorobenzene.



Describe the mechanism of the reaction in step I.

[3]

- (b) Aluminum chloride, the chloride of a Period 3 element, is used as a catalyst in (a).

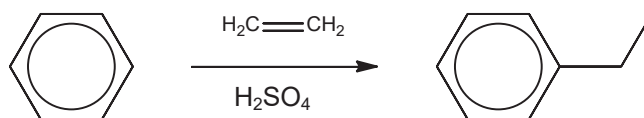
- (i) Use the concept of activation energy, together with a sketch of the Boltzmann distribution curve, to explain how a catalyst increases the rate of the reaction.
- (ii) The melting points of four Period 3 elements, Na, Si,  $\text{P}_4$  and  $\text{Cl}_2$  decrease as follow:

<u>Element</u>	<u>Melting point / K</u>
Si	1683
Na	371
$\text{P}_4$	317
$\text{Cl}_2$	172

Based on your understanding of the structure and bonding of the elements, explain why the melting points decrease in this order.

[7]

- (c) Ethylbenzene, an important precursor to synthetic polymers and plastics, can be made from benzene in the reaction shown below.



In an experiment to investigate the kinetics of this reaction, 0.80 mol of ethene was reacted with 8 mol of benzene (in excess). The total volume of the reaction mixture was 1.0 dm<sup>3</sup>. The following results were obtained.

Time / min	[ethylbenzene] / mol dm <sup>-3</sup>
12	0.25
38	0.58
61	0.71
80	0.76

- (i) State the final concentration of ethylbenzene upon completion of the reaction.
- (ii) Plot a graph to show how the concentration of ethylbenzene changes during the first 80 min of the reaction and deduce the order of reaction with respect to ethene.
- (iii) From your graph in (c)(ii), determine the initial rate of reaction.
- (iv) A second experiment was conducted in which the concentration of ethene was kept the same and the concentration of benzene was halved. The following results were obtained.

Experiment	[ethene] / mol dm <sup>-3</sup>	[benzene] / mol dm <sup>-3</sup>	Initial rate of formation of ethylbenzene / mol dm <sup>-3</sup> min <sup>-1</sup>
2	0.8	4.0	0.0106

Use this information to deduce the order of reaction with respect to benzene.

- (v) Write the rate equation and calculate a value for the rate constant, giving its units.
- (vi) Diethylbenzene is a side product of this reaction. By considering the reactivity of the benzene ring, explain why it is formed.

[10]

[Total: 20 marks]

– End of paper –

**HWA CHONG INSTITUTION**  
**2013 C1 H2 CHEMISTRY PROMOTIONAL EXAM**  
**SUGGESTED SOLUTIONS**

**Paper 1**

1	2	3	4	5	6	7	8	9	10
A	C	B	D	B	D	C	B	D	C
11	12	13	14	15	16	17	18	19	20
B	C	A	D	A	A	A	B	C	D
21	22	23	24	25					
C	B	B	C	D					

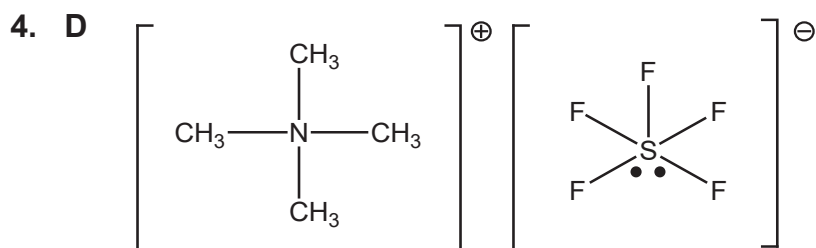
**Comments**

1. **A** No of moles of  $0.005 \text{ mg Cl}_2$  gas in  $1 \text{ dm}^3 = 0.005 \times 10^{-3} / 71$  [ $M_r$  of  $\text{Cl}_2$ ]  
 1 mol of  $\text{Cl}_2$  gas consists of  $6 \times 10^{23}$  molecules  
 $\Rightarrow (0.005 \times 10^{-3} / 71) \text{ mol of Cl}_2 \text{ gas consists of } (6 \times 10^{23}) \times 0.005 \times 10^{-3} / 71$   
 molecules

2. **C** The total number of electrons of each particle after losing an electron is as follow:

A	${}_{13}\text{Al}^+$	$12 - 1 = 11\text{e}$	$1s^2 2s^2 2p^6 3s^1$
B	${}_{14}\text{Si}^-$	$15 - 1 = 14\text{e}$	$1s^2 2s^2 2p^6 3s^2 3p^2$
C	${}_{15}\text{P}^-$	$16 - 1 = 15\text{e}$	$1s^2 2s^2 2p^6 3s^2 3p^3$ – half-filled p orbitals
D	${}_{16}\text{S}^+$	$15 - 1 = 14\text{e}$	$1s^2 2s^2 2p^6 3s^2 3p^2$

3. **B**
- |   |   |
|---|---|
| A | $\text{Na}^+$ : $1s^2 2s^2 2p^6$ ;<br>$\text{Cl}^-$ : $1s^2 2s^2 2p^6 3s^2 3p^6$ (one more quantum shell of electrons than $\text{Na}^+$ )<br>$\Rightarrow$ ionic radius of $\text{Na}^+$ is smaller than that of $\text{Cl}^-$<br>Can refer to <i>Data Booklet</i> for the ionic radii.<br>Refer to lecture notes p50 (Topic 2: Atomic Structure and Physical Periodicity) |
| B | No. of electrons in $\text{S}^{2-} = 16 + 2 = 18\text{e}$ ; No. of electrons in $\text{K}^+ = 19 - 1 = 18\text{e}$  |
| C | Both P and N are in Group V. N is in period 2 and P is in period 3.<br>Atomic radius of P < that of N, so N is more electronegative than P.   |
| D | First ionisation energy of Group II > Group III<br>Can refer to <i>Data Booklet</i> for the first ionisation energies.<br>Refer to lecture notes p54 (Topic 2 : Atomic Structure and Physical Periodicity)  |



4 bond pairs around N, thus tetrahedral

5 bond pairs and 1 lone pair around S, thus square pyramidal

5. B HCl is polar and cannot form H-bonding, thus it possesses pd-pd interactions.

NH<sub>3</sub> has H-bonding.

CO<sub>2</sub> is non-polar and it possesses dispersion forces.

6. D The ideal gas equation would give an accurate value of the M<sub>r</sub> if the gas behaves ideally. A real gas behaves more ideally if the temperature is high and the pressure is low.

7. C When 25 cm<sup>3</sup> of 0.5 mol dm<sup>-3</sup> HCl reacted with equal volume of 0.5 mol dm<sup>-3</sup> KOH,  
 $\Delta H_1 = -50 \times c \times 3.4 / 25 \times 10^{-3} \times 0.5 \text{ J mol}^{-1}$

When 50 cm<sup>3</sup> of 1 mol dm<sup>-3</sup> HCl reacted with equal volume of 1 mol dm<sup>-3</sup> KOH,  
 $\Delta H_2 = -100 \times c \times \Delta T / 50 \times 10^{-3} \times 1 \text{ J mol}^{-1}$

Both neutralisation reactions involve strong acid (HCl) and strong base (KOH).

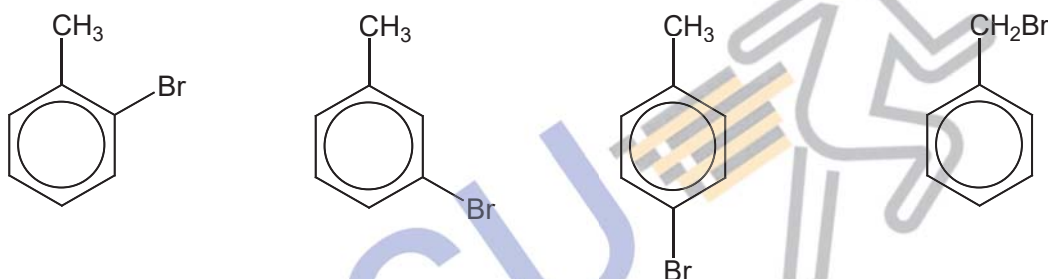
Hence  $\Delta H_1 = \Delta H_2 \Rightarrow \Delta T = 2 \times 3.4 = 6.8^\circ\text{C}$

8. B	A	H <sub>2</sub> is not regenerated $\Rightarrow$ H <sub>2</sub> does not act as a catalyst, it is a reactant.
	B	From slow step: rate = $k[\text{N}_2\text{O}_2][\text{H}_2]$ .....(1); but N <sub>2</sub> O <sub>2</sub> is an intermediate From the first reversible reaction: $K_c = [\text{N}_2\text{O}_4] / [\text{NO}]^2 \Rightarrow [\text{N}_2\text{O}_4] = K_c [\text{NO}]^2$ .....(2) Substitute (2) into (1) $\Rightarrow$ rate = $k \times K_c [\text{NO}]^2 [\text{H}_2] = k' [\text{NO}]^2 [\text{H}_2]$ Overall order of reaction = 2 + 1 = 3
	C	N <sub>2</sub> O <sub>2</sub> is an intermediate, hence cannot appear in the rate equation.
	D	Increasing the concentration of NO increases the rate of reaction as the reaction is 2 <sup>nd</sup> order with respect to NO.

9. D A catalyst increases the rates of both the forward and reverse reactions (for a reversible reaction); the rate constants of both the forward and reverse reactions are increased. A catalyst does not change the yield or quantity of product obtained at equilibrium. A catalyst does not change the value of the equilibrium constant.

10. C	A	When the temperature is decreased, position of equilibrium shifts to the <u>left</u> so as to produce more heat since the <u>reverse reaction is exothermic</u> .
	B	When the temperature is increased, position of equilibrium shifts to the <u>right</u> so as to absorb the excess heat since the <u>forward reaction is endothermic</u> . The value of $K_p$ <u>increases</u> .
	C	When the total pressure is decreased, position of equilibrium shifts to the right so as to increase the pressure since right-hand-side of the equilibrium contains more gas molecules. (In fact, no gas molecules are present on the left-hand-side of the equilibrium.)
	D	Change in the amount of solid does not affect equilibrium as solid does not appear in the $K_p$ expression. The value of the equilibrium constant changes <u>only</u> if there is a change in temperature. (one exception case: $\Delta H = \text{zero}$ )

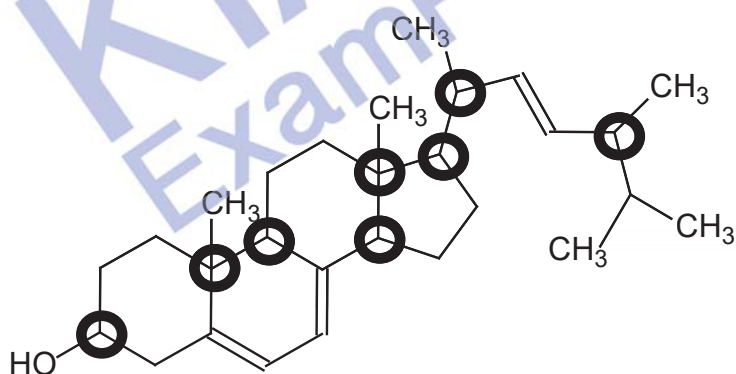
11. B For the molecular formula,  $C_7H_7Br$ , the structural isomers are:



None of these structures form stereoisomers.

Total no. of aromatic isomers = 4.

12. C There are 8 chiral carbons in the molecule:



13. A  $0.33 / 44.0 = 0.0075 \text{ mol CO}_2$   
 $0.18 / 18.0 = 0.01 \text{ mol H}_2\text{O}$

C : H ratio =  $3 : (2 \times 4) = 3 : 8 \rightarrow$  empirical formula of hydrocarbon is  $C_3H_8$ .  
 (For every 1 mol of water formed, there should be 2 H present)

Notice that the empirical formula fits the general formula of an alkane,  $C_nH_{2n+2}$ . **A** is the only structure with this empirical formula.

**14. D** Bromine is the electrophile for this reaction, thus the cyclic bromonium ion is the intermediate. The products that are formed are those from the reaction between the bromonium ion and one of the 3 ( $\text{Br}^-$ ,  $\text{Cl}^-$  and  $\text{H}_2\text{O}$ ). **D** is not formed because it cannot be a result of the reaction with the bromonium ion intermediate.

**15. A** For the electrophilic substitution reaction, one pair of electrons from the delocalised electron pi cloud is used to form a bond with the electrophile, so the number of delocalised electrons becomes  $6 - 2 = 4$  (not 5).

**16. A** **A** is the correct answer as the reagents used and the position of substitution is correct.

**B** is rejected because dilute nitric acid does not work for the second intermediate.

**C** is rejected because aqueous bromine and dilute nitric acid do not work.

**D** is rejected because the alkyl group is not on the 3-position upon alkylation of nitrobenzene.

**17. A** In order not to destroy ozone, C-Cl or C-Br bonds should not be present as they are easily broken. C-F can be present because this bond is strong and cannot be broken easily.

$\text{CH}_2\text{F}_2$  is the only compound that does not contain C-Cl or C-Br bonds.

**18. B**

1	$\text{C}_n\text{H}_{2n} + (3n/2)\text{O}_2 \rightarrow n\text{CO}_2 + n\text{H}_2\text{O}$ volume of $\text{O}_2$ required for combustion $\propto$ no. of C atoms present in the molecule.
2	The gas produced at $25^\circ\text{C}$ is $\text{CO}_2$ . One mole of $\text{C}_n\text{H}_{2n}$ produces $n$ moles of $\text{CO}_2$ . Similarly, one mole of $\text{C}_n\text{H}_{2n+2}$ produces $n$ moles of $\text{CO}_2$ .
3	At $120^\circ\text{C}$ , $\text{C}_n\text{H}_{2n} + (3n/2)\text{O}_2 \rightarrow n\text{CO}_2(\text{g}) + n\text{H}_2\text{O}(\text{g})$ volume of $\text{CO}_2$ = volume of steam

**19. C**

1	False. $\text{BF}_3$ is simple molecular with covalent bonds between B and F atoms, and dispersion forces between molecules. $\text{AlF}_3$ has a giant lattice, there are ionic bonds between $\text{Al}^{3+}$ and $\text{F}^-$ ions. (Please note: $\text{AlF}_3$ is giant ionic while $\text{AlCl}_3$ is simple covalent molecular.)
2	True. Both are simple molecular with covalent bonds between atoms, and van der Waals forces between molecules.
3	True. Both are giant covalent. (Please note: Si is giant covalent, diamond is giant covalent, SiC is also giant covalent.)

**20. D**

1	$\Delta H_4$ is the enthalpy change of hydration of bromide ion.
2	The value of $\Delta H_2$ should be $+97 \text{ kJ mol}^{-1}$ , breaking of Br-Br bond is endothermic process.
3	$\Delta H_3$ is the first electron affinity of Br.

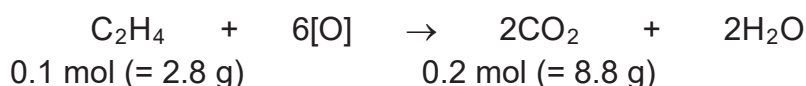


21. C	1	Only when rate $\propto$ [concentration] <sup>n</sup> where n $\neq$ 0.
	2	Increasing temperature always increases the rate of reaction. Refer to lecture notes p88 (Topic 6 Reaction Kinetics: Effect of temperature)
	3	Catalyst speeds up the rate of reaction. Refer to lecture notes p90 (Topic 6 Reaction Kinetics: Effect of Catalyst)

22. B	1	True. The sudden rise in [Y] suggests that more Y was added (there was no sudden change in [X] or [Z]). By Le Chatelier's Principle, position of equilibrium shifts to the <u>right to remove Y</u> . Thus after time t <sub>1</sub> , [Y] falls, [X] falls, [Z] rises, until a new state of equilibrium is achieved with the concentrations reaching constant levels. Notice also that at the new state of equilibrium, [Y] is slightly higher than that at the previous equilibrium. This is because the system can only respond to partially remove the disturbance or minimise the change.
	2	True. When the equilibrium mixture is cooled, position of equilibrium shifts to the <u>right</u> to produce more heat, since the forward reaction is exothermic. Thus after time t <sub>2</sub> , [X] falls, [Y] falls, [Z] rises, until a new state of equilibrium is achieved with the concentrations reaching constant levels again.
	3	False. A catalyst has no effect on the position of equilibrium. The concentrations of X, Y and Z would not change. In addition, the system was already at equilibrium at time t <sub>3</sub> . So adding a catalyst at this time has no effect at all.

23. B	1	P and T are geometric isomers of each other. P is the cis-isomer, T is the trans-isomer.
	2	Q and S are geometric isomers of each other.
	3	R and U do not have the same structural formula. Geometric isomerism is a type of stereoisomerism. Stereoisomers have the same structural formula but differ in the spatial arrangement of atoms or groups.

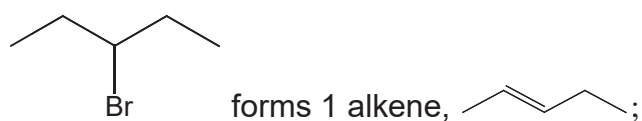
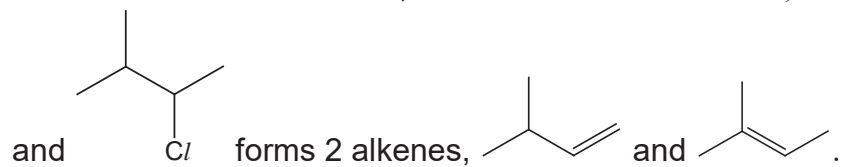
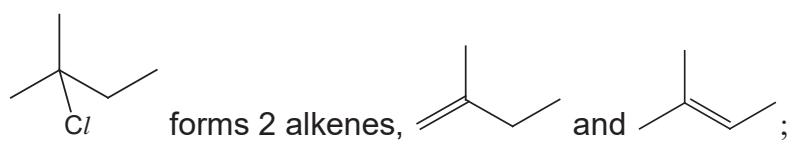
24. C Ethene undergoes mild oxidation with cold dilute KMnO<sub>4</sub> to form ethane-1,2-diol (no chiral carbon). It also undergoes oxidative cleavage with hot acidified KMnO<sub>4</sub> to form CO<sub>2</sub>.

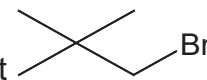


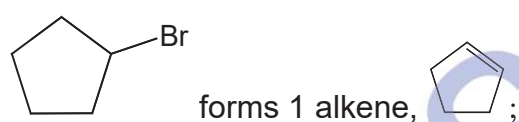
Hence choice 1 is wrong. [Note: When choice 1 is wrong, there is only one answer, C.]



25. D When the following halogenoalkanes undergo elimination with alcoholic KOH,



but  does not undergo elimination as there is no H on the adjacent carbon (the adjacent carbon is already bonded to 4 carbons).



Setter: Mrs Phee PL

Marker: Mdm Ching MY (13S60 – 13S6J); Mr Liw MH (13S6K – 13S73);

Mrs Phee PL (13S74 – 13S7J)

1 (a)

$$K_c = \frac{[\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5] [\text{H}_2\text{O}]}{[\text{CH}_3\text{CO}_2\text{H}] [\text{C}_2\text{H}_5\text{OH}]} \quad [1]$$

Most candidates have gotten the correct answer for this part. The common mistake is to leave out  $[\text{H}_2\text{O}]$ .

When writing this expression, it is important to note the state symbols stated in the chemical equation. The organic compounds are all in liquid state, suggesting that  $\text{H}_2\text{O}$  is not present in large excess. Thus,  $[\text{H}_2\text{O}]$  would not be a constant term and it is necessary to include it in the  $K_c$  expression.

(b) To provide a constant temperature since  $K_c$  is dependent on temperature. [1]

Temperature is the only factor affecting  $K_c$  and thus it is important to keep it constant for such experiment.

Quite a handful of candidates merely state that it is to keep the temperature constant which is obvious from the question – “thermostatically controlled water bath”. There is a need to elaborate why it is important to keep the temperature constant for this experiment.

(c) Water will dilute the reactants and slow down the reaction. [1]

The addition of water will greatly decrease the concentration of the reactants, which will in turn decrease the frequency of effective collisions. The rate of reaction will thus be reduced.

To gain the 1 mark, candidates need to mention both ‘the dilution of reactants’ and the ‘slowing down of the reaction’/‘frequency of effective collisions decreases’ (or words to the same effect). If you merely mention ‘to quench the reaction’, this is not accepted since you are just quoting directly from the question. Do take note that though ‘to stop the reaction’ is accepted here, the reaction does not stop entirely. The rate of reaction is so slow that the rate of reaction can be considered to be negligible.

- (d)
- Top up a burette with  $0.50 \text{ mol dm}^{-3} \text{ NaOH}$  and record the initial burette reading
  - Pipette  $25.0 \text{ cm}^3$  of solution from volumetric flask into a  $250 \text{ cm}^3$  conical flask

- Add two to three drops of bromothymol blue (or other suitable indicator)
- Titrate until the yellow solution just turns green (or other corresponding colour change) and record the final burette reading
- Repeat the titration until consistent results are obtained

[1/2 for each point]

[1/2 for “record initial and final burette readings”]

The procedure for titration is very standard. Please refer to your past practical handouts if you are still unsure of what to write for this part.

You may wish to take note of some important words in the question “volumetric analysis of FA1” and “titration procedure”. For your answer, you are only expected to describe the titration process and not the part on the preparation of FA1 solution. Neither are you expected to give details of how to process the data obtained. For those of you who describe the preparation (dilution) of FA1 solution, the markers will indicate that part as “irrelevant” and there will be a penalty for not identifying “volumetric analysis” correctly.

For the indicator to be used, as you have yet to study the topic on “Acids, Bases and Salts”, we will accept any indicator commonly used for titration. The colour change will be marked according to the indicator that you have chosen. Universal indicator should not be used for titration as the colour varies a lot and does not give a sharp colour change.  $\text{KMnO}_4$  is a strong oxidising agent, not an acid-base indicator and thus should not be used.

Since this is a titration between a weak acid (ethanoic acid) and a strong base (NaOH), the appropriate indicators to be used will be phenolphthalein, bromothymol blue or phenolphthalein (you will learn about the choice of indicators next year). It is disappointing that ‘phenolphthalein’ is often misspelled even though it is found in the question paper on Pg 11.

The markers expect the candidates to state the exact quantity of indicators used, which ideally should be 2 to 3 drops. For those have stated  $1 \text{ cm}^3$  or more, do take note that indicators are weak acids/bases themselves and may affect the titre values. So you should only add a sufficient amount of indicator that is just enough for a sharp colour change to be observed clearly.

