



**NATIONAL JUNIOR COLLEGE**  
**SH2 PRELIMINARY EXAMINATION**  
Higher 2

CANDIDATE  
NAME

SUBJECT  
CLASS

REGISTRATION  
NUMBER

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**CHEMISTRY**

Paper 1 Multiple Choice

Additional Materials:

Optical Answer Sheet  
Data Booklet

**9729/01**

**Thur 13 September 2018**

**1 hour**

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**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **30** 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 separate Answer Sheet.

**Read the instructions on the Answer Sheet very carefully.**

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