Most candidates forgot to “take the initial burette reading” and/or to “take the final burette reading”. Some described them wrongly as “volume”. Do take note that the burette reading is not equivalent to the volume of the solution present in the burette.

- 1 (e)
- Swirl the conical flask continuously during titration.
  - Add reagent dropwise when near the end-point
  - Wash down splashes on the inner walls or neck of the conical flask using deionized water

**[2 mark for any 2 points]**

Some important words to take note of in the question are “two”, “important”, “techniques” and “titration”. Points such as “using white tile”, “taking readings at eye level” etc are not important points.

The markers were appalled by the language ability of the C1 Chemistry students. Instead of stating “swirl the conical flask”, many candidates used the words “shake” (which we accepted eventually), “swing”, “spin”, “sway” or “twirl”! Some of these actions could be hazardous when performed in the laboratory.

(f) No. of moles of HCl added = 0.005 mol

$$\text{No. of moles of HCl titrated} = 0.005 \times \frac{25}{50} \times \frac{p}{250} = 1.0 \times 10^{-5} p \text{ mol [1]}$$

$$\text{No. of moles of NaOH titrated} = \frac{q}{1000} \times 0.50 = \text{No. of moles of H}^+ \text{ present in } p \text{ cm}^3$$

No. of moles of  $\text{CH}_3\text{CH}_2\text{OH}$  present in conical flask **A**

$$= \left( \frac{0.50q}{1000} - 1.0 \times 10^{-5} p \right) \times \frac{250}{p} \times \frac{50}{25}$$

$$= \frac{q}{4p} - 0.005 \text{ mol [1]}$$

This question is generally very badly done with only a few candidates in the cohort scoring both marks.

Students need to be aware that the dilute HCl used was mixed with other reactants, then transferred to a volumetric flask for dilution. Only  $p \text{ cm}^3$  (not  $25 \text{ cm}^3$ ) of this diluted solution was withdrawn for titration.

In addition to the method shown above, there is another method which will be shown here step by step.

No. of moles of NaOH titrated

$$= \frac{q}{1000} \times 0.50 = \frac{q}{2000}$$

= Total no. of moles of  $\text{H}^+$  present in  $p \text{ cm}^3$  of FA1

= No. of moles of HCl + No. of moles of  $\text{CH}_3\text{CO}_2\text{H}$

Total no. of moles of  $\text{H}^+$  present in  $250 \text{ cm}^3$  volumetric flask

$$= \frac{q}{2000} \times \frac{250}{p} = \frac{q}{8p}$$

Total no. of moles of  $\text{H}^+$  present in conical flask A =  $\frac{q}{8p} \times \frac{50}{25} = \frac{q}{4p}$

No. of moles of  $\text{HCl}$  added =  $\frac{5}{1000} \times 1 = 0.005$

No. of moles of  $\text{CH}_3\text{CO}_2\text{H}$  present in conical flask A =  $\frac{q}{4p} - 0.005$



Setter: Mrs Jacqueline Tano

Marker: Mrs Jacqueline Tano (13S60 – 13S74); Mr Low KS (13S75 – 13S7J)

- 2 (a) (i) Low temperature should be used as it will favour the forward exothermic reaction / generate additional heat. [1]

High pressure should be used as it will favour the forward reaction which has a decrease in amount / no. of moles of gas molecules. [1]

Students should explain qualitatively i.e. give descriptions of the temperature and pressure based on Le Chatelier's principle. Clear explanations should make reference to the mole ratio in the equilibrium equation (from 4 moles of gas to 2 moles of gas) and the enthalpy change data given (exothermic).

- (ii) The temperature cannot be too low that the reaction will be too slow and hence uneconomical. [1]

The pressure cannot be too high that the cost of maintenance of the equipment becomes too high and hence uneconomical. [1]

Students should focus on the economical consideration that industries would have and give clear reasoning for each condition i.e. temperature and pressure respectively.

- (iii)  $\Delta S$  is negative as there is a decrease in the amount / number of gas molecules in the system and hence a decrease in the number of ways particles can distribute / disperse / spread out their energy. [1]

Students should make reference to the decrease in the number of moles of gas and also link directly to the definition of entropy i.e. the number of ways the energy can be dispersed through the motion of its particles.

- (iv)  $\Delta G^\ominus = (-92.4) - (298)(-0.198) = -33400 \text{ J mol}^{-1}$  [1]

$$-33400 = -(8.31)(298) \ln K$$

$$K = \underline{7.20 \times 10^5}$$
 [1] (ignore any units written)

The very large numerical value means that the reaction would be effectively complete. [1] (ecf allowed)

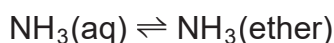
Students should ensure consistency in units when substituting into the equation. Please note the units for R ( $\text{J K}^{-1} \text{ mol}^{-1}$ ), hence it may be better to keep all calculations consistent in  $\text{J mol}^{-1}$  for this question.



$K$  is an equilibrium constant and its magnitude is a useful indication of the **position of equilibrium**. The very large value is not simply because 'the equilibrium position lies towards the right' or 'yield is very high' or 'equilibrium composition consists of largely products', but that 'the reaction would be effectively complete'. Answers should not contain irrelevant material with reference to the relative rates of the forward and backward reactions.

For wrong answer of  $K$  to be about 1, students should indicate that significant quantities of both reactants and products would be present **at equilibrium**.

- 2 (b) Let  $x$  be the amount of ammonia extracted/separated into ether.



Eqm / mol            0.10 –  $x$              $x$

$$K_D = \frac{\left(\frac{x}{0.070}\right)}{\left(\frac{0.10 - x}{0.120}\right)} = 8.0 \quad [1]$$

$$x = \underline{\underline{0.0824 \text{ mol}}} \quad [1]$$

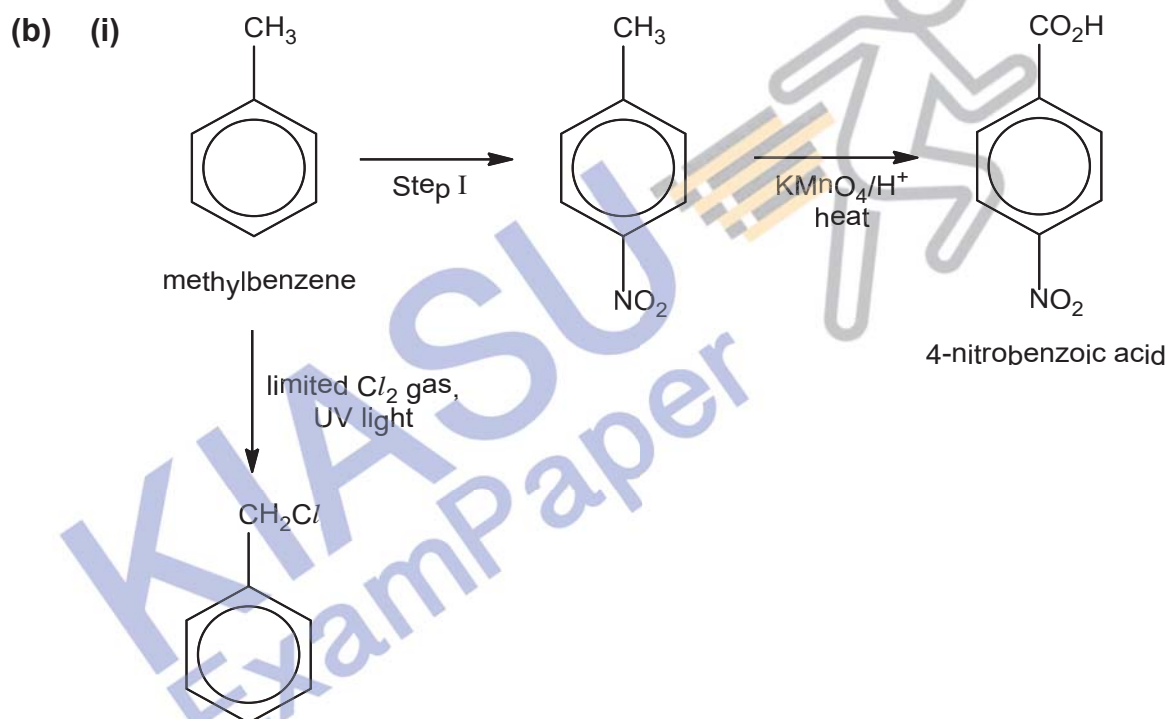
Students should realise that amount refers to the number of moles. Please note that ether and water are two immiscible solvent, hence we are looking at two layers with different volumes to consider when substituting into the  $K_D$  expression. Students must remember to substitute in the no. of moles at equilibrium and not the initial amount.

Setter: Mrs Tay SA  
Marker: Mrs Tay SA (13S60 – 13S7J)

- 3 (a)  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$  [1]  
*Reject noble gas configuration*

Many candidates incorrectly gave  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$  as the answer. The electronic configuration for Mn is  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$ . To form  $Mn^{2+}$ , 2 electrons will be removed starting from the highest energy (outermost) subshell (once the 3d orbitals are occupied by electrons, the 4s orbital is repelled to a slightly higher energy level).

At A-levels, configurations of the form of 2.8.8.5 are not accepted. The noble gas configuration cannot be used unless specified by the question.



[1] correct structure of X

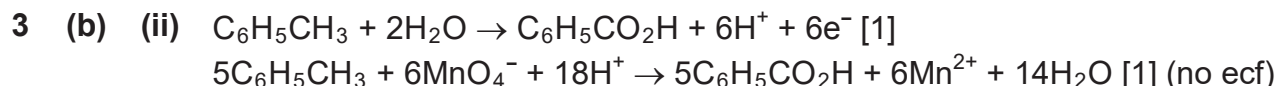
[1] correct structure of Y

[1] step I: concentrated  $HNO_3$ , concentrated  $H_2SO_4$ ,  $30^\circ C$

Many candidates incorrectly stated the temperature for nitration as  $55^\circ C$  or merely heat. The temperature used for the nitration of methylbenzene in Step I is  $30^\circ C$  (as opposed to  $55^\circ C$  in the nitration of benzene) because methylbenzene is more reactive than benzene. The methyl group activates the ring towards electrophilic substitution by releasing electron density into the benzene ring which becomes more electron rich and hence more prone to attack by electrophiles. Concentrated  $HNO_3$  and concentrated  $H_2SO_4$  should be used instead of  $HNO_3(aq)$  and  $H_2SO_4(aq)$ .



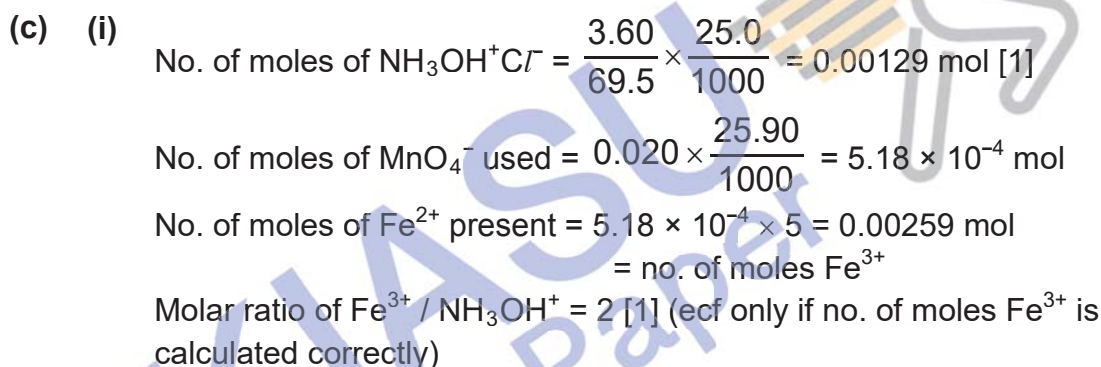
When drawing the structures of X and Y, the bond from the benzene ring must be bonded to the C atom of the side chains.



When writing a **balanced half-equation**, the equation has to be balanced by  $\text{H}^+$  (since the question mentioned acidified potassium manganate(VII)) and  $\text{e}^-$ . The [O] method is not accepted.

The half-equation for the reduction of  $\text{MnO}_4^-$  in acidic condition is given in the question itself but some candidates tried to write a half-equation for the reduction of  $\text{MnO}_4^-$  to  $\text{MnO}_2$  in alkaline condition, which is incorrect as the question stated that acidified potassium manganate(VII) is used.

$\text{C}_6\text{H}_5\text{CH}_3$  and  $\text{C}_6\text{H}_5\text{CO}_2\text{H}$  cannot be written as merely  $\text{CH}_3$  and  $\text{CO}_2\text{H}$  respectively.



There are 2 redox reactions: the first one between  $\text{NH}_3\text{OH}^+\text{Cl}^-$  and  $\text{Fe}^{3+}$  and the second between  $\text{Fe}^{2+}$  (formed during the first redox reaction) and  $\text{MnO}_4^-$ .

When calculating the number of moles of  $\text{NH}_3\text{OH}^+$ , many candidates incorrectly used the  $M_r$  of  $\text{NH}_3\text{OH}^+$ . The  $M_r$  of  $\text{NH}_3\text{OH}^+\text{Cl}^-$  should be used as the mass given (3.60g) is the mass of  $\text{NH}_3\text{OH}^+\text{Cl}^-$ . One can subsequently find the number of moles of  $\text{NH}_3\text{OH}^+$  as 1 mol of  $\text{NH}_3\text{OH}^+\text{Cl}^-$  gives 1 mol of  $\text{NH}_3\text{OH}^+$ .

- 3 (c) (ii) Oxidation number of N in  $\text{NH}_3\text{OH}^+ = -1$   
Oxidation number of N in the product =  $-1 + 2 = +1$  [1] (ecf only if oxidation number of N in  $\text{NH}_3\text{OH}^+ = -1$  is calculated correctly)

To "determine" the oxidation number of N, working must be shown.

In the reaction between  $\text{NH}_3\text{OH}^+\text{Cl}^-$  and  $\text{Fe}^{3+}$ ,  $\text{Fe}^{3+}$  is reduced and thus, N should be oxidised (oxidation number of N should increase). 1 mol of  $\text{Fe}^{3+}$  gains 1 mol  $\text{e}^-$ . 2 mol of  $\text{Fe}^{3+}$  react with 1 mol of  $\text{NH}_3\text{OH}^+$ , thus 1 mol of  $\text{NH}_3\text{OH}^+$  loses 2 mol of  $\text{e}^-$ , causing an **increase** in the oxidation number of N.

Many candidates wrongly assumed that the oxidation number of N in  $\text{NH}_3\text{OH}^+$  is  $-3$  and hence deduced the oxidation number of N in the product incorrectly.

KIASU  
ExamPaper

Setter: Mrs Lim SF

Marker: Mr Sam Lee (13S60 – 13S6Q); Mrs Lim SF (13S6T – 13S77);

Mr Lee GH (13S78 – 13S7J)

- 4 (a) (i) 2-chlorobutane, 2-bromobutane, 2-iodobutane [1]: *correct trend*

Increase in size of electron cloud, hence stronger dispersion / van der Waals forces [1]: *correct type of intermolecular force, and why it becomes stronger*

More energy required to break the intermolecular forces [1]: *correct link between energy required to overcome intermolecular force and proposed boiling point trend*

For polar molecules which have large electron cloud size, it is likely that the main type of intermolecular force is dispersion forces rather than permanent dipole-permanent dipole (pd-pd) interactions. In this question, although pd-pd interactions are present for the 2-halobutane compounds, the main intermolecular force is actually dispersion forces. The proposed boiling point trend should hence be based on the variation in strength of dispersion forces rather than pd-pd interactions.

A number of students wrongly correlated the boiling point trend to the energy needed to break the C-X bond. Do remember that for simple covalent molecules, only the intermolecular forces are broken during boiling; the covalent bonds remain intact and cannot be broken. Otherwise, a chemical reaction would have taken place and the halobutane compounds would have been converted to other compounds.

- (ii) Bimolecular nucleophilic substitution  
OR Nucleophilic substitution ( $S_N2$ ) [1]

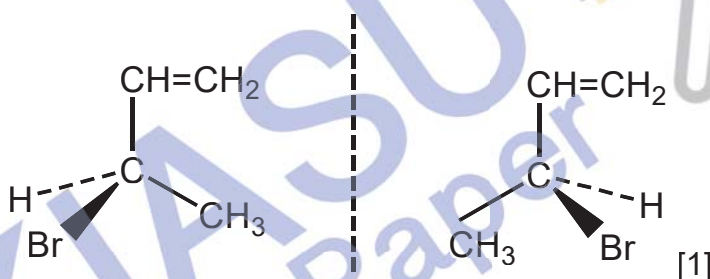
Most students were able to correctly identify the type of reaction as a nucleophilic substitution reaction since the halogen atom in the alkyl halide will be substituted by the electron-rich  $\text{OH}^-$  (nucleophile). However, as the question asked for the *mechanism* of this reaction, students were expected to make a distinction between an  $S_N1$  and  $S_N2$  mechanism. In general, for an  $S_N1$  mechanism, it would be impossible to obtain a product that is optically active (question states that product is able to rotate plane-polarised light) since the planar carbocation would have allowed the nucleophile to attack from either the top or bottom of the plane. A racemic mixture would hence be obtained if a chiral molecule has undergone an  $S_N1$  mechanism.

- 4 (a) (iii) Bond energy(C-Cl):  $340 \text{ kJ mol}^{-1}$ ; Bond energy (C-Br):  $280 \text{ kJ mol}^{-1}$ ; Bond energy (C-I):  $240 \text{ kJ mol}^{-1}$  [1]: *quote bond energy of all three C-X bonds*

Least energy needed to break the C-I bond, hence reaction is fastest for 2-iodobutane. [1]

When candidates are asked to quote relevant data from the *Data Booklet*, they should do so as this will support the explanation in their answers. Here, students are expected to be able to interpret the different reactivities of halogenoalkanes with particular reference to hydrolysis and to the relative strengths of the C-halogen bonds (Topic 12, LO(c)). Hence, the bond energy data for all three types of C-X bonds should have been quoted, and not just the C-I bond. Students should note the phrasing of their answers when quoting the bond energy data as well; these values should be referred as the *bond energy* with the corresponding units stated and not "C-Cl = 340", for instance.

- (b) (i) Optical isomerism [1]

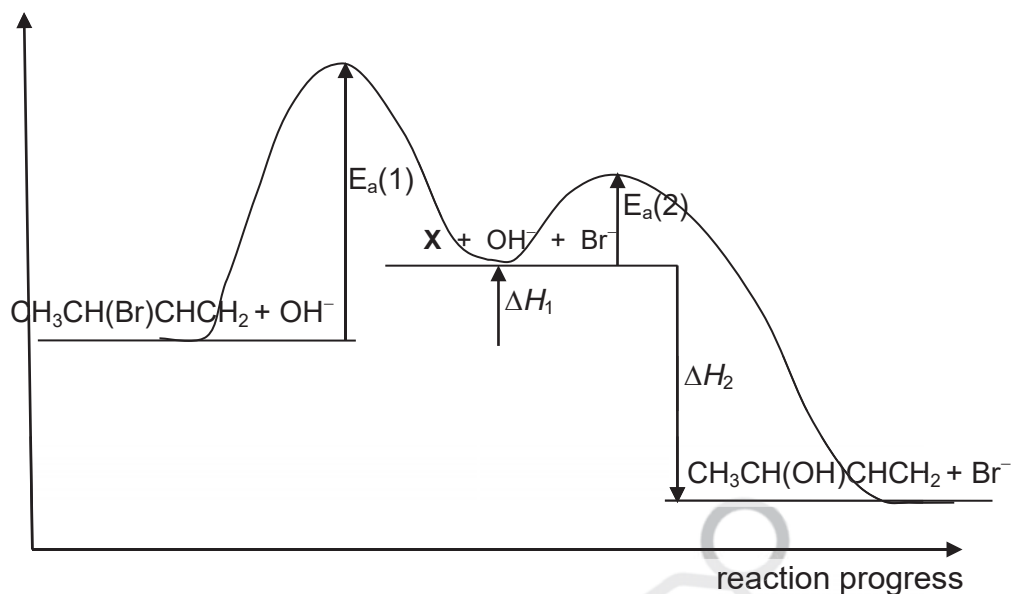


When drawing a pair of optical isomers, students should indicate the three-dimensional structures according to the convention shown in their syllabus (refer to pg 20 of syllabus document on Moodle). Students should also take note of their representations of the structural formula of the R groups, especially when writing them on the left of the chiral carbon ( $C^*$ ). The following are **incorrect** and penalised as a result:

- $\text{CHCH}_2\text{-C}^*$  ( $C^*$  is not bonded to  $\text{CH}_2$  otherwise C in  $\text{CH}_2$  has 5 bonds)
- $\text{H}_2\text{CHC-C}^*$  or  $\text{H}_2\text{C=HC-C}^*$  (reversed formulae)
- $\text{C}^*\text{-C}_2\text{H}_3$  (unclear which atom is bonded to  $C^*$ , structure of  $\text{C}_2\text{H}_3$  is unclear too)

In general, atoms which are joined to carbon atoms in the chain should be drawn after the carbon atom to which they are connected, e.g.  $\text{CH}_2\text{CH-C}^*$ .

4 (b) (ii) Energy/kJ mol<sup>-1</sup>



[1] Correct shape (2 humps) and relative energy levels of intermediate (higher than reactants) and products (lower than intermediate). No penalty if overall endothermic reaction.

[1]  $E_a(1) > E_a(2)$

[1] Correct axes, labels of species (accept if not balanced), and indication of  $E_a$  and  $\Delta H$  for each step. Penalise  $\frac{1}{2}m$  if anything wrong or missing.

In this question, students were asked to "indicate the activation energies, species involved and the enthalpy changes for each step of the reaction" in the diagram.

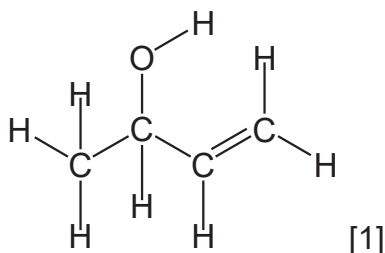
Mark point 1: The energy profile diagram should reflect a two-step reaction that is consistent with the mechanism given in the question. Step 1 is an endothermic process since the C-Br bond is broken (hence the intermediate is at a higher energy level than the reactants), while step 2 is an exothermic process since the C-O bond is formed (products are hence at a lower energy level than intermediate). Comparison of the bond energies of the C-Br and C-O bond should enable students to deduce that the overall reaction is exothermic, though this was not a marking point in this question.

Mark point 2: The activation energy ( $E_a$ ) for each step in a reaction mechanism is correlated to the rate of that step. Since step 1 is the slow step, the energy profile diagram should show a larger  $E_a$  for step 1 compared to step 2.

Mark point 3: When indicating the  $E_a$  and  $\Delta H$  for each step of the reaction, it is crucial that the arrows represent the correct direction (only single-headed arrows allowed for  $\Delta H$ ) and magnitude of energy change. Several students were confused and showed the  $E_a$  and  $\Delta H$  for the reverse reactions instead. Students are advised to refer to Physical Chem (I)

lecture notes pg 82 – 83 if they need more details regarding the energy profile diagram.

4 (c) (i)

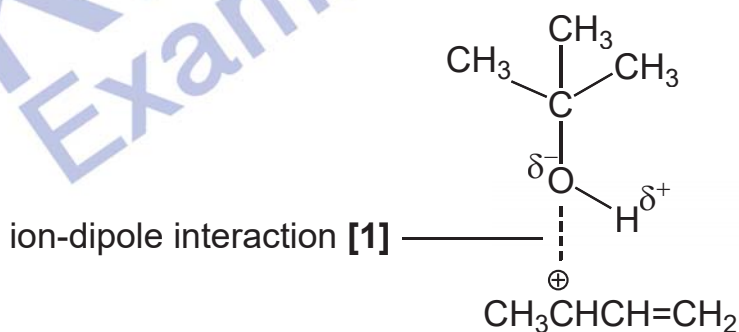


Based on the overall balanced equation, compound **A** must have the molecular formula  $C_4H_8O$ . Students were also told that compound **A** was formed via the intermediate,  $CH_3CH^+CH=CH_2$ . This suggests that an  $S_N1$  mechanism similar to that shown in (b) may have taken place when 3-bromobut-1-ene was reacted with water. Step 2 of the mechanism would however involve  $H_2O$  acting as the nucleophile to generate another intermediate with a positively charged oxygen. Compound **A** is formed after one of the O-H bonds is broken as shown below:



Students are reminded that all covalent bonds must be shown when a displayed formula is required.

(ii)



[1]: correct diagram (a pair of dipoles in  $(CH_3)_3COH$ , positive charge indicated on intermediate **X**, interaction shown with dotted line)

Students were asked for a diagram showing how  $(CH_3)_3COH$  can be attracted to **X**, as well as the type of interaction involved. Hence, the answer must illustrate the type of intermolecular force of attraction between the two species. Most students however misinterpreted the question by



drawing a reaction mechanism (as shown by curly arrow from lone pair on O to positively charged C in intermediate **X**) when the question did not actually ask how the two species will react with one another.

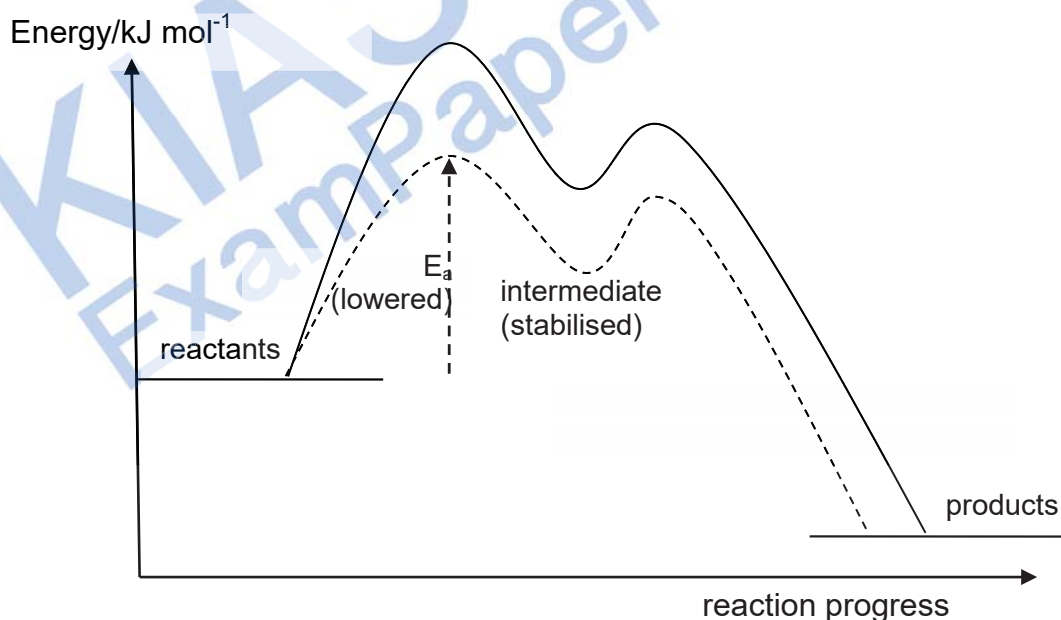
- 4 (c) (iii) As the solvent polarity increases, reaction rate increases (or v.v.) [1]

This is due to stronger / more extensive ion-dipole interactions formed [ $\frac{1}{2}$ ] which aids in stabilising intermediate X to a greater extent [ $\frac{1}{2}$ ].

The activation energy for the rate-determining step is thus lowered and the reaction occurs faster when a more polar solvent is used.

Students were first asked to describe the effect of solvent polarity on the rate of reaction. A description of how the reaction rate changes with solvent polarity is hence required.

This was to be followed by an explanation that is based on the answer to (c)(ii). The answer should hence comment on how solvent polarity affects the strength or extensiveness of the interaction formed between the solvent and intermediate **X**, as well as the stability of **X**. As shown by the energy profile diagram below, when a reaction intermediate is stabilised, the activation energy of the rate-determining step will be lowered, hence the overall rate of reaction will be increased.



Do note that the reaction equation showed H<sub>2</sub>O as the reactant, hence CH<sub>3</sub>COCH<sub>3</sub> and (CH<sub>3</sub>)<sub>3</sub>COH are acting mainly as solvents in the second and third experiment. A discussion on the reaction between intermediate **X** and CH<sub>3</sub>COCH<sub>3</sub> or (CH<sub>3</sub>)<sub>3</sub>COH would hence be irrelevant for this question.

Setter: Mr Li JX

Marker: Mr Loy HC (13S60 – 13S6E); Mr Li JX (13S6F – 13S6P; 13S7B – 13S7J);

Mdm Lau PC (13S6Q – 13S7A)

- 1 (a) [1] Excessive CO<sub>2</sub> contributes to global warming OR ENHANCED greenhouse effect (reject “CO<sub>2</sub> is a greenhouse gas” as this does not give the consequence)

Acid rain and chemical smog are not effects of excessive CO<sub>2</sub> and neither is CO<sub>2</sub> considered a hazardous/toxic gas.

(b) (i) [1]  $K_p = \frac{P_{CH_4} (P_{H_2O})^2}{P_{CO_2} (P_{H_2})^4}$

[1] atm<sup>-2</sup>

Ecf (for units) given only if partial pressure is used but powers are wrong.

Accept Pa<sup>-2</sup> if atm<sup>-2</sup> is used in (b)(ii) or if student performs unit conversion in next part.

Award mark if units shown in (b)(ii) but not here

Common mistakes include using square brackets (which represents concentration) instead of partial pressure term.

Students need to answer to the context of the question. Pascal is correct when applied to a general expression but atm is the unit used in this question so it is the preferred answer.

(ii)  $P_{H_2O} = 30 \text{ atm}$

$P_{CH_4} = 15 \text{ atm}$

$P_{H_2} = 40 \text{ atm}$

$P_{CO_2} = 11 \text{ atm}$

[1]  $K_p = \frac{15 \cdot 30^2}{11 \cdot 40^4} = 4.79 \times 10^{-4} \text{ atm}^{-2}$

[1]  $K_p = 4.79 \times 10^{-4} \text{ atm}^{-2}$  OR  $4.67 \times 10^{-14} \text{ Pa}^{-2}$  (based on conversion factor of 1atm = 101325 Pa) OR  $2.64 \times 10^{-13} \text{ Pa}^{-2}$  (based on conversion factor of 1atm = 101000 Pa)

Ecf from previous part.

No penalty if units were already given previously but missing here.

Penalise ½ if units were previously correct but wrong in this part.

Unit conversion from atm to Pa was not required in this question but accepted nevertheless. Students are also advised to answer to the context to the question and not blindly regurgitate units from memory.

Many students also wrong used square brackets. Square brackets are used to indicate concentration, not pressure.



1 (b) (iii) [1]

380 °C, Partial pressure of methane is the maximum at this temperature. Hence amount/yield of methane produced is maximised. *(If this reason was given, 380 °C is the only accepted value.)*

OR

450°C, The amount of methane produced is about the same/ only slightly less but much faster production of methane is afforded at higher temperature.

The most common error made is the assumption that highest  $K_p$  is equivalent to the optimal condition. Whilst the highest  $K_p$  gives greatest yield when considering all products in general for the system, it may not give the greatest yield of the product of interest, which is methane in this case.

(iv) Accepted values for partial pressure of each gas in the system:

$$P_{\text{H}_2\text{O}} = 48 - 49 \text{ atm}$$

$$P_{\text{CH}_4} = 26 - 27 \text{ atm}$$

$$P_{\text{H}_2} = 14 \text{ atm}$$

$$P_{\text{CO}_2} = 5 \text{ atm}$$

$$\text{Total Pressure (380 °C)} = 93 - 95 \text{ atm}$$

Ecf allowed based on part (b)(iii)

Total pressure = sum of partial pressure of each gas in the system.

[1]: correctly reads partial pressure off the graph and correct calculation of final answer.

Most students were able to recognise this question as an application of Dalton's law of partial pressure where the total pressure of the system equals to the sum of the partial pressures of each constituent gas.

(v) [1] Negligible intermolecular forces OR Volume of gas particles is negligible compared to volume of the container OR Perfectly elastic collisions between gas particles. *(Student will lose 2<sup>nd</sup> mark if this assumption is given unless they can explain which molecule has the least elastic collision)*

[1] *(Answer has to follow previous assumption stated)*  $\text{H}_2\text{O}$  will deviate the most from ideal gas behaviour due to strong hydrogen bonding between water vapor molecules. *(If pd-pd interaction mentioned without hydrogen bonding for  $\text{H}_2\text{O}$ , award  $\frac{1}{2}$  only)* OR  $\text{CO}_2$  as it is the largest molecule (or has the largest electron cloud), hence it has the most significant molecular size.

Some students still do not realise hydrogen bonds are intermolecular forces, confusing it with O–H covalent bonds.

Some students also consider permanent dipole – permanent dipole interactions as a separate intermolecular force from hydrogen bonding, indicating they do not fully understand hydrogen bonding as the strongest type of permanent dipole – permanent dipole interactions.

Some students did not link the gas identified to the previous stated assumption as required by the question. Even though their answers are correct conceptually, no marks were awarded. Please read the question carefully.

- 1 (b) (vi) [1] Significant attractive intermolecular forces between gas particles attracts the particles together

[1] This leads to the gas particles to strike the wall with less impact/force/frequency, leading to lower pressure.

Some students attempted to reason that the attraction or repulsion between gaseous particles would lead to inelastic collisions, hence causing energy to be lost. However, attractive/repulsive forces do not necessarily prevent elastic collisions from occurring. Kinetic energy can be conserved even if the particles are attracting or repelling one another.

An alternative explanation for the loss of energy of the particles can be the consideration that molecules are not rigid spheres; the bonds can rotate/compress/scissor during collisions, hence causing energy to be lost.

- (c) (i) Describes [0.5] adsorption before and [0.5] desorption processes after the reaction

[1] Reaction is sped up by either increase of local/surface concentration of reactants. (If no mention of concentration on surface, only award ½)

OR

bonds within the reactants are weakened hence lowering the activation energy

OR

the catalyst brings the reactants together in the correct orientation

*Accept answers in diagram form or use of diagrams as aid.*

Many students seem to have the misconception that adsorption includes the migration and reaction processes in heterogeneous catalysis. Adsorption

simply refers to the adhesion of reactants onto the surface of the catalyst.

A number of students also misspelled or did not realise the spelling of adsorption is different from absorption. The 2 words have different meanings and are not interchangeable.

- 1 (c) (ii) [1] Porous support leads to increased surface area/ more active/catalytic/reaction sites, and hence a faster rate of reaction.  
(If student mentions increase efficiency of catalyst without mention of increased surface area, award ½ only)

In this question, students were expected to be able to relate the effect of surface area to the rate of reaction. Please refer to your Physical Chem (I) lecture notes pg 87 and 95 for more details.

- (d) (i) [1] *uv* light OR sunlight OR heat

Students are expected to be able to describe the chemistry of alkanes as exemplified by their substitution reaction with chlorine or bromine.

- (ii) [1] Stating "Free Radical Substitution" as name of mechanism

[2] Correct Initiation, Propagation and Termination steps.

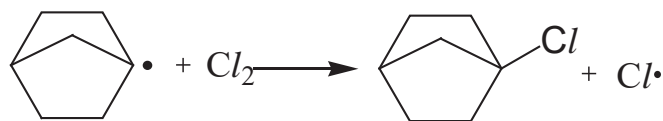
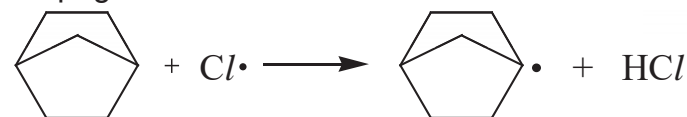
–0.5m for each minor mistake.

For labelling of steps, missing one or two labels –0.5m, if all labels missing, –1m.

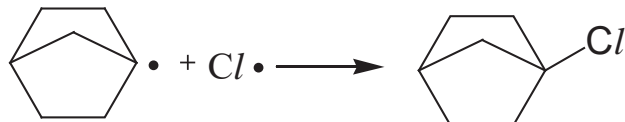
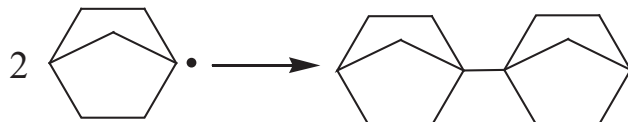
Initiation



Propagation

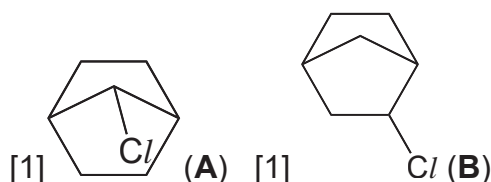


Termination

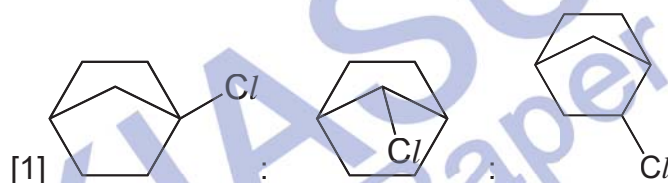


The most common mistake made by students was confusing the ring with a benzene ring and stated electrophilic substitution as the mechanism. Students are advised to learn to recognize the structure of benzene and understand how it differs structurally from other ring compounds.

1 (d) (iii)



If more than 2 structures are drawn, -1 for repeated structures of each answer.

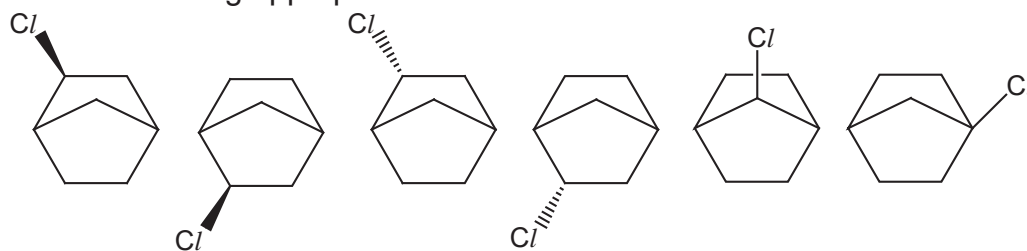


= 2:2:8 OR 1:1:4

Ecf is allowed but must be correctly stated.

Question is only looking for structural isomers of monochlorinated norbornane although 2 pairs of optical isomers exist for structural isomer (B).

Answers considering stereoisomerism is accepted only if all 4 stereoisomers are shown using appropriate 3D notations. i.e.



Ratio = 2:2:2:2:2:2

### General Comments

Students are reminded of use of good English and legible handwriting.  
Markers will not attempt to interpret illegible answers.

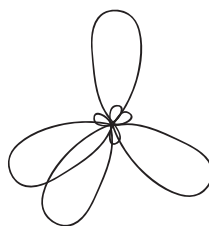
Students are advised not to attempt to spam answers in hopes of getting the correct one. If the answer contains both correct and wrong items, it is still considered wrong.



Setter: Mr Lim JY

Marker: Ms Ella Sze (13S60 – 13S74); Mr Lim JY (13S75 – 13S7J)

2 (a) (i)



[1] *no marks if small lobes not shown.*

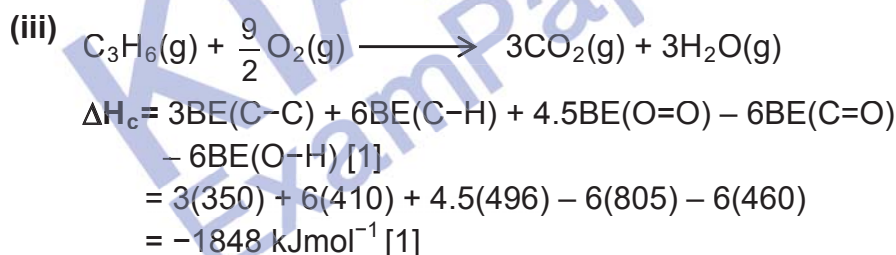
The three carbons in cyclopropane are  $sp^3$  hybridised, as each carbon atom distinctively has four bond pairs around it.

Most candidates did well for this question.

(ii)  $60^\circ$ . [1]

The carbon backbone of the cyclopropane ring is planar and obviously takes on the shape of an equilateral triangle since all the C–C bond lengths must be the same. The angle indicated must therefore be  $60^\circ$ .

A number of candidates stated the angle as  $120^\circ$ , which is illogical. The angle shown is obviously an acute angle. Some candidates are unable to see that although the shape about the carbon atom is tetrahedral, the angle  $\alpha$  cannot be  $109.5^\circ$  given the constraints of the shape of the molecule.

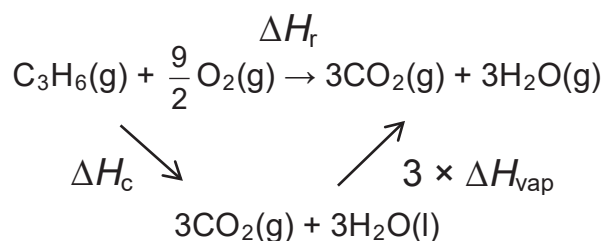


The solution to the above can be easily obtained by considering the breaking of all the bonds in the reactants and forming of all the bonds in the products. Please refer to your **Physical chemistry (I)** lecture notes booklet, **Chapter 5, topic 5** under bond enthalpy (pages 18 – 21), for more details.

Many candidates were careless in reading the question. Clearly it was stated that the bond energy of C=O is to be taken as  $805 \text{ kJ mol}^{-1}$  for this question. Instead, the value obtained from the data booklet was used. Some candidates were also mixed up with the fact that bond breaking is endothermic and bond forming is exothermic.



2 (a) (iv)



[1]: Correctly drawn energy cycle

By Hess's Law,

$$\Delta H_r = \Delta H_c + (3 \times 40.7) \quad [1]$$

$$\Delta H_c = -1848 - 122.1 = -1970 \text{ kJ mol}^{-1} \quad [1]$$

The enthalpy change of vapourisation of water is defined for the vapourisation of 1 mole of liquid water. Hence for 3 moles of water formed, there is a need to multiply by 3.

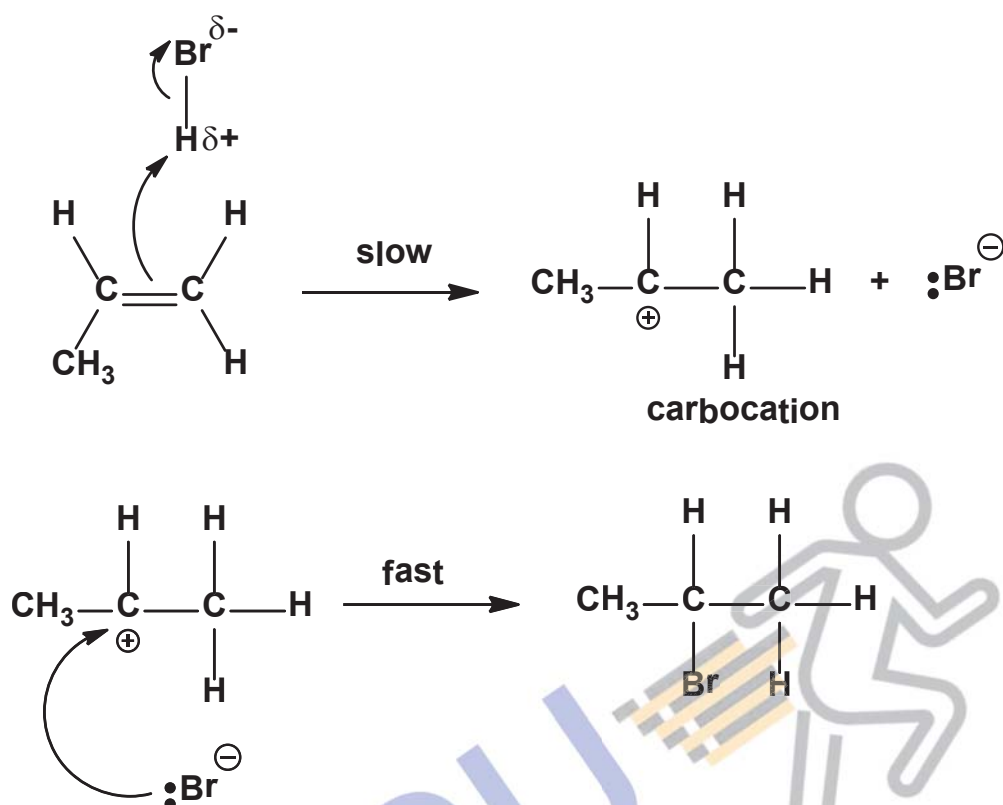
Quite a number of candidates failed to realise that 3 moles of water were vapourised according to the energy cycle that was drawn. Thus, they did not multiply the  $\Delta H_{\text{vap}}$  by a factor of 3. A few candidates drew an energy level diagram instead of an energy cycle. Some candidates are still unsure of the use of Hess's Law and are advised to quickly rectify this problem.

- (v) The bond angle of  $60^\circ$  is much smaller than the bond angle of  $109.5^\circ$  between  $\text{sp}^3$  hybridised orbitals, resulting in weakening of the C-C bonds in cyclopropane due to poorer orbital overlap/ high angle strain. [1]

In a cyclopropane ring, the bond angles are forced to be much smaller than they ought to be. This is known as angle strain. As a result of this, the overlap between the  $\text{sp}^3$  orbitals is less efficient as they are misaligned and cannot overlap fully head-on.

A number of students did not answer the question with reference to their answers in (a)(i) and (a)(ii), which was to explicitly compare the discrepancy in the bond angles, and hence could not gain the credit by just stating that poorer orbital overlap caused the bond strength to be weakened. Some candidates recognised that the bond pairs are brought closer due to the smaller angle, which will increase repulsion and destabilise the structure of the molecule, leading to a weakening of bonds, which was an acceptable answer as well if they explained it comprehensively.

2 (b) Electrophilic addition



[1] for name

[1] for first step (-1/2 for every mistake, max -1 mark)

[1] for second step (-1/2 for every mistake, max -1 mark)

The exact same mechanism is found in your **Organic chemistry (I)** lecture notes booklet, **Chapter 10, subtopic 4.1**, under Electrophilic addition of hydrogen halides (page 76). You shouldn't be getting this wrong.

Quite a number of candidates did not show the arrows originating from the correct bond/atom and ending on the correct bond/atom. Candidates should note that the arrow pushing should not end on the positive charge of the carbocation, but on the carbon atom as it is the carbon atom that is forming the bond with bromine. A number of candidates also lost marks by drawing the more unstable carbocation (leading to the minor product instead) or missing out the stating of the slow step. More disappointing perhaps, was the omission of the writing of the name of the mechanism despite countless reminders by both lecturers and tutors.

(c) (i)  $n = 8 - (12/2) + 1 = 3$  [1]

This was generally well done.

(ii) Oxidative cleavage [1]



The hydrocarbon **X**,  $C_8H_{12}$ , has been cleaved into two, forming compound **Y**, with 4 carbons. This must have been an oxidative cleavage. Another clue would be that compound **X** probably is a symmetrical hydrocarbon to give only one product.

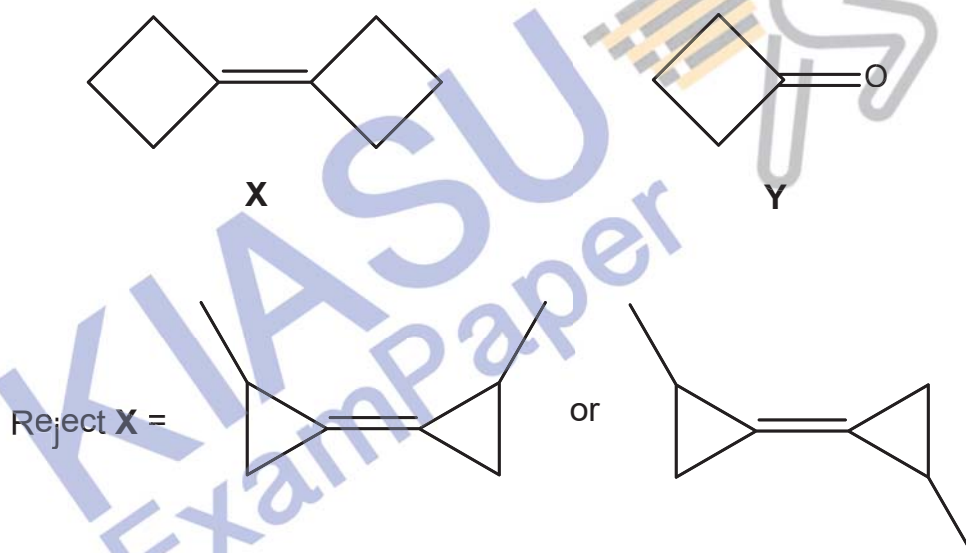
Candidates generally did well in this question.

2 (c) (iii) Ketone [1]

With only one oxygen atom on compound **Y**, it is impossible for the functional group present to be a carboxylic acid group, which so many students wrote! The oxidative cleavage can only produce a ketone here.

“Carbonyl” is a common answer written by candidates which was not accepted, because this group comprises ketones and aldehydes.

(iv)



[1] mark for each correct structure

The formula given in the question was intended to help candidates deduce that **X** has a total of 3 pi bonds or rings. Since there was an oxidative cleavage that took place and nicely cleaved **X** into two identical fragments of 4 carbons, **X** must have only contained one pi bond, which means that it contains two rings. It is not difficult from there to put the information together to find the structures of **X** and **Y**.

Quite a number of candidates managed to get the structure of both compounds correctly.

2 (d) (i)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\begin{aligned}\text{Volume of hydrocarbon combusted} &= \frac{40 \times (130 + 273)}{(25 + 273)} \\ &= 54.1 \text{ cm}^3 [1]\end{aligned}$$

This is a simple use of the ideal gas law.

Some candidates did not get the answer because they did not convert the units of temperature to Kelvin.

(ii) 271 cm<sup>3</sup> [1]

This was generally well done. Do remember that anhydrous calcium chloride is often used as a drying agent to remove water. Other common drying agents include anhydrous sodium sulfate, anhydrous calcium sulfate and anhydrous magnesium sulfate.

(iii) Volume of CO<sub>2</sub> formed = 216 cm<sup>3</sup>

$$\frac{n_{C_xH_y}}{n_{CO_2}} = \frac{1}{x} = \frac{54.1}{216}$$

$$x = 4 [1]$$

$$\frac{n_{C_xH_y}}{n_{H_2O}} = \frac{1}{y/2} = \frac{54.1}{271}$$

$$y = 10 [1]$$

The hydrocarbon is C<sub>4</sub>H<sub>10</sub>. ( $-\frac{1}{2}$  if student calculates  $x$  and  $y$  correctly but molecular formula is not written out explicitly)

(Alternative method to determine  $y$ ):

$$\text{Volume of O}_2 \text{ reacted} = 400 - 48.4 = 351.6 \text{ cm}^3$$

$$\frac{n_{C_xH_y}}{n_{O_2}} = \frac{1}{4 + \frac{y}{4}} = \frac{54.1}{351.6}$$

$$y = 10$$

Students should understand that the mole ratio of gases corresponds to the volume ratio as well. The values of  $x$  and  $y$  can be determined by comparing the volume ratio of  $\text{CO}_2$  and  $\text{H}_2\text{O(g)}$  to that of the hydrocarbon.

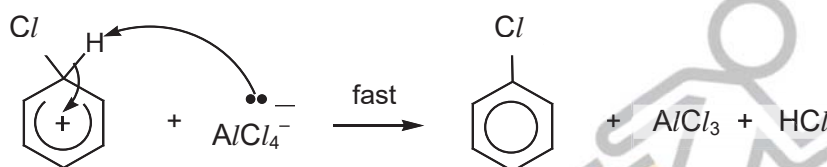
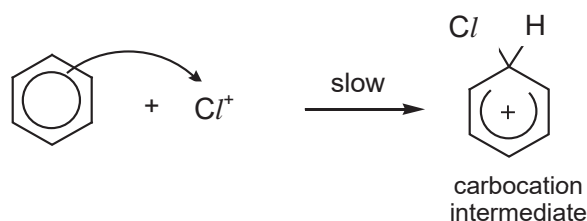
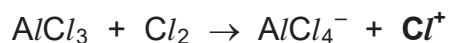
It was not enough to conclude that the hydrocarbon is  $\text{C}_4\text{H}_{10}$ , by comparing the ratio of carbon dioxide to steam without any comparison to the hydrocarbon  $\text{C}_x\text{H}_y$ . Candidates who did this might still be able to get a ratio of  $x:y$  to be 2:5. However, they had to explicitly state that the only possible hydrocarbon which could exist with a ratio of  $x:y$  to be 2:5 is  $\text{C}_4\text{H}_{10}$  as  $\text{C}_2\text{H}_5$  is not a possible structure and  $\text{C}_8\text{H}_{20}$ , or any other hydrocarbon with more carbons than 8, do not exist as well. Candidates also need to take note of their time management. Some students did not manage to attempt part **(d)** of question 2 as they could not finish the paper.



Setter: Ms Wong HM

Marker: Ms Wong HM (13S60 – 13S66; 13S7A – 13S7J), Mr Loo KH (13S67 – 13S6G), Mrs Lee CK (13S6H – 13S79)

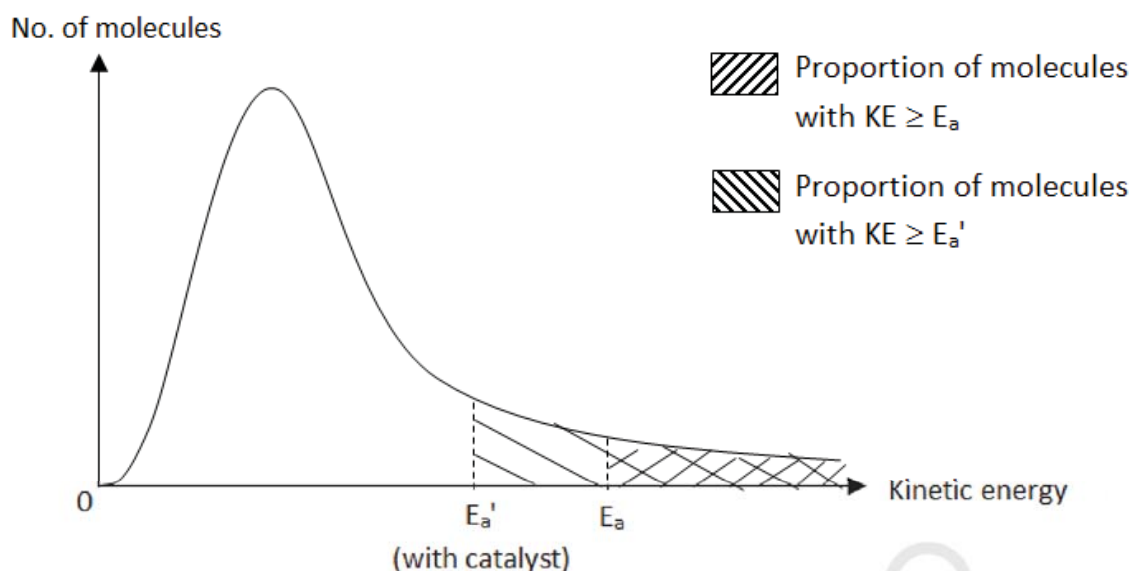
3 (a) Name: **Electrophilic substitution** [1]



[2] for 3 steps; any mistakes minus  $\frac{1}{2}$

This is a knowledge type of question which requires the candidates to recall the mechanism that arenes undergo (refer to notes). When asked to 'describe' the mechanism, do include the name of the mechanism (not generic type of reaction such as halogenation). You are only required to provide the equations on how the reaction took place. No marks are awarded for a written description of the process. Any missing arrows from step 2 and 3 will be penalised. It is important to show the direction of the arrows accurately as they symbolize the movement of electrons in the reaction. Some candidates forget that the arrows must be drawn starting from a bond (e.g. the C–H bond in step 3) or from a lone pair (drawn on chlorine of  $\text{AlCl}_4^-$ ). It is also important to note the slow/fast step.

3 (b) (i)



Axes + Shape of curve: non-symmetrical curve, broader and more spread out to the right of the maximum [1] (If legend not given, explanation should make reference to the difference in proportion of molecules with energy  $\geq E_a$ .)

- $E_a$  is too near the peak [ $-\frac{1}{2}$ ]
- Curve touching x-axis [ $-\frac{1}{2}$ ]

Catalyst provides an alternative reaction pathway which requires lower activation energy ( $E'_a$ ) than the uncatalysed reaction ( $E_a$ ). [1]

This allows a greater proportion of molecules with energy  $\geq E_a \rightarrow$  frequency of effective collisions increases and hence rate increases. [1]

- any missing keywords [0]

The Boltzmann curve must be drawn as an asymmetric curve, starting from the origin at '0' value (frequently absent from many answers). The curve should not taper off to touch the x-axis or resemble a bell curve. When indicating activation energy ( $E_a$ ) on the x-axis, do remember that usually only a small proportion of molecules have energy  $E_a$  and above. Please do not mark off such points near the peak of the curve which signifies that most molecules would have this energy. It is important to recognise the increase in **proportion/fraction/percentage** of molecules that have energy  $> E_a$  is more important than increase in absolute number of molecules. It is important that answers contain the keywords that are underlined above for complete elaboration of the concept.

3 (b) (ii) Na: Strong electrostatic forces of attraction between  $\text{Na}^+$  and sea of delocalized electrons in a giant metallic lattice [1]

Si: Strong covalent bonds holding Si atoms in a giant molecular structure/macromolecule [1]

$\text{P}_4$  and  $\text{Cl}_2$ : Simple covalent molecules held together by weak Van der Waals forces (or dispersion forces). [1]

[1] for any of the points below:

1.  $\text{P}_4$  has larger electron cloud / more electrons than  $\text{Cl}_2$ , hence its electron cloud is more polarizable, resulting in greater dispersion forces between its molecules and higher melting point.

2. Metallic bonding in sodium is much weaker than the covalent bonding in silicon, hence melting point of sodium is much lower than that of silicon.

3. Closeness of the melting points of sodium and phosphorus ( $44^\circ\text{C}$ ) must mean that the metallic bonding in sodium is not much stronger than van der Waals forces in phosphorus.

Many did not get full credit for this question as their answers did not fulfil the requirement to discuss both “the *structure* and *bonding* of the elements”. There are poor use of key terms here, students need to know the difference between ‘cations’, ‘atoms’, ‘molecules’ and ‘intermolecular’ forces. ‘Atom’ should only be used to refer to neutral particles such as the Si atom in a giant molecular structure and ‘intermolecular forces’ exists between particles that are atomic (e.g. helium) or simple molecules (e.g.  $\text{P}_4$ ). The use of the terms to describe the particles must be accurate and pertains to the correct type of bonding. Take note that once the structure is identified wrongly, (e.g. silicon is a metal or sodium is an ionic compound), no marks will be awarded for that element. This reflects a serious error in understanding and should be rectified as soon as possible. Many students also have the misconception that  $\text{P}_4$  is a polar molecule, which is easily proven erroneous since it is made of up of the same type of atom (P) and there is no electronegativity difference.

(c) (i)  $0.80 \text{ mol dm}^{-3}$  [1] (Accept 2 sf)

Using mole ratio of 1:1 as shown in the equation, this is easily calculated by most students. However, many wrote the wrong unit which should be for ‘*concentration*’ ( $\text{mol dm}^{-3}$ ).



3 (c) (ii) Correct axes and correct shape [1]

- No/wrong units for axis [ $-\frac{1}{2}$ ]
- No '0' at origin [ $-\frac{1}{2}$ ]
- Graph did not start at origin [0]

$t_{1/2}$  is constant at 20 min [1] ( $t_{1/2}$  must be taken at these two concentrations (0 – 0.4) and (0.4 – 0.6), otherwise [0])

- construction lines not shown [ $-\frac{1}{2}$ ]
- No ave  $t_{1/2}$  quoted in answer [ $-\frac{1}{2}$ ]

Hence order of reaction w.r.t ethene is 1 [1] (must be deduced from the correct method of taking half-life for product time curve and mentioned that half-life is constant).

The half-life of a [product]-time curve is taken differently from a [reactant]-time curve, which most students are familiar with.

Reactant → Product

1	0
$\frac{1}{2}$	$\frac{1}{2}$
$\frac{1}{4}$	$\frac{3}{4}$

For a [product]-time curve, it is important to know the maximum amount of product formed (**(c(i))**) as the half-life is taken at  $\frac{1}{2}$  and  $\frac{3}{4}$  of that amount. Some students mistakenly thought that the maximum concentration is  $0.76 \text{ mol dm}^{-3}$  and took the half-life at (0 – 0.38) and (0.38 – 0.57). This is considered a correct method and will be given a mark for the correct deduction of order (but  $t_{1/2}$  will be penalised).

(iii) Initial rate =  $0.02125 \text{ mol dm}^{-3} \text{ min}^{-1}$  [1] (acceptable range: 0.016 – 0.026)

Initial rate is taken at the time where concentrations of the reactants are the closest to those stated in the question (i.e. beginning of the reaction). Hence for a concentration-time curve, rate (change in concentration of reactants or products ÷ change in time) can be found from the gradient of tangent to the curve and initial rate is taken at the point at  $t=0$ . It must be noted that for a tangent at a point, you may wish to lightly sketch a continuation of the graph before  $t = 0$  so that a 'mirror reflection' is obtained. A long tangent line should be drawn so that error is minimised. It was noticed that some students with answers that were out of range, tend to have very short tangent lines or those that were wrongly drawn (would cut the curve at two points if curve was extrapolated before  $t=0$ ). Do note that the units of rate should follow the units of time used in the question, which in this case, is minutes.

- 3 (c) (iv) When [benzene] is doubled, rate of formation of product doubled (Initial rate in (c)(iii)/0.0106), hence order of reaction w.r.t. benzene is 1 [1]  
[0] if no working is shown.

It is important to read the question: “**Use this information to deduce...**”. The values of concentrations (in the table) and initial rates (in (c)(iii) and table) must be quoted (either as working or in the statement) to substantiate your answer. By showing how changes in concentrations of benzene caused initial rate to change proportionally, this indicates that the order with respect to benzene is 1. When referring to order, the species must be clearly stated.

- (v) Rate =  $k[\text{benzene}][\text{ethene}]$  [1]

- e.c.f. allowed if orders are wrongly deduced in (ii) and (iv)

From expt 1,  $0.0106 = k(0.8)(4)$

$$k = 0.00331 \text{ [1]} \quad \text{mol}^{-1}\text{dm}^3\text{min}^{-1} \text{ [1]}$$

- ecf allowed for wrong rate equation for these two marks

This is a standard part of a kinetics question, which will usually follow after the deduction of order of the reactants and rate equation. A student, who did not make any deductions in (ii) and (iv), would not be able to gain the rate equation mark. The formula  $k = \ln 2 / t_{1/2}$  should only be used for overall first order reactions. Since this is an overall second order reaction,  $k$  should be found using the rate equation. Students can also use information from Expt 2 to find  $k$ . To find units of  $k$ , students must remember to divide the units of rate ( $\text{mol}^{-1} \text{dm}^3 \text{t}^{-1}$ ) by the number of concentration units (in this case,  $\text{mol}^2 \text{dm}^{-6}$ ). The time for this experiment is taken in minutes, not seconds.

- (vi) For ethylbenzene, the electron-donating alkyl group increases the electron density of the benzene ring OR the alkyl group is an activating group [1], making the ring more susceptible to further electrophilic substitution.

The question requires students to explain why a di-substituted product is formed. Since electrophilic substitution takes place in stages where benzene  $\rightarrow$  ethylbenzene  $\rightarrow$  diethylbenzene, it should be considered in terms of why ethylbenzene (with the alkyl substituent) has the tendency to undergo further substitution. The question requires students to have a good understanding of the electrophilic substitution mechanism and how the electron-rich  $\pi$  cloud of benzene attracts electrophiles. By adding an electron-donating alkyl substituent to benzene, this increases the electron density of the ring and further enhances its tendency to undergo electrophilic substitution.







**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**14S**

**CHEMISTRY**

**9647/01**

Paper 1 Multiple Choice

**26 September 2014**

**40 min**

Additional Materials: Multiple Choice Answer Sheet  
Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Complete the information on the Multiple Choice Answer Sheet as shown below.

1. Enter your **NAME** ( as in **NRIC** ).

Write your **name**

2. Enter the **SUBJECT TITLE**.

3. Enter the **PAPER NUMBER**.

Write your **CT group**

4. Enter your **CT GROUP**.

5. **Date**.

6. Enter your **NRIC NUMBER** or **FIN NUMBER**.

7. Now **SHADE** the corresponding  
lozenge in the grid for  
**EACH DIGIT** or **LETTER**

NRIC / FIN															
S	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E
F	1	2	3	4	5	6	7	8	9	0	L	M	N	O	P
G	2	3	4	5	6	7	8	9	0	1	Q	R	S	T	U
T	3	4	5	6	7	8	9	0	1	2	V	W	X	Y	Z
	4	5	6	7	8	9	0	1	2	3					
	5	6	7	8	9	0	1	2	3	4					
	6	7	8	9	0	1	2	3	4	5					
	7	8	9	0	1	2	3	4	5	6					
	8	9	0	1	2	3	4	5	6	7					
	9	0	1	2	3	4	5	6	7	8					

Write and  
**shade** your  
**NRIC**  
or **FIN** number

There are **twenty-five** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.

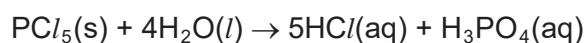
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

## SECTION A

- 1 When  $7.27 \times 10^{-4}$  mol of  $\text{PCl}_5$  was dissolved in  $25.0 \text{ cm}^3$  of water, the resultant solution required  $23.80 \text{ cm}^3$  of a solution of NaOH for reaction.



Assume that 1 mole of  $\text{H}_3\text{PO}_4$  releases 2 moles of  $\text{H}^+$  ions in water.

What is the concentration of the NaOH solution (in  $\text{mol dm}^{-3}$ ) used for the reaction?

- A**      0.0611      **B**      0.157      **C**      0.180      **D**      0.214
- 2 When  $10 \text{ cm}^3$  of a hydrocarbon was burnt in  $100 \text{ cm}^3$  of excess oxygen, the volume of the residual gas mixture contracted by  $20 \text{ cm}^3$  after passing through a solution of aqueous sodium hydroxide. The remaining volume of gas was sufficient to completely burn exactly  $30 \text{ cm}^3$  of the same hydrocarbon. All volumes were measured at room temperature and pressure.

What is the formula of the hydrocarbon?

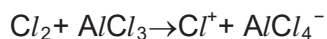
- A**       $\text{C}_2\text{H}_2$   
**B**       $\text{C}_2\text{H}_3$   
**C**       $\text{C}_2\text{H}_4$   
**D**       $\text{C}_2\text{H}_6$
- 3 The electronic configuration of the gold atom, Au, is  $[\text{Xe}]4\text{f}^{14}5\text{d}^{10}6\text{s}^1$ . What is the number of unpaired electrons in the 5d orbitals of the gold ion in  $\text{AuCl}_3$ ?

- A**      1      **B**      2      **C**      3      **D**      4
- 4 A crystal of iodine produces a purple vapour when gently heated.

Which pair of statements correctly describes this process?

	type of bond broken	formula of purple species
<b>A</b>	covalent	I
<b>B</b>	covalent	$\text{I}_2$
<b>C</b>	induced dipole-dipole	$\text{I}_2$
<b>D</b>	permanent dipole-dipole	$\text{I}_2$

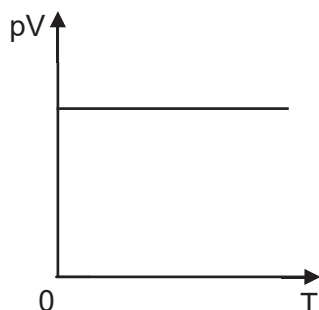
- 5 Aluminium chloride catalyses the electrophilic substitution reaction between benzene and chlorine gas by forming the electrophile  $\text{Cl}^+$  as shown.



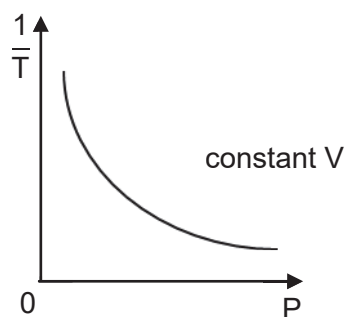
Which property of  $\text{AlCl}_3$  makes this reaction possible?

- A  $\text{AlCl}_3$  exists as the dimer  $\text{Al}_2\text{Cl}_6$  in the vapour phase.
  - B  $\text{AlCl}_3$  is a covalent molecule.
  - C The aluminium atom in  $\text{AlCl}_3$  has an incomplete octet of electrons.
  - D The aluminium atom in  $\text{AlCl}_3$  has an unshared pair of electrons.
- 6 Which one of the following graphs does **not** correctly describe the behaviour of a fixed mass of an ideal gas?

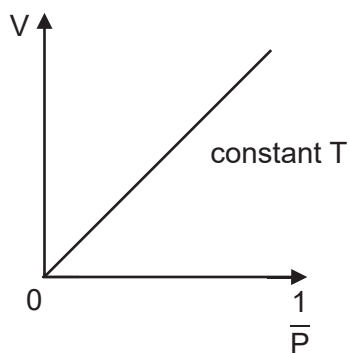
A



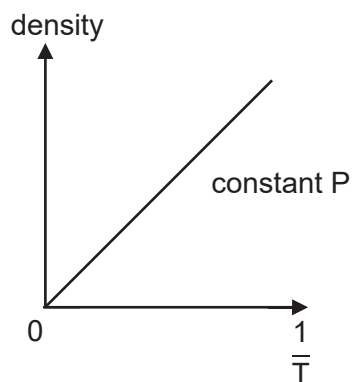
B



C

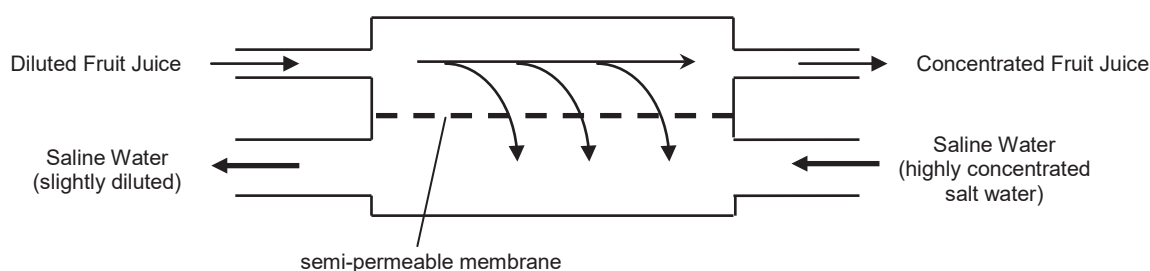


D



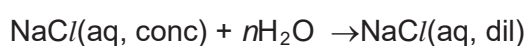
- 7 Forward osmosis is a spontaneous process using a semi-permeable membrane to effect the separation of water by using an osmotic pressure gradient. A common application

involves concentrating fruitjuice as shown in the diagram below.



The semi-permeable membrane only allows small molecules such as water through, but keeps back all other molecules and ions.

The enthalpy change of dilution of  $\text{NaCl}(\text{aq})$ , i.e.  $\Delta H$  for the process



is very small, and can be considered as being zero.

What are the correct signs of  $\Delta S$  and  $\Delta G$  for the forward osmosis process?

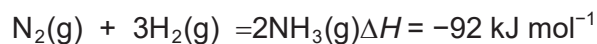
	$\Delta S$	$\Delta G$
<b>A</b>	–	–
<b>B</b>	–	+
<b>C</b>	+	–
<b>D</b>	+	+

- 8 When water boils,  $40.66 \text{ kJ mol}^{-1}$  of heat enthalpy is absorbed.

What is the entropy change when 54 g of water boils at  $100^\circ\text{C}$ ?

- A**  $+327 \text{ J K}^{-1}$   
**B**  $+109 \text{ J K}^{-1}$   
**C**  $-109 \text{ J K}^{-1}$   
**D**  $-327 \text{ J K}^{-1}$

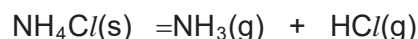
- 9 Ammonia gas is manufactured from nitrogen and hydrogen by the Haber process according to the following equation:



Which of the following increases the yield of ammonia gas?

- A high pressure and high temperature
- B high pressure and low temperature
- C low pressure and high temperature
- D low pressure and low temperature

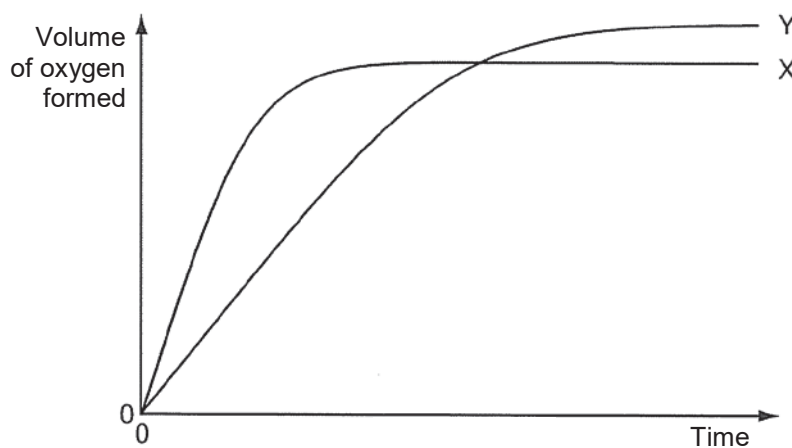
- 10 The values of the equilibrium constant,  $K_p$ , for the reaction



are  $4.98 \times 10^{-2}$  and 2.15 at 298 K and 800 K respectively.

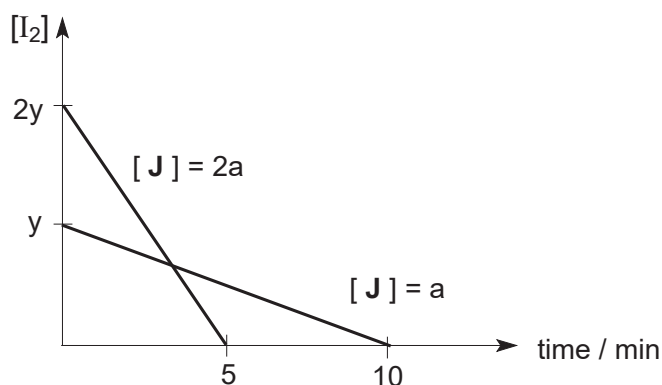
Which of the following statements is correct?

- A A decrease in temperature will increase the yield of  $\text{NH}_3$ .
  - B Decreasing the volume will increase the proportion of  $\text{NH}_3$  and  $\text{HCl}$  at equilibrium.
  - C The reverse reaction has a lower activation energy than the forward reaction.
  - D The value of  $K_p$  will increase when additional  $\text{NH}_4\text{Cl}$  is added.
- 11 In the diagram below, curve X represents the decomposition of  $100 \text{ cm}^3$  of  $1.0 \text{ mol dm}^{-3}$  hydrogen peroxide, catalysed by manganese(IV) oxide.



Which change to the original experimental conditions would produce curve Y?

- A Adding water
  - B Adding some  $0.1 \text{ mol dm}^{-3}$  hydrogen peroxide
  - C Lowering the temperature of the reaction
  - D Using less manganese(IV) oxide
- 12 The kinetics of the reaction between iodine and compound J is investigated.

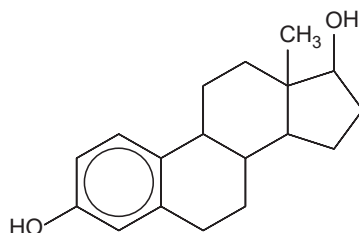


What conclusion can be drawn from the graphs?

- A** Both iodine and compound **J** are involved in the rate determining step.
- B** The half-life of iodine is constant.
- C** The reaction is second order with respect to compound **J**.
- D** The unit of the rate constant  $k$  is  $\text{mol}^{-2} \text{dm}^6 \text{min}^{-1}$ .

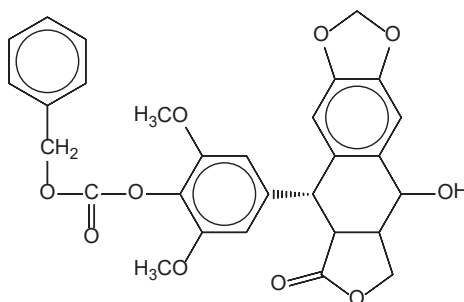
- 13** Estradiol is a type of estrogen hormonal drug used for treatment of different cancers in both men and women.

What is the number of chiral centres present in its structure?



- A** 3      **B** 4      **C** 5      **D** 6

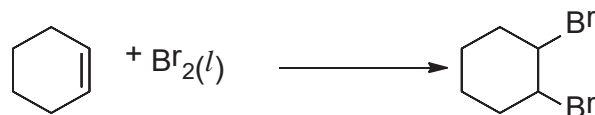
- 14** Which functional group is present in the molecule shown?



- A** Alcohol
  - B** Alkene
  - C** Carboxylic acid
  - D** Phenol
- 15** Which one of the following properties of straight-chain alkanes does **not** increase as chain length increases?

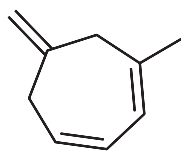
- A Density
- B Boiling point
- C Solubility in water
- D Size of electron cloud

16 Which statement about the reaction below is **incorrect**?



- A It only takes place in the absence of light.
- B Reddish brown  $\text{Br}_2(l)$  decolourises.
- C The intermediate of the reaction is a bromonium ion.
- D Cyclohexene acts as a nucleophile.

17 The following hydrocarbon is heated with excess  $\text{KMnO}_4$  and  $\text{H}_2\text{SO}_4$ .



How many moles of carbon dioxide gas are produced per mole of this hydrocarbon?

- |          |          |          |          |
|----------|----------|----------|----------|
| A      0 | B      1 | C      2 | D      3 |
|----------|----------|----------|----------|

18 Which one of the following sequences is expected to give the best yield for the synthesis of 2-chloro-4-nitromethylbenzene from benzene?

- A Alkylation, nitration, chlorination
- B Alkylation, chlorination, nitration
- C Nitration, chlorination, alkylation
- D Nitration, alkylation, chlorination

## SECTION B



For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1, 2 and 3</b> are correct	<b>1 and 2</b> only are correct	<b>2 and 3</b> only are correct	<b>1</b> only is correct

No other combination of statements is used as a correct response.

**19** Which statement about 24.0 g of  $^{12}\text{C}$  is correct?

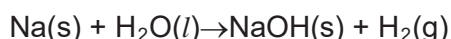
- 1** The number of electrons is the same as the number of protons in 24.0 g of  $^{24}\text{Mg}$ .
- 2** The number of neutrons is  $7.22 \times 10^{24}$ .
- 3** The number of atoms is the same as the number of electrons in 12.0 g of  $^{24}\text{Mg}$ .

**20** Which of the following statements are correct for the sequence of compounds below considered from left to right?

NaF                      MgO                      AlN                      SiC

- 1** The formula units of these compounds are isoelectronic.
- 2** The electronegativity difference between the elements in each compound decreases.
- 3** The lattice structure changes from giant ionic to simple covalent.

**21** Sodium reacts with water to form sodium hydroxide and hydrogen according to the equation:

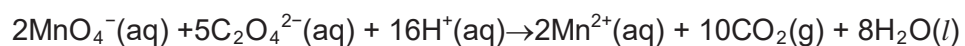


The standard enthalpy change for this reaction can be measured in the laboratory.

What further information is needed in order to calculate the standard enthalpy change of formation,  $\Delta H_f^\ominus$ , of sodium hydroxide?

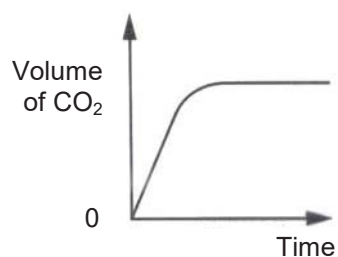
- 1**  $\Delta H_f^\ominus$  of  $\text{H}_2\text{O(l)}$
- 2**  $\Delta H_f^\ominus$  of  $\text{H}_2\text{(g)}$
- 3** First ionisation energy of Na

- 22** Ethanedioate ions,  $\text{C}_2\text{O}_4^{2-}$ , are oxidised by acidified, aqueous potassium manganate(VII) according to the equation below. The reaction is autocatalysed by  $\text{Mn}^{2+}$ .

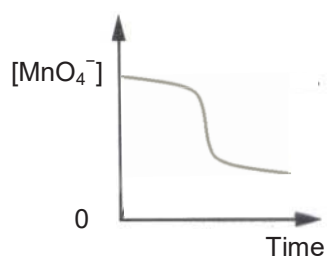


Which of the following graphs is correct for the above reaction?

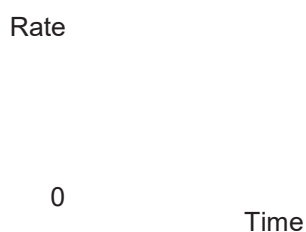
**1**



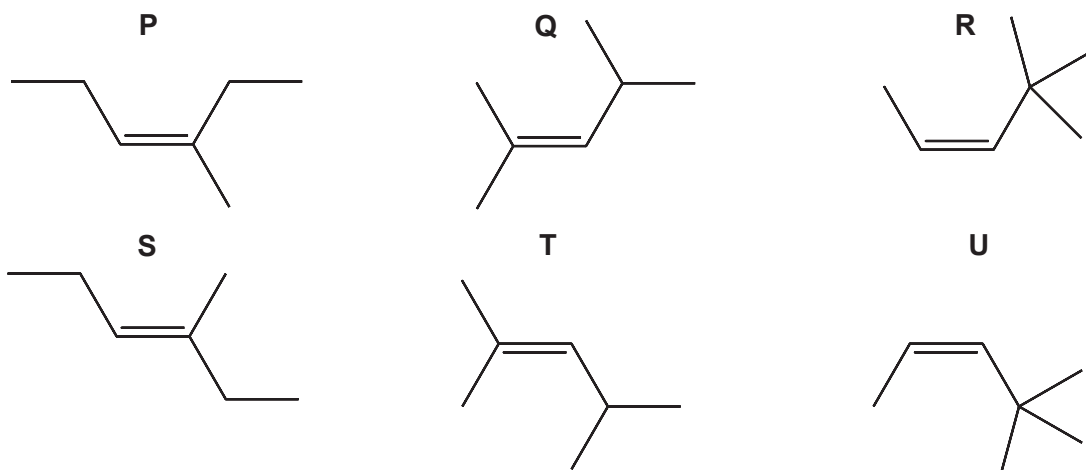
**2**



**3**



23 Which molecules are geometric isomers of each other?



- 1 **P and S**
- 2 **Q and T**
- 3 **R and U**

24 Production of chlorofluorocarbons (CFCs) was slowly phased out under the Montreal Protocol due to the ability of CFCs to deplete the ozone layer by forming highly reactive radicals.

One such CFC is dichlorodifluoromethane,  $\text{CCl}_2\text{F}_2$ , which forms radicals when irradiated with ultraviolet light:



A mixture of  $\text{CCl}_2\text{F}_2$  and methane,  $\text{CH}_4$ , was irradiated with ultraviolet light in a sealed container. Which of the following is a possible product of the chain reaction?

- 1  $\text{C}_2\text{H}_6$
- 2  $\text{CH}_2\text{Cl}_2$
- 3  $\text{CH}_3\text{F}$

25 Which of the following statements are correct about benzene and methylbenzene?

- 1 Only one of the two decolourises hot acidified potassium manganate(VII).
- 2 In mono-nitration, both form only one possible product.
- 3 Both compounds are planar.

**END OF PAPER**



**HWA CHONG INSTITUTION**  
**2014C1H2 CHEMISTRY PROMOTIONAL EXAM**  
**SUGGESTED SOLUTIONS**

Paper 1

1	2	3	4	5	6	7	8	9	10
D	A	B	C	C	A	C	A	B	C
11	12	13	14	15	16	17	18	19	20
B	C	C	A	C	A	D	A	B	B
21	22	23	24	25					
D	C	D	B	D					

**Comments**

1. **D**  $n(\text{PCl}_5) = 7.27 \times 10^{-4} \text{ mol}$   
 $n(\text{H}^+) = 7.27 \times 10^{-4} \text{ mol} \times 7 = 0.005089 \text{ mol}$   
 $\Rightarrow n(\text{NaOH}) \text{ in } 23.80 \text{ cm}^3 = 0.005089 \text{ mol}$   
 $[\text{OH}^-] = 0.005089 \div \frac{23.80}{1000} = 0.214 \text{ mol dm}^{-3}$

2. **A** Mole ratio of hydrocarbon: $\text{CO}_2 = 1:2$   
 $\therefore$  let formula of hydrocarbon be  $\text{C}_2\text{H}_x$   
 $\Rightarrow \text{C}_2\text{H}_x(\text{g}) + (2 + \frac{x}{4})\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + \frac{x}{2}\text{H}_2\text{O}(\text{l})$

Since the excess  $\text{O}_2$  can burn up exactly  $30 \text{ cm}^3$  of the same hydrocarbon, this means that  $100 \text{ cm}^3$  of  $\text{O}_2$  can burn  $40 \text{ cm}^3$  of the hydrocarbon.

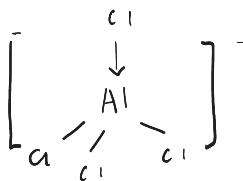
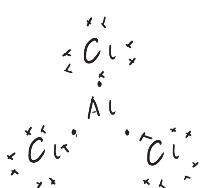
$\Rightarrow$  Mole ratio of hydrocarbon: $\text{O}_2 = 40:100 = 1:2.5$

$$\Rightarrow 2 + \frac{x}{4} = 2.5 \Rightarrow x = 2$$

Formula of hydrocarbon is  $\text{C}_2\text{H}_2$ .

3. **B** Oxidation state of Au in  $\text{AuCl}_3$  is +3. Au loses 3 electrons to form  $\text{Au}^{3+}$  in  $\text{AuCl}_3$ . In the formation of cations, electrons are removed starting from the highest energy level. For transition metals like Au, the 6s electron is removed first. This is because once the 5d orbitals are occupied by electrons, the 6s orbital is repelled to a slightly higher energy level. The order of removal of the first 3 electrons is thus from 6s, 5d and 5d. Electron configuration of  $\text{Au}^{3+}$  is  $[\text{Xe}]4f^{14}5d^8$ . Therefore, there are 2 unpaired electrons in the 5d orbitals of each  $\text{Au}^{3+}$  ion in  $\text{AuCl}_3$ .

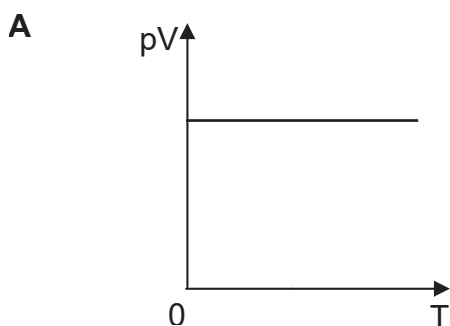
4. **C** Iodine exists as  $I_2$  molecules, with a simple molecular structure. In the molecule, the atoms are held by a covalent bond. Since the molecules are non-polar, they are held by dispersion forces. When iodine undergoes sublimation, the molecule remains intact. The strong covalent bonds do not break to give iodine atoms. Only the dispersion forces are broken. Hence, answer is **C**.
5. **C** Options **A** and **B** are true, but do not explain the role of  $AlCl_3$ . Option **D** is incorrect as the  $Al$  atom does not have a lone pair around it. The six electrons around it are all bonding pairs of electrons. In fact, the  $Al$  atom has an incomplete octet ( $< 8$  electrons) and so accepts a lone pair from  $Cl^-$  (form a dative bond) forming  $AlCl_4^-$ . Hence, answer is **C**.



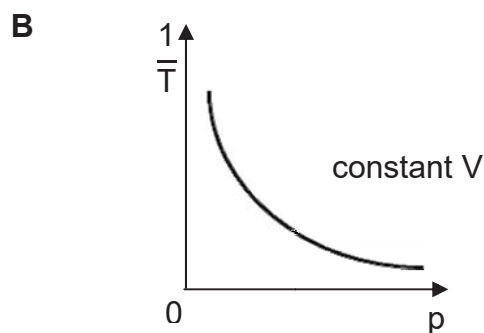
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6. **A** In each case, rearrange ideal gas equation  $pV = nRT$  to make the variable on the vertical axis the subject of the equation:

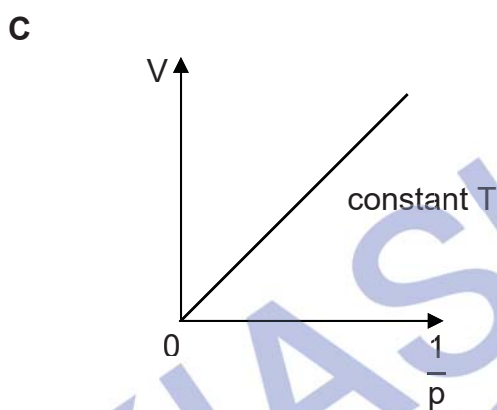


$pV = nR \cdot T \Rightarrow$  straight line graph of (non-zero) gradient  $nR$ . Hence **A** is false.



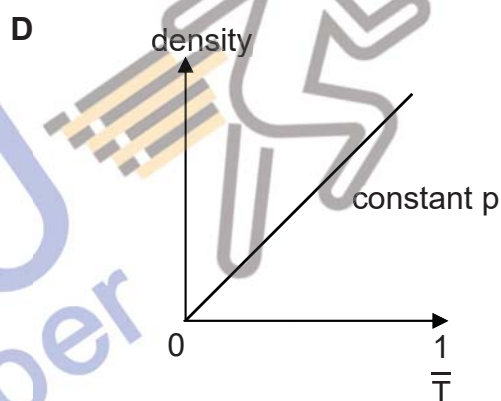
$$pV = nRT \Leftrightarrow \frac{1}{T} = \frac{nR}{V} \cdot \frac{1}{p}$$

$\Rightarrow \frac{1}{T}$  inversely proportional to  $P$



$$pV = nRT \Leftrightarrow V = nRT \cdot \frac{1}{p}$$

$\Rightarrow$  straight line graph, gradient  $nRT$



$$pV = nRT, n = \frac{m}{M_r}, \rho = \frac{m}{V}$$

$$\rho = \frac{pM_r}{R} \cdot \frac{1}{T}$$

$\Rightarrow$  straight line graph, gradient  $\frac{pM_r}{R}$

7. **C**  $\Delta G = \Delta H - T\Delta S$

Forward osmosis is spontaneous  $\Rightarrow \Delta G$  is negative

$\Delta H$  is negligible  $\Rightarrow \Delta S$  must be positive.

Although there are fewer ways to rearrange the energy of the water and solute molecules in the fruit juice after being concentrated, the ways to rearrange the energy of the water molecules after passing through the membrane in the diluted saline water and the ions in the diluted saline water more than compensate so there is a net positive change in entropy.

8. **A** When water boils at  $T = 373 \text{ K}$ ,  $\Delta G = 0$  and  $\Delta H = +40.66 \text{ kJ mol}^{-1}$ .

Using  $\Delta G = \Delta H - T\Delta S$ ,

$$\Delta S = \frac{\Delta H}{T} = \frac{+40.66}{373}$$

$$= +0.109 \text{ kJ mol}^{-1}\text{K}^{-1} = +109 \text{ J mol}^{-1}\text{K}^{-1}$$

Hence, for 54 g (3 mol) of water, the entropy change is  $+109 \times 3 = +327 \text{ J K}^{-1}$

9. **B** If you want to increase the yield of ammonia gas, in other words, you want the equilibrium to shift to the right.

In the Haber process to manufacture ammonia, there is a lower amount of gaseous products than gaseous reactants. Hence, a high pressure will favour the equilibrium shifting to the right to reduce the increased pressure as the forward reaction produces a lower amount of gaseous products.

The Haber process is an exothermic reaction. Hence, a low temperature will favour the equilibrium shifting to the right to produce more heat to offset the decrease in temperature. This will thus produce more ammonia gas and increase the yield of ammonia gas.

10. **C** **A:** When temperature is low (298K),  $K_p$  is small ( $4.98 \times 10^{-2}$ ). This implies that at low temperature, equilibrium lies on the left. When temperature is high (800K),  $K_p$  is large (2.15). This implies that at high temperature, equilibrium lies on the right.

This implies that this forward reaction is an endothermic reaction. Hence, a decrease in temperature will favour the backward exothermic reaction and shift equilibrium to the left to offset the decrease in temperature and thus decrease the yield of  $\text{NH}_3$ .

**B:** This reaction has 2 moles of gaseous product and 0 moles of gaseous reactant. Decreasing the volume means increasing the pressure. With an increase in pressure, the equilibrium will shift the equilibrium to the left to decrease the pressure. Hence, decreasing the volume will decrease the proportion of  $\text{NH}_3$  and  $\text{HC}$  instead of increasing it.

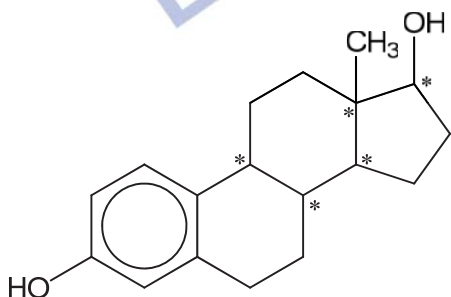
**C:** As deduced from **A**, the forward reaction is an endothermic reaction. Visualize the energy profile diagram of an endothermic reaction, you will then realize that the reverse reaction has a lower activation energy than the forward reaction.

**D:**  $K_p$  is unaffected by changes in concentration or pressure of either reactants or products. It is only dependent on temperature.

- 11. B** Gradient of the product-time graph represents rate of the reaction. The gradient of graph **Y** is less steep, meaning the rate of reaction of **Y** is slower than that of **X**. Graph **Y** plateaus off at a higher volume of  $O_2$ , suggesting that for **Y**, more product is formed. For option **B**, some additional reactants are added and thus will give more products at the end of the reaction (plateau at a higher volume of product). However addition of a lower concentration of reactants (10 times lower) will decrease the overall concentration of the reactant and thus the rate decreases (less steep).

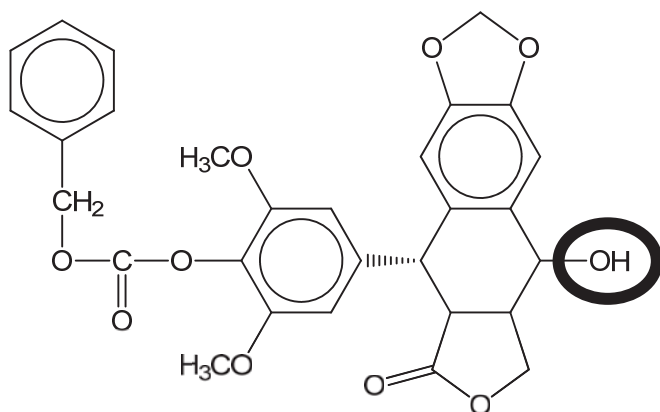
For option **A**, the addition of water will lower the rate of reaction (less steep), as concentration of reactants decreases when water is added. However, the amount of product formed should still be the same. For option **C**, lowering the temperature of reaction will decrease the overall kinetic energy of particles, and will lower the effective collision of reactants particle which resulted in lower rate of reaction (less steep). However the amount of product form will still be the same. For option **D**, using less catalyst will lower the rate of reaction (less steep), but amount of product should be the same.

- 12. C** Less than 30% of the cohort got this right. As both graphs have constant gradient, it implies that the rate of reaction is constant throughout (as the gradient of concentration-time graph represents rate). Thus the change in concentration of iodine doesn't affect the gradient, which is the rate, i.e. reaction is zero order wrt iodine. Option **A** is incorrect. Iodine is not in the rate determining step. For iodine, half-life is not constant as it is not first order. To determine the order of reaction wrt **J**, when  $[J]$  is doubled from  $a$  to  $2a$ , the rate (represented by gradient) increases from  $y/10$  to  $2y/5$ , which is 4 times. Thus the order of reaction wrt to **J** is 2. The rate equation will be  $\text{Rate} = k[J]^2$ , and from here the unit of  $k$  is  $\text{mol}^{-1} \text{dm}^3 \text{min}^{-1}$ .
- 13. C** There are 5 chiral centres in this molecule.





14. A The alcohol functional group is present.



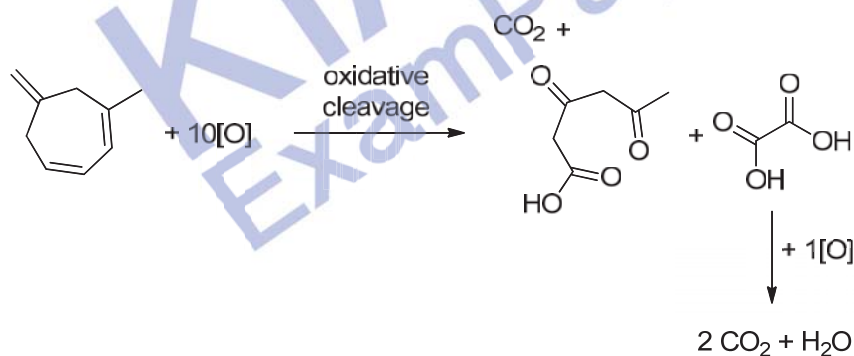
15. C An increase in length of carbon chain of an alkane results in increase in number of electrons. Hence, size of electron cloud increases. This causes the magnitude of dispersion forces between alkane molecules to increase, which increases the boiling point and also density.

Solubility would decrease with increasing carbon chain length as increased energy is required to overcome the dispersion forces between larger alkane molecules.

16. A A is false. Electrophilic addition of  $\text{Br}_2(l)$  to alkenes can take place in the presence of light but may be accompanied by free radical substitution.

B, C and D are true. Cyclohexene is the nucleophile due to its electron-rich  $\pi$  bond. Polarised  $\text{Br}_2(l)$  is the electrophile due to the partial positive charge on one of the Br atoms.

17. D



- 18. A** 2-chloro-4-nitromethylbenzene has methyl, chloro and nitro groups attached to the benzene ring. As these 3 groups are in the 1-, 2- and 4- positions, I will then insert an electron-donating group as the first substituent into benzene in this synthesis, as being electron donating in nature, it will more likely direct the remaining substituent(s) into the 2- and 4- positions. Hence, I will choose alkylation to insert the electron donating methyl group into benzene first over nitration to insert the electron withdrawing nitro group. This will narrow down my options to **A** and **B** only.

After alkylation of the benzene to form methylbenzene, I will choose carry out nitration next (option **A**) instead of chlorination (option **B**). As once the methyl and nitro groups are attached to the benzene ring, both will direct the last substituent (the chloro group) to the same position.

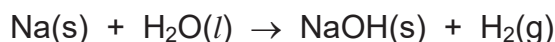
However, if after alkylation of the benzene to form methylbenzene, if I were to choose to carry out chlorination next (Option **B**), then when the methyl and chloro groups are attached to the benzene ring, the methyl group will direct the last nitro substituent to the 4- position w.r.t the methyl group, as what the question wants, BUT, the chloro group will not direct the nitro group there. Hence, Option **B** will not give the best yield for this synthesis.

- 19. B**  $n(^{12}\text{C})$  in 24.0 g =  $24.0 \div 12.0 = 2.00$  mol  
no of atoms =  $6.02 \times 10^{23} \times 2 = 1.204 \times 10^{24}$   
 $n(\text{protons}) = n(\text{neutrons}) = n(\text{electrons}) = 2.00 \times 6 = 12.0$  mol  
number of neutrons =  $6.02 \times 10^{23} \times 12 = 7.22 \times 10^{24}$

$n(\text{protons})$  in 24.0 g of  $^{24}\text{Mg} = (24.0 \div 24.0) \times 12 = 12.0$  mol  
 $n(\text{electrons})$  in 12.0 g of  $^{24}\text{Mg} = (12.0 \div 24.0) \times 12 = 6.00$  mol

- 20. B** Statement **1** is correct. Each compound has 20 electrons. For example, SiC has  $14 + 6 = 20$  electrons.  
Statement **2** is correct. Electronegativity increases across the Period and decreases down the group.  
Statement **3** is incorrect. NaF and MgO have giant ionic structures. AlN (aluminium nitride) and SiC (silicon carbide) have giant covalent structures.

21. D



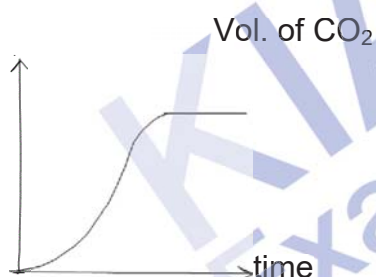
Using the general equation,

$$\begin{aligned}\Delta H_r^\ominus &= \sum m\Delta H_f^\ominus(\text{products}) - \sum n\Delta H_f^\ominus(\text{reactants}) = \\ &= \Delta H_f^\ominus(\text{NaOH}) - \Delta H_f^\ominus(\text{H}_2\text{O})\end{aligned}$$

Since  $\Delta H_f^\ominus$  can be measured in the laboratory, finding  $\Delta H_f^\ominus(\text{NaOH})$  would only require  $\Delta H_f^\ominus(\text{H}_2\text{O})$ .

Note:  $\Delta H_f^\ominus(\text{H}_2) = 0$

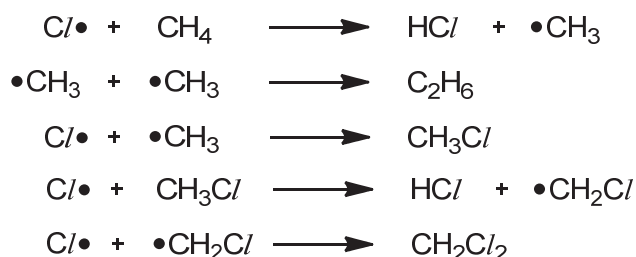
22. C About half of the cohort got this question correct. In autocatalysis, one of the products of the reaction, in this case  $\text{Mn}^{2+}$ , is a catalyst for the reaction itself. For option **2**, the gradient increases slowly initially, which implies that the reaction starts slowly, and rate speeds up (gradient increases drastically after awhile) as more  $\text{Mn}^{2+}$  (autocatalyst) is produced. After awhile, the rate slows down (gradient decreases again) due to decreasing concentrations of reactants. Reaction will stop once all reactants are used up (gradient is zero at the end). The same explanation is also for option **3**. For option **1**, since  $\text{CO}_2$  is a product, the formation of product was slow initially and increases as more  $\text{Mn}^{2+}$  is formed, the graph should look like this:



23. D

1	<b>P</b> and <b>S</b> are geometric isomers of each other. Note: they are not <i>cis/trans</i> as they have 4 different groups attached to the carbons of the C=C bond.
2	<b>Q</b> and <b>T</b> are the same molecule. Furthermore, they both have two methyl groups attached to one of the C=C bond carbons, which disallows geometric isomerism.
3	<b>R</b> and <b>U</b> are the same molecule, and they are both <i>cis</i> .

24. B Formation of  $C_2H_6$  and  $CH_2Cl_2$  is possible from the following chain propagation and termination steps:



$CH_3F$  cannot be formed, as the C—F bond is very strong and is least likely to cleave to form fluorine radicals.

25. D **Statement 1:** This is correct as the methyl group in methylbenzene can undergo a side-chain oxidation to decolourize hot acidified potassium manganate(VII) whereas benzene cannot undergo an oxidation reaction with hot acidified potassium manganate(VII).

**Statement 2:** In mono-nitration, methylbenzene can give rise to 2 products: 2-nitromethylbenzene and 4-nitromethylbenzene.

**Statement 3:** Benzene is planar but methylbenzene is not planar as the carbon atom of the methyl group is  $sp^3$  hybridized and is tetrahedral, making the whole methylbenzene molecule non-planar.





CANDIDATE  
NAME

CT GROUP

14S

## CHEMISTRY

9647/02

Paper 2 Structured Questions

26 September 2014

1 hr 20 min

Candidates answer on the Question Paper.

Additional Materials: Data Booklet.

### INSTRUCTIONS TO CANDIDATES

- 1) Write your **name** and **CT class** clearly in the spaces at the top of this page.
- 2) Answer **all** questions in the spaces provided in this Question Booklet.

### INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

You may use a calculator.

You are reminded of the need for good English and clear presentation in your answers.

### FOR EXAMINERS' USE ONLY

Paper 1	Paper 2	Paper 3	TOTAL
Multiple Choice	Structured	Free Response	110
	Q1 / 10	Q1 / 20	
	Q2 / 9	Q2 / 20	
	Q3 / 8	Q3 / 20	
	Q4 / 9		
	Q5 / 9		
/ 25	Subtotal / 45	Subtotal / 40	

Answer all the questions in the spaces provided.

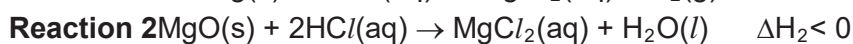
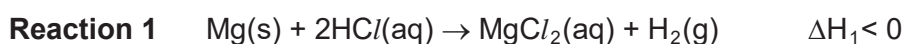
## 1 Planning (P)

Magnesium and oxygen react together upon heating to form magnesium oxide. The reaction proceeds in an uncontrolled and highly exothermic fashion. Hence, it is not possible to measure this enthalpy change of formation of magnesium oxide directly.

- (a) Write an equation, with state symbols, to show the enthalpy change of formation of magnesium oxide.

.....[1]

The enthalpy change of formation of magnesium oxide can only be determined by an indirect method, using an energy cycle that includes the following reactions:



- (b) You will plan an experiment to determine the enthalpy change of reaction for **Reaction 1**.

You may assume that you are provided with the following:

- magnesium ribbon
- $2.0 \text{ mol dm}^{-3}$  aqueous hydrochloric acid

Suggest an appropriate volume of hydrochloric acid and justify the mass of magnesium ribbon to use for the experiment.

Volume of hydrochloric acid: .....

Mass of magnesium: .....

[2]

- (c) Outline, in a series of numbered steps, the experimental work you would carry out to determine the enthalpy change of reaction for **Reaction 1**.

Your plan should include

- suitable choice of apparatus
- masses and volumes of reagents

.....[3

- (d) Construct an energy cycle that incorporates the equations for **Reactions 1** and **2** to show how the enthalpy change of formation of magnesium oxide can be determined.



- (e) Identify one significant source of error if you are to carry out the experimental work in (c). Discuss its impact on the value of the enthalpy change of reaction obtained.

.....  
 .....  
 .....[2]

[Total: 10]

- 2 Ozone,  $O_3$ , is fairly stable, but rapidly decomposes in the presence of silver catalyst. The total volume, after the catalyst is added to an  $800\text{ cm}^3$  sample of a mixture of oxygen and ozone, is shown in the table below. All volumes are measured at the same temperature and pressure.

Time /s	0	210	430	495	680	820	1290	1800	2230
Volume / $\text{cm}^3$	800	807	812	813	815	816	818	819	819

- (a) Write a balanced equation for the decomposition of ozone into oxygen.

.....[1]

- (b) From the data given, deduce the initial composition of the oxygen-ozone mixture by volume.

[2]

- (c) The decomposition of ozone is consistent with first order kinetics. Use this information to write the rate equation for the reaction.

.....[1]

- (d) (i) The decomposition of ozone proceeds through the formation of oxygen atom intermediates. Draw an electron-in-box diagram representing the electronic configuration of an oxygen atom. Label your diagram clearly.

- (ii) By reference to your diagram, explain why oxygen atoms are considered radicals.

.....  
.....

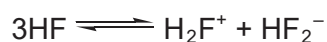
- (iii) Thus, comment on the rate of formation of oxygen atoms, briefly stating your reasoning.

.....  
.....  
..... [3]

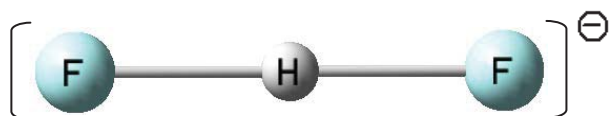
- (e) From your answers to parts (c) and (d), propose a mechanism for the decomposition of ozone.

[2]  
[Total: 9]

- 3 Hydrogen fluoride is a colourless liquid with a strong and irritating odour. In its liquid state, it undergoes autodissociation according to the equation below.



- (a) The structure of bifluoride,  $\text{HF}_2^-$ , was determined experimentally to be as follows:



- (i) What is unusual about the bonding of the central hydrogen atom in  $\text{HF}_2^-$ ?

.....

.....

- (ii) It was initially postulated that hydrogen bonding is present within  $\text{HF}_2^-$ . Draw a labeled diagram to illustrate the bonding in the postulated structure.

- (iii) The bond lengths between H and F in HF and  $\text{HF}_2^-$  are summarized in the table below.

	in HF	in $\text{HF}_2^-$	HF---HF (intermolecular hydrogen bond)
Bond length/ pm	92	115	155

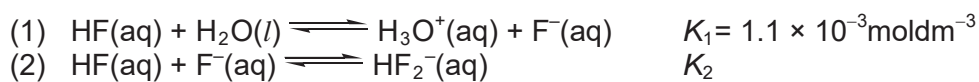
Comment on the experimental observed H–F bond length in  $\text{HF}_2^-$ .

.....

.....

.....[4]

- (b) In water, HF behaves as a weak acid and dissociates partially. Below are the two most important equilibria which take place simultaneously when HF is bubbled into water.



The equilibrium concentrations of HF and  $\text{F}^-$  are found to be  $8.89 \times 10^{-2} \text{mol dm}^{-3}$  and  $9.77 \times 10^{-3} \text{mol dm}^{-3}$  respectively.

- (i) Write expressions for  $K_1$  and  $K_2$ .

- (ii) Use your expression for  $K_1$  to calculate  $[\text{H}_3\text{O}^+]$  at equilibrium.

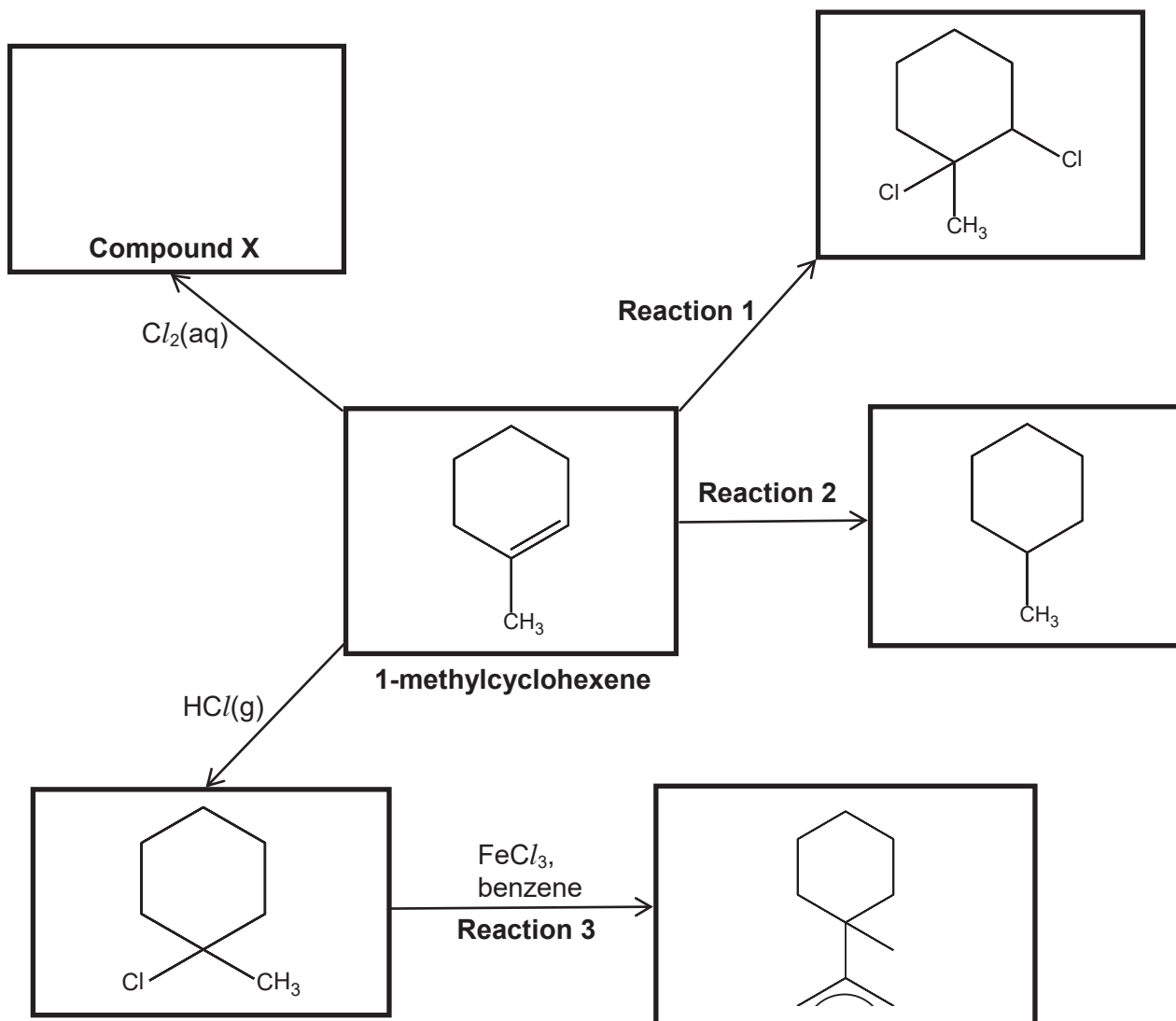
- (iii) Given that the system has no net charge, state the relationship between  $[\text{F}^-]$ ,  $[\text{HF}_2^-]$  and  $[\text{H}_3\text{O}^+]$  at equilibrium.

.....

- (iv) Write the equation for the equilibrium reaction which has  $K_c = K_1 \times K_2$ .

[4]  
[Total: 8]

4 The reaction scheme below involves the reactions of 1-methylcyclohexene.



(a) Draw the structure of **Compound X** in the box provided. [1]

(b) State the reagents and conditions used in **Reaction 1** and **2**.

**Reaction 1:** .....

**Reaction 2:** .....[2]

(c) State the type of reaction occurring in **Reaction 2**.

.....[1]

- (d) Depending on the conditions used, 1-methylcyclohexene can react with potassium manganate(VII) to yield different organic products. State the reagents and conditions used and draw the structures of the expected organic products.

Reagents and conditions: .....	Reagents and conditions: .....
Structure of organic products:	Structure of organic products:

[3]

- (e) **Reaction 3** is a type of Friedel-Crafts alkylation in which an alkyl group is substituted on the benzene ring.

An organic side product of this reaction is isolated and has the molecular formula  $C_{20}H_{30}$ . Suggest a possible structure for this product and explain its formation.

.....

.....

.....

[2]

[Total: 9]

5 Alkanes undergo free radical substitution to form multiple substitution products.

(a) When methane undergoes free radical substitution, the methyl radical formed is trigonal planar in shape.

(i) State the hybridisation state of the carbon atom in the methyl radical.

.....

(ii) State which orbital the unpaired electron resides in on the methyl radical.

.....[2]

(b) 2-methylbutane,  $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)_2$ , undergoes free radical substitution with  $\text{Cl}_2$  to give 4 mono-substituted products **A**, **B**, **C**, and **D**.

Type of Hydrogen	Relative Reactivity	Energy of C–H Bond/ $\text{kJ mol}^{-1}$
Primary, $1^\circ$	1	420
Secondary, $2^\circ$	3.5	401
Tertiary, $3^\circ$	5	390

(i) Using the C–H bond energy data provided, account for the relative reactivities of the 3 different types of hydrogen.

.....

.....

.....

.....[1]

(ii) The following information will allow you to determine the structures of **A**, **B**, **C** and **D**.

- The ratio of the four products formed can be found by multiplying the relative reactivity of the hydrogen responsible for the formation of the product to the number of hydrogen atoms in the compound that can form that product.
- There is twice as much of **C** as compared to **A** in the product mixture.
- **B** and **C** are both optically active.

Draw the structures of the 4 monochlorinated products and label each structure (**A**, **B**, **C** or **D**). Explain your answer.

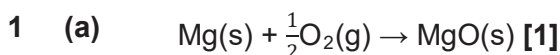
Structure	Label ( <b>A</b> , <b>B</b> , <b>C</b> or <b>D</b> )	Explanation

[6]  
[Total: 9]

**END OF PAPER**



## 2014 HCl Chemistry Promotional Exam Paper 2 (Suggested Answers)



Enthalpy change of formation is defined as the energy change when one mole of the substance is formed from its constituent elements. The specific equation has to refer to one mole of MgO formed.

Common mistakes:

- balancing the equation correctly but using 2 moles of MgO.
- writing oxygen as 'O' instead of 'O<sub>2</sub>'.

(b)  $n_{\text{HCl}} = 2.0 \times 25/1000 = 0.0500 \text{ mol}^*$

$n_{\text{Mg}} = 0.0500 / 2 = 0.0250 \text{ mol}$

Mass of magnesium =  $0.0250 \times 24.3 = 0.61\text{g}$

Magnesium is the limiting reagent. Hence, an appropriate mass to use is 0.50g.

\* A reasonable volume of HCl(aq) to be used could be between 20 cm<sup>3</sup> – 200 cm<sup>3</sup> (to ensure the volume covers the bulb & to ensure that the volume does not exceed two-third of the capacity of the cup).

Mass of Mg used could be in the range of 0.486g to 4.86g based on the volume range of HCl(aq) used.

**[1] - correct calculation of  $n_{\text{Mg}}$**

**[1] – HCl(aq) in excess/Mg is limiting.**

Common mistakes include not reading the question and therefore failing to provide any form of justification (in the form of writing or calculations). Showing stoichiometric calculations would have been sufficiently clear enough as justifications for the quantities proposed.

Sufficient acid should be used to cover the bulb of the thermometer but preferably not exceed 2/3 of the styrofoam cup (capacity around 250 cm<sup>3</sup>) to avoid spillage. Hence an appropriate volume of HCl is 20 cm<sup>3</sup>– 200 cm<sup>3</sup>.

As the question suggests to suggest a volume of HCl and thereafter justify the mass of Mg, no. of moles of HCl should first be determined, and used to calculate the no. of moles of Mg, and not vice versa.

Mg must be the limiting reagent (or HCl in excess) as the objective of the experiment was to find out the enthalpy change of reaction for the reaction of Mg with HCl.

Another common error was to round up the value obtained for the mass of Mg to 3 significant figures when using the exact stoichiometric ratio of Mg to HCl to work out the mass. For example, if 25 cm<sup>3</sup> of HCl was used, the mass of Mg would be exactly 0.6075

g. Rounding up this mass to 0.61 g and using it as the proposed quantity would result in the Mg being in excess. And so the second mark was not awarded. It would always be safer to round down to ensure that the Mg is the limiting reagent.

- (c)
1. Weigh accurately 0.50 g (mass in part (b)) of magnesium into a weighing bottle.
  2. Measure out 25 cm<sup>3</sup> (vol. in part (b)) of hydrochloric acid into a polystyrene/styrofoam cup using a measuring cylinder/burette.
  3. Record the initial temperature of hydrochloric acid solution.
  4. Add solid magnesium into the cup, cover with a lid and stir the mixture gently.
  5. Record the highest temperature reached.

**[1] apparatus (weighing bottle, polystyrene cup, measuring cylinder)**

**[1] correct sequence**

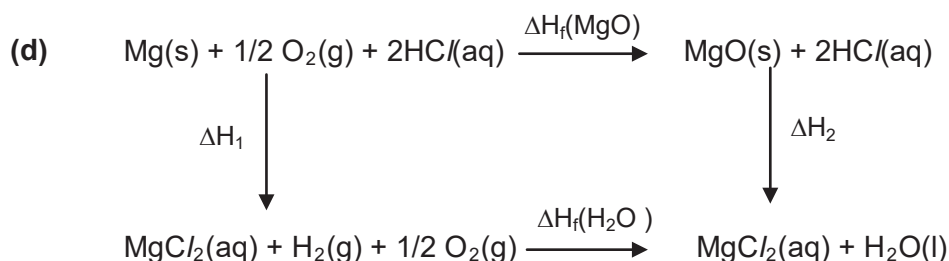
**[1] measurements (temperature, volume, mass)**

A procedure must be written in a logical sequence with essential details (e.g. quantities, apparatus, when and what measurements to take) such that someone else can follow the instructions and obtain the results without further guidance.

A common and costly mistake was to forget to weigh the Mg ribbon. Note also that Mg ribbon, not powder was provided. There was also a common tendency to leave out a weighing bottle for the weighing process. The correct terminology to use is electronic weighing balance (precise to 0.01g). What is used in the laboratory is strictly speaking not a weighing scale. A weighing scale is what you get in a vegetable market!

While the temperature correction procedure is indeed a better method, the student should look at the number of marks allocated and write a procedure that fits the awarded marks. The temperature correction procedure had many more steps and procedures and would definitely be awarded more marks. Students who used that procedure would have used up more time to write down everything correctly.

Do remember to stir the mixture with a thermometer to ensure even mixing as far as possible.



[2] for correct energy cycle.

Deduct  $\frac{1}{2}$  mark for each type of the following errors

- Missing or wrong state symbols, arrow direction, labels on arrows
- Unbalanced equations
- Accept labelling on arrows with correct symbols and/or values

The energy cycle was quite poorly done as most students failed to recognize that the hydrogen and oxygen gas produced formed water as part of the cycle and hence failed to include the enthalpy change of formation of water or combustion of hydrogen gas in their cycles. Most students failed to earn any marks here.

Common mistakes include using bond energy values for the formation of water. This is wrong as bond energy values are only applicable when the atoms and molecules are in gaseous state.

For an energy cycle, candidates need to ensure that the equations in the cycle are balanced and accompanied with state symbols.

(e) **Heat capacity**[1] of the cup is not accounted. This results in a lower calculated value for heat change and hence a **less exothermic enthalpy change** [1].

OR

**Heat loss to the surroundings**[1] is not accounted. This results in a lower calculated value for heat change and hence a **less exothermic enthalpy change**. [1]

For any thermo-chemistry experiment conducted in a school laboratory, one of the significant sources of errors will always be the loss of heat to the environment. The environment would encompass the apparatus, as well as the general space / air around the experimental setup.

Candidates can be more precise in their answer when discussing the impact of the enthalpy change, i.e. the resulting impact on enthalpy change is less exothermic.

- 2 (a)  $2\text{O}_3(\text{g}) \rightarrow 3\text{O}_2(\text{g})$  [1]  
State symbols not required.

- (b) Let  $a \text{ cm}^3$  be the initial volume of ozone, and  $(800-a) \text{ cm}^3$  be the initial volume of oxygen in the mixture.

	$2\text{O}_3(\text{g})$	$\rightarrow$	$3\text{O}_2(\text{g})$
Initial vol. / $\text{cm}^3$	$a$		$800 - a$
Change in vol.	$-2x$		$+3x$
Final vol. / $\text{cm}^3$	$a - 2x = 0$		$800 - a + 3x$

Total volume at the end of the reaction =  $819 \text{ cm}^3$

$$\therefore a - 2x + 800 - a + 3x = 819$$

$$\Rightarrow x = 19 \text{ cm}^3$$

When ozone is fully decomposed,  $a - 2x = 0$   
 $\Rightarrow a = 38 \text{ cm}^3$

Thus initial vol. of ozone =  $38 \text{ cm}^3$

And initial vol. of oxygen =  $800 - 38 = 762 \text{ cm}^3$

i.e. oxygen-ozone composition = 20 : 1

Or any other method of finding initial composition [2]

- (c) Rate =  $k[\text{O}_3]$  [1]

- (d) (i) Electronic configuration of O atom:



- (ii) The oxygen atom is considered a radical (in fact, it is a diradical) since it **possesses unpaired electrons in its 2p subshell.**[1]

- (iii) A reaction that forms oxygen atoms will generally be **slower** since they are high energy free radicals – the reaction would thus involve **a relatively high activation energy.**[1]

- (e)  $\text{O}_3 \rightarrow \text{O}_2 + \bullet\text{O}\bullet$  (slow)  
 $\bullet\text{O}\bullet + \text{O}_3 \rightarrow 2\text{O}_2$  (fast)

Correct elementary steps [1]

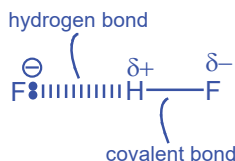
Relative speed of reaction/indication of correct r.d.s. [1]

(radical “ $\bullet$ ” not required to be shown)



- 3 (a) (i) There are a **total of 4 electrons around the central hydrogen** and this is rarely seen in hydrogen as it usually cannot hold more than 2 electrons in its valence shell. [1]

(ii)



[2] Correct structure showing the hydrogen bond, covalent bond, dipoles in HF and lone pair of electrons on fluoride.

- (iii) The **formation of the hydrogen bond between fluoride and HF weakens the covalent bond considerably** and coupled with the **unfavourable 4 electrons interactions around the central hydrogen**, result in the bond energy between H and F in bifluoride to weaken considerably.

[1] for the first underlined point.

Do not accept: The bond energy is now an average between that of the hydrogen bond and the H-F covalent bond.

(b) (i) 
$$K_1 = \frac{[H_3O^+][F^-]}{[HF]}$$

$$K_2 = \frac{[HF_2^-]}{[HF][F^-]}$$

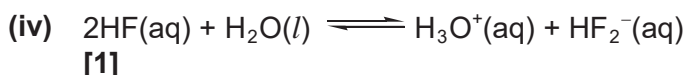
[1] for both correct expressions

(ii) 
$$[H_3O^+] = \frac{K_1[HF]}{[F^-]} = \frac{(1.1 \times 10^{-3})(8.89 \times 10^{-2})}{9.77 \times 10^{-3}} = 0.0100 \text{ mol}^{-1} \text{ dm}^3$$

[1] for correct calculation

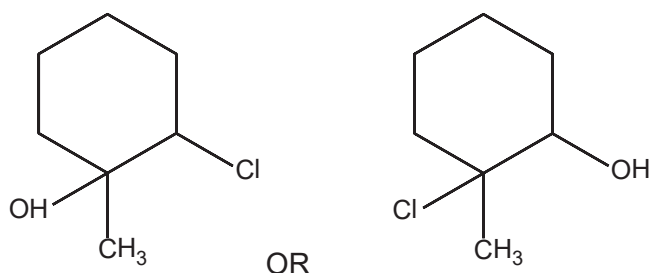
- (iii) As the system has no net charge, the total amount of anions must be the equal to the total amount of cations. The charged species ( $H_3O^+$  and  $F^-$ ) is derived from the partial dissociation of HF in water so their total amount must match. However  $F^-$  further dissociates to give  $HF_2^-$  and whatever amount of  $HF_2^-$  formed must come from  $F^-$ . Therefore  **$[F^-] + [HF_2^-] = [H_3O^+]$** .

[1] for relationship





4 (a)



[1] correct structure

Common mistake involves electrophilic addition of both Cl into the  $sp^2$  carbons. Some students even add bromine atom to the double bond.

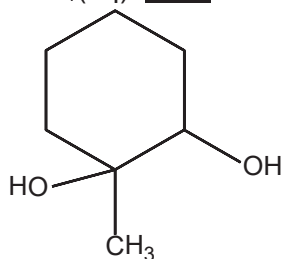
- (b) Reaction 1:  $Cl_2(g)$  or  $Cl_2$  in  $CCl_4$  [1]  
 Reaction 2:  $H_2$ , Ni catalyst, high temperature & pressure [1]

For reaction 1, the reaction can be carried out at room temperature in the absence of uv light or heat to prevent free radical substitution. Students should distinguish between  $Cl_2(g)$  and  $Cl_2(aq)$ ;  $Cl_2$  is a gas at rtp;  $Cl_2(aq)$  refers to  $Cl_2$  dissolved in  $H_2O$ . A number of students suggested  $Cl_2(l)$  as the reagent which is not possible. For reaction 1, it is clearly electrophilic addition of  $Cl_2$  into 1-methylcyclohexene. The only nucleophile that can attack the carbocation is  $Cl^-$  and the final product should be 1,2-dichloromethylcyclohexane. For reaction 2, other catalysts such as Pt or Pd can be accepted. Reaction 2 requires conditions of high temperature and pressure to proceed. While in general, conditions are stated correctly, a number of students missed out on stating  $H_2$  gas as a reagent.

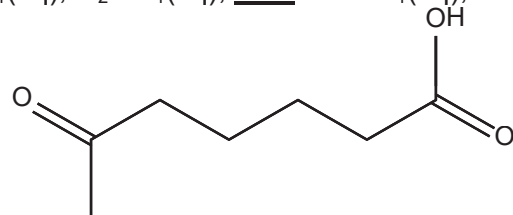
- (c) Addition/Reduction/Hydrogenation [1]  
 Do not accept: Electrophilic addition

The question asked for "type" of reaction; do not accept hydrogenation (this is "name" of reaction not "type"). Electrophilic addition is not acceptable because the addition of hydrogen across the double bond requires the use of heterogeneous catalysts. (Please refer to Reaction Kinetics pg XXX).

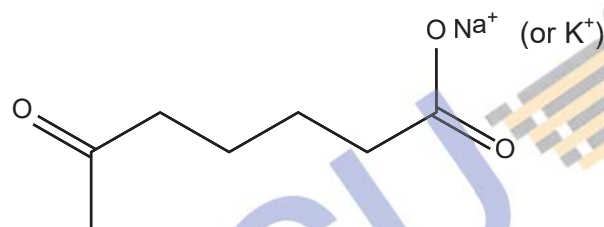
(d) Cold  $\text{KMnO}_4(\text{aq})$ / Cold  $\text{KMnO}_4(\text{aq})$ ,  $\text{NaOH}(\text{aq})$ / Cold  $\text{KMnO}_4(\text{aq})$ ,  $\text{H}_2\text{SO}_4(\text{aq})$



$\text{KMnO}_4(\text{aq})$ ,  $\text{H}_2\text{SO}_4(\text{aq})$ , heat/  $\text{KMnO}_4(\text{aq})$ ,  $\text{NaOH}(\text{aq})$ , heat



(acidic conditions)



(alkaline conditions)

[1] for **both reagents and conditions** stated correctly

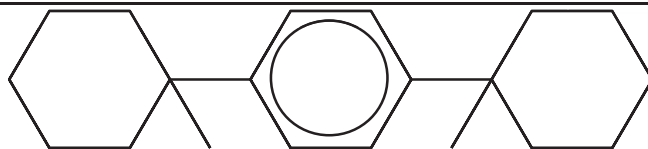
[1] each for the two products (diol & carboxylic acid) drawn correctly.

The symbol [O] used in a balanced equation in oxidative cleavage or diol formation represents oxidising agent such as  $\text{KMnO}_4$ ; they are not oxygen atoms. Students commonly missed out on stating the oxidising agent or use [O] to represent the oxidising agent, which is not accepted.

Since the question requires reagents to be stated, giving acidic ( $\text{H}^+$ ) or alkaline ( $\text{OH}^-$ ) conditions as the answer will not be accepted. Reagents such as dilute  $\text{H}_2\text{SO}_4(\text{aq})$  or  $\text{NaOH}(\text{aq})$  must be clearly stated.

$\text{KMnO}_4$  is acidified using dilute  $\text{H}_2\text{SO}_4(\text{aq})$  and not dilute  $\text{HCl}(\text{aq})$  because  $\text{KMnO}_4$  would oxidise  $\text{HCl}$  to  $\text{Cl}_2$ . (Refer to chapter 1 page 28)

(e)



The alkyl group is an **electron-donating group**. Once it is substituted into the benzene ring, it will **activate the benzene ring** towards electrophilic substitution/ **make the ring more susceptible to electrophiles**, resulting in polyalkylation. Only the 1,4-disubstituted product is formed. (1,2-substituted product is not formed due to steric hindrance).

[1] for structure. Accept 1,2-substituted and 1,3-substituted products.

[1] explanation.



1,4-disubstituted product is the major product

1,2-disubstituted and 1,3-disubstituted products are the minor products

The product of reaction 3 consists of 13 carbons, and the side product has the formula of  $C_{20}H_{30}$ . This suggests that there is an additional 7 more carbons, which means another 1-methylcyclohexane alkyl group is substituted on the same benzene ring, resulted in di-substitution of alkyl group occurred.

1,2-disubstituted product is the minor product and unlikely to be formed due to steric hindrance between the two bulky alkyl groups.

1,3-disubstituted product is the minor product as the alkyl group is activating and therefore, is 2-4-directing.



- 5 (a) (i)  $sp^2$  [1]  
(ii) p-orbital [1]

- (b) (i) Bond Energy of the  $1^\circ$  C–H bond is the strongest and that of the  $3^\circ$  C–H bond is the weakest. Since the  **$3^\circ$  C–H bond is the easiest to break**, it is the most reactive. [1]

(ii)

Structure	Label (A, B, C or D)	Explanation
$\begin{array}{c} \text{H} \quad \text{CH}_3 \\   \quad   \\ \text{Cl/H}_2\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	<b>A</b>	<ul style="list-style-type: none"> <li>Since <b>B</b> and <b>C</b> are optically active, they can only be:</li> </ul> $\begin{array}{c} \text{Cl} \quad \text{CH}_3 \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array} \quad \text{or} \quad \begin{array}{c} \text{H} \quad \text{CH}_2\text{Cl} \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
$\begin{array}{c} \text{Cl} \quad \text{CH}_3 \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	<b>B</b>	
$\begin{array}{c} \text{H} \quad \text{CH}_2\text{Cl} \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	<b>C</b>	<ul style="list-style-type: none"> <li>Since there is twice the amount of <b>C</b> as compared to <b>A</b>, the hydrogen atoms responsible for their formation should be from the <math>\text{CH}_3</math> groups.</li> </ul> $\begin{array}{c} \text{H} \quad \text{CH}_3 \\   \quad   \\ \text{Cl/H}_2\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$ <p><b>A</b> must be and <b>C</b> must be</p> $\begin{array}{c} \text{H} \quad \text{CH}_2\text{Cl} \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
$\begin{array}{c} \text{H} \quad \text{CH}_3 \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{Cl} \end{array}$	<b>D</b>	

[2] for 4 correct structures

[2] for correct labelling of the 4 structures

[2] explanation



**HWA CHONG INSTITUTION**  
**C1 Promotional Examination**  
**Higher 2**

NAME

CT GROUP

14S

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**CHEMISTRY**

**9647/03**

**Paper 3 Free Response**

**26 September 2014**

**1 hr**

Candidates answer on separate paper.

Additional Materials: Answer Paper, Cover Page and Data Booklet.

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**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer Question 1 and either Question 2 or Question 3.

A Data Booklet is provided.

You may use a calculator.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each part question.

At the end of the examination, fasten all your work securely together, together with the cover page.

All candidates should answer Question 1.

1 Nitrogen forms several oxides, such as NO, NO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>3</sub> and N<sub>2</sub>O<sub>5</sub>.

(a) Nitrogen monoxide, NO, reacts with oxygen to form nitrogen dioxide, NO<sub>2</sub>.



The kinetics of Reaction 1 was studied by reacting NO and O<sub>2</sub> at 25 °C at constant volume. The following data was obtained.

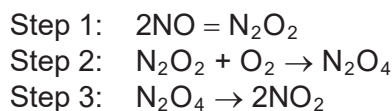
Experiment	1	2	3
Initial partial pressure of NO / kPa	6.00	3.00	3.00
Initial partial pressure of O <sub>2</sub> / kPa	7.00	14.00	21.00
Partial pressure of O <sub>2</sub> after 40 s / kPa	6.68	13.84	20.76
Initial rate of reaction / kPa s <sup>-1</sup>	0.00800	0.00400	0.00600

The rate equation may be written as

$$\text{Rate} = k(p_{\text{NO}})^m(p_{\text{O}_2})^n$$

- (i) Show that the order of reaction with respect to NO and O<sub>2</sub> is 2 and 1 respectively.
- (ii) Find the rate constant k.
- (iii) Find the total pressure after 40 s in Experiment 1.

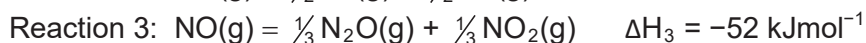
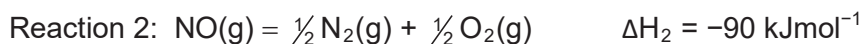
The mechanism for Reaction 1 was suggested as follows:



- (iv) Draw the dot-and-cross diagram for the intermediate dimer N<sub>2</sub>O<sub>2</sub>, given that oxygen are the terminal atoms.
- (v) Use the Data Booklet to suggest a value for ΔH of Step 1.
- (vi) Suggest which of the three steps in the mechanism is the rate-determining step. You should use information obtained from the kinetics experiment to support your answer.
- (vii) Give a reason why it is important that oxides of nitrogen are removed from the exhaust gas of vehicles.

[10]

- (b) Under suitable conditions, nitrogen monoxide can undergo either of the following reactions.



The activation energy of Reaction 2,  $E_{a2}$ , is much greater than that of Reaction 3,  $E_{a3}$ .

- (i) Using the same axes, construct a fully-labelled reaction pathway diagram for these two reactions.
- (ii) State and explain what conditions of pressure and temperature (high or low) might favour nitrogen monoxide undergoing Reaction 3 over Reaction 2. You should consider ideas of chemical equilibria and reaction kinetics in your answer.

[6]

- (c) Nitrogen monoxide reacts with hydroxide ions to give three products, namely nitrite ( $\text{NO}_2^-$ ), an oxide of nitrogen **Z** and water.

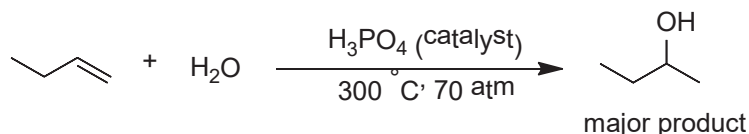
- (i) Given that the reaction is a disproportionation, deduce the oxidation number of nitrogen in **Z**, showing your reasoning. Refer to the oxides of nitrogen listed at the beginning of Question 1 and hence suggest the identity of **Z**.
- (ii) Write a balanced equation for the reaction.

[4]

[Total: 20]

Answer either Question 2 or Question 3.

- 2 Addition is an important class of reactions for alkenes and it can be used to prepare a variety of organic compounds. Industrially, butan-2-ol is produced through the hydration of butene.



The reaction occurs in several steps.

- The first step is a reaction between the alkene and the  $\text{H}^+$  from  $\text{H}_3\text{PO}_4$ .
- The intermediate then reacts with water, and eventually forms the alcohol.

- (a) (i) State the name of the mechanism and draw diagrams to illustrate the mechanism of this reaction. Show the structure of the intermediate, relevant lone pairs and dipoles, and use curly arrows to indicate the movement of electron pairs.

- (ii) Explain why butan-2-ol is the major product of this reaction instead of butan-1-ol.

[4]

- (b) (i) Deduce the sign of the entropy change of the system when butene reacts with water at the given conditions.

- (ii) The hydration of butene is an exothermic reaction. Under what conditions will the reaction be spontaneous? Give reasons for your answer.

[3]

- (c) Butene also undergoes an addition reaction with hydrogen gas, which is commonly known as hydrogenation. The reaction is carried out in the presence of an iron catalyst, at high temperature and pressure.

- (i) State the type of catalysis which occurs.

- (ii) Describe the mode of action of iron in hydrogenation of butene.

[4]

- (d) The compressibility factor,  $Z = \frac{pV_m}{RT}$ , where  $V_m$  is the volume of 1 mol of the gas, is a measure of ideality of a real gas over a range of pressure. A compressibility graph is obtained by plotting  $Z$  against pressure at constant temperature.

- (i) Sketch a compressibility graph, which compares the compressibility factor of 1 mol of ideal gas and butene.

- (ii) Account for the shape of your sketch of  $Z$  against pressure for butene at low pressure.

- (iii) Methane, like butene, is not an ideal gas. Predict and explain which gas behaves less ideally.

[4]

- (e) **W** is an organic compound with formula  $C_9H_{10}$ . When aqueous bromine is added dropwise to a sample of **W**, the aqueous bromine remains yellow. Reaction of **W** with  $Cl_2$  in the presence of uv light yields two monochlorinated products, **X** and **Y**. **W** was also reacted with acidified potassium manganate(VII), and carbon dioxide was produced in addition to compound **Z**. It was found that **Z** reacts with sodium hydroxide in a 1:2 ratio.

Suggest structures for the compounds **W**, **X**, **Y** and **Z** and explain the observations.

[5]

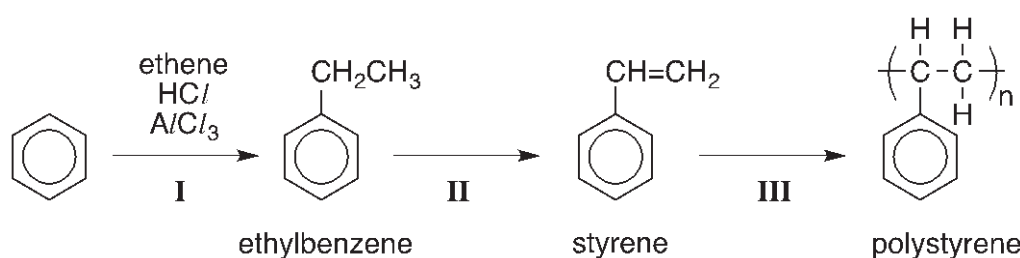
[Total: 20]

3 Michael Faraday first discovered benzene in 1825. Forty years later, Friedrich August Kekulé proposed a six-membered carbon ring. In 1928, studies confirmed that benzene is hexagonal and flat.

(a) Describe the structure of benzene in terms of hybridization, its orbitals and bonding. You may find that including suitable sketches or diagrams will help you in your answer. [3]

(b) Explain why benzene forms a separate layer in water but is completely miscible in ethanol. [3]

Benzene is useful as a starting material in the industrial production of polystyrene, a widely used polymer in toys, food containers and packaging material. The reaction scheme below shows the steps in the production of polystyrene from benzene.



$\text{HC/}$  and  $\text{AlCl}_3$  act as catalysts in Reaction I.

(c) (i) In Reaction I, ethene,  $\text{HC/}$  and  $\text{AlCl}_3$  react to form an electrophile and  $\text{AlCl}_4^-$ . The electrophile then reacts with benzene to form ethylbenzene. Identify this electrophile and write an equation to show its formation.

(ii) Describe the mechanism of the reaction between the electrophile and benzene to form ethylbenzene. In your answer, show clearly the movement of electrons, the structure of the intermediate, and the regeneration of the catalysts.

(iii) When propene is used in Reaction I instead of ethene, only **one** of two possible isomers is formed in significant amount. Draw the structure of this isomer and explain why it is the one formed in significant amount. [7]

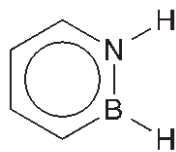
(d) Reaction II is a catalytic reaction which forms styrene and another product. Write the formula of the other product formed in Reaction II. [1]

(e) After the discovery of benzene, scientists sought to synthesize analogs of benzene, containing boron and nitrogen atoms in place of carbon atoms so as to study their properties.

(i) Draw energy level diagrams to represent the electrons in the **atomic** orbitals of boron and nitrogen respectively. Show in your diagrams the relative energy levels of the orbitals within each atom.



One analog, **X**, had been particularly elusive despite its simple structure. It was synthesized only in 2009, after decades of attempts.



**X**

The structure of **X** is similar to benzene, with two adjacent carbon atoms replaced with boron and nitrogen atoms.


- (ii) **X** is a planar molecule. State the hybridization of boron and nitrogen in **X**.
- (iii) Given that **X** is aromatic like benzene, deduce the number of electrons that boron and nitrogen **each** contribute to the aromatic ring.

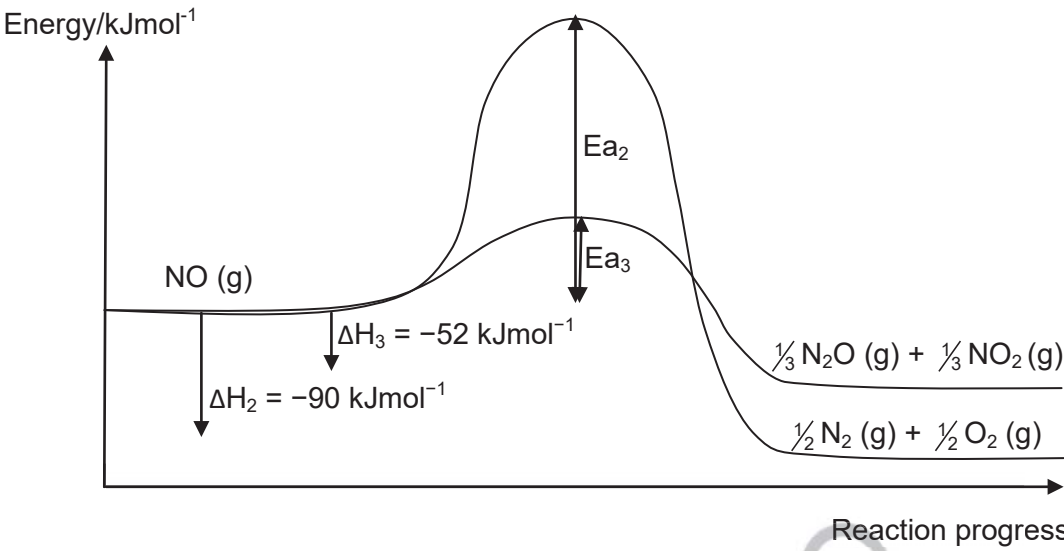
[6]

[Total: 20]

-- End of paper --

## Question 1 Answers

(a)	(i)	$\frac{Rate_2}{Rate_3} = \frac{k(3)^m(14)^n}{k(3)^m(21)^n} = \frac{0.00400}{0.00600}$ $n = 1 \text{ shown [1]}$ $\frac{Rate_1}{Rate_2} = \frac{k(6)^m(7)}{k(3)^m(14)} = \frac{0.00800}{0.00400}$ $m = 2 \text{ shown [1]}$
	(ii)	$Rate = k(p_{NO})^2(p_{O_2})$ $0.00800 = k(6)^2(7)$ $k = 3.18 \times 10^{-5} \text{ kPa}^{-2} \text{ s}^{-1} \text{ [1] for value and [1] for units}$
	(iii)	$p_{NO, 40s} = 6.00 - 2(7.00 - 6.68) = 5.36 \text{ kPa}$ $p_{NO_2, 40s} = 2(7.00 - 6.68) = 0.64 \text{ kPa}$ $p_{Total, 40s} = 6.68 + 5.36 + 0.64 = 12.68 \text{ kPa or } 12.7 \text{ kPa (3sf) [1]}$
	(iv)	
	(v)	$-160 \text{ kJ mol}^{-1} \text{ (for N-N bond) [1]}$
	(vi)	<p>Step 2 is the rate-determining step. [1], no marks without any reasoning</p> $Rate = k p_{N_2O_2} p_{O_2}$ $= k K_p (p_{NO})^2 (p_{O_2})$ $= k' (p_{NO})^2 (p_{O_2}) \text{ which is consistent with the orders of reaction obtained. [1]}$
	(vii)	<p>Oxides of nitrogen contribute to the production of photochemical smog. [1]</p>

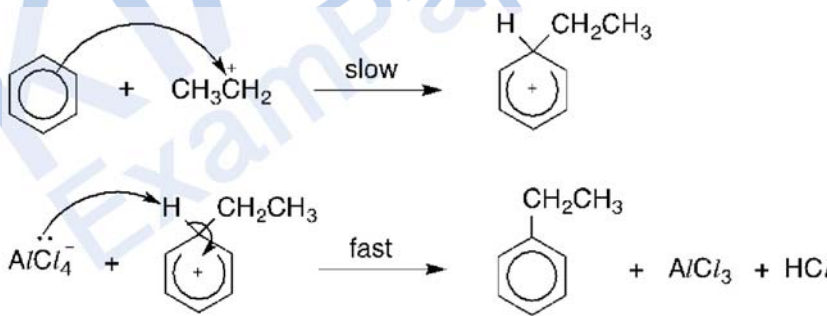
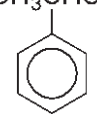
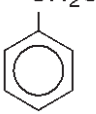
(b)	<p>(i)</p>  <p>[0.5] for axis/labels, [0.5] for reactant and product labels, [0.5] for relative activation energies, [0.5] for relative enthalpy changes</p>
	<p>(ii)</p> <p>High pressure, low temperature [2 x 1]</p> <p>By Le Chatelier's Principle, high pressure will favour Reaction 3 as the equilibrium will shift towards the right hand side as there are fewer number of gaseous molecules. There is no change in the number of gaseous molecules for Reaction 2. [1]</p> <p>Low temperature will favour both exothermic forward reactions energetically but kinetically it will favour Reaction 3 more than Reaction 2 because the activation energy of Reaction 2 is much greater than that of Reaction 3 and most molecules will not have enough energy to overcome this large <math>E_a</math> at low temperature. [1]</p>
(c)	<p>(i)</p> <p>Oxidation number of N in NO = +2 Oxidation number of N in <math>\text{NO}_2^-</math> = +3</p> <p>As the reaction is a disproportionation, the oxidation number of N in Z must be +1 (it must be less than +2 yet positive as Z is a nitrogen oxide)</p> <p>[1] for +1 and [1] for correct explanation</p> <p>Z = <math>\text{N}_2\text{O}</math> [1]</p>
	<p>(ii)</p> <p><math>4\text{NO} + 2\text{OH}^- \rightarrow 2\text{NO}_2^- + \text{N}_2\text{O} + \text{H}_2\text{O}</math> [1]</p>

## Answers

2	(a)	(i)	<p>Electrophilic Addition</p> <p>*** Accept transfer of proton from <math>\text{H}_3\text{PO}_4</math></p> <p>*** Accept deprotonation using <math>\text{H}_2\text{O}</math> and <math>\text{H}_2\text{PO}_4^-</math></p> <p>[1] Name of reaction [2] Mechanism (–1/2 for each type of mistake. Arrows, lone pairs, slow step, structure of carbocation)</p>
		(ii)	<p>When butene reacts with a proton in the slowest step, it can form either a secondary carbocation or a primary carbocation. <b>Secondary carbocations are more stable than primary carbocations</b> because there are more electron-donating alkyl substituents which <u>disperse</u> the positive charge to a greater extent. Hence, the major product is a secondary alcohol. [1]</p>
	(b)	(i)	<p>As the reaction proceeds, the <b>number of gaseous molecules decreases</b>, thus there are <b>less ways in which energy can be distributed in the system</b> and the entropy of the system decreases. [1]</p>
		(ii)	<p>For a spontaneous reaction, <b><math>\Delta G</math> has to be less than zero</b>. [1] Given that hydration is exothermic and the entropy of the system decreases as the reaction proceeds, <b><math>\Delta G</math> will be negative when <math>\Delta H &lt; T\Delta S</math>, thus the reaction will be spontaneous at low temperature</b>. [1]</p>
	(c)	(i)	<p><b>Heterogeneous catalysis</b> [1]</p>
		(ii)	<ul style="list-style-type: none"> <li>The reactants diffuse onto the surface of the iron catalyst and are <u>adsorbed onto the active sites</u>.</li> <li>This results in <u>formation of weak partial bonds</u> between iron and the reactant.</li> <li>This also <u>weakens the bonds in the reactant molecule</u> and thus the <u>activation barrier is lower</u>.</li> <li>This brings the <u>reactants closer together</u>.</li> <li>This also causes the molecules to be <u>orientated in the correct direction</u>, thus the frequency of effective collisions increases.</li> <li>Once butane is formed, it is <u>desorbed from the active site</u> and diffuses away. Thus the <u>active site is regenerated</u>.</li> </ul> <p>6 points [3 m] 4 – 5 points [2 m] 2 – 3 points [1 m] 0 – 1 point [0 m]</p>

(d)	<div> <p>(i)</p> <p>**y-intercept is not required**  [1] for ideal gas  [1] for butene</p> </div>														
	<p>(ii)</p> <p>At low pressure, <b>dispersion forces between butene molecules cause the molecules to be closer than expected</b>, thus the product, <math>pV</math>, of the butene is smaller than that of an ideal gas at low pressure, and hence <math>Z_{\text{Real Gas}} &lt; Z_{\text{Ideal Gas}}</math>. [1]</p>														
	<p>(iii)</p> <p>Butene will deviate from ideality to a greater extent than methane at low pressure. This is because <b>butene has a greater number of electrons and thus a larger electron cloud than methane</b>, thus the <b>dispersion forces between butene molecules is stronger and thus more significant</b> than the dispersion forces between methane molecules. [1]</p>														
(e)	<p><b>List of relevant deductions</b></p> <table border="1"> <thead> <tr> <th>Observation</th><th>Deduction</th></tr> </thead> <tbody> <tr> <td>• High C:H ratio</td><td>• <b>W</b> contains benzene ring or many double bonds</td></tr> <tr> <td>• Aqueous bromine is not decolourised</td><td>• <b>W</b> does not contain double or triple bonds</td></tr> <tr> <td>• <b>W</b> reacts with <math>\text{Cl}_2</math> in the presence of uv light</td><td>• <b>W</b> contains alkyl groups</td></tr> <tr> <td>• <b>W</b> reacts with acidified potassium manganate(VII)</td><td>• Oxidation has occurred</td></tr> <tr> <td>• Carbon dioxide is formed</td><td>• Oxidative cleavage of a <math>=\text{CH}_2</math> or <math>-\text{CH}_3</math> group has occurred.</td></tr> <tr> <td>• <b>Z</b> reacts with sodium hydroxide in a 1:2 ratio</td><td>• <b>Z</b> contains two carboxylic acid functional groups</td></tr> </tbody> </table> <div style="text-align: center; margin-top: 20px;"> <div style="display: flex; justify-content: space-around; width: 100%;"> <span><b>W</b></span> <span><b>X</b></span> <span><b>Y</b></span> <span><b>Z</b></span> </div> </div> <p>[1] each for <b>W</b>, <b>X/Y</b>, and <b>Z</b>  [2] for any 2 relevant deductions</p>	Observation	Deduction	• High C:H ratio	• <b>W</b> contains benzene ring or many double bonds	• Aqueous bromine is not decolourised	• <b>W</b> does not contain double or triple bonds	• <b>W</b> reacts with $\text{Cl}_2$ in the presence of uv light	• <b>W</b> contains alkyl groups	• <b>W</b> reacts with acidified potassium manganate(VII)	• Oxidation has occurred	• Carbon dioxide is formed	• Oxidative cleavage of a $=\text{CH}_2$ or $-\text{CH}_3$ group has occurred.	• <b>Z</b> reacts with sodium hydroxide in a 1:2 ratio	• <b>Z</b> contains two carboxylic acid functional groups
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## Answers

3 (a)	<p>Each carbon atom in benzene is <math>sp^2</math> hybridised and bonded to one hydrogen atom, and two other carbon atoms in a trigonal planar geometry. The six carbon atoms form a planar ring. [1]</p> <p>Each carbon atom has an unhybridised p orbital perpendicular to the plane of the ring. Each of the 6 unhybridised p orbital overlaps with its adjacent p orbitals [1] forming a delocalized electron cloud of 6 electrons above and below the plane [1] of the benzene ring.</p>
3 (b)	<p>Benzene is immiscible with water because the energy released by forming weak solute-solvent (id-pd) interactions is not sufficient to compensate the energy required to overcome the dispersion forces between benzene molecules and the relatively strong hydrogen bonding between water molecules.</p> <p>Benzene is miscible in ethanol because it can form favorable dispersion forces with the hydrocarbon chain in ethanol, which is strong enough to release energy to overcome the hydrogen bonding and dispersion forces between ethanol molecules and the dispersion forces between benzene molecules.</p> <p>Identify hydrogen bonding between water molecules, dispersion forces between benzene molecules [1]          Identify dispersion forces between benzene and ethanol molecules, hydrogen bonding (&amp; dispersion forces) between ethanol molecules [1]          Compare the relative strengths (energy) correctly [1]</p>
3 (c) (i)	<p><math>CH_2=CH_2 + HCl + AlCl_3 \rightarrow AlCl_4^- + CH_3CH_2^+</math></p> <p>Correct equation and electrophile [1]</p>
3 (c) (ii)	<p>Electrophilic substitution [1]</p>  <p>Correct movement of electrons [1]          Correct intermediate structure [1]          Correct slow/fast step and regeneration of catalysts [1]</p>
3 (c) (iii)	<p>   </p> <p>[1] is formed in significant amount compared to</p> <p>The (secondary) carbocation intermediate <math>CH_3CH^+CH_3</math> is more stable than the (primary) carbocation intermediate <math>CH_3CH_2CH_2^+</math>, hence <math>CH_3CH^+CH_3</math> forms the major product. [1]</p>

	(d)	H <sub>2</sub>	[1]
	(e)	(i)	<p>boron                      nitrogen</p> <p>correct electronic configuration for B and N [2]  relative energy levels (gap between 1s and 2s bigger than between 2s and 2p,  correct sequence of orbitals) [1]</p>
		(ii)	sp <sup>2</sup> hybridization for B [1/2]; sp <sup>2</sup> hybridization for N [1/2]
		(iii)	N contributes two electrons (its lone pair) to the $\pi$ electron cloud of the ring [1] B does not contribute electrons to the $\pi$ electron cloud of the ring [1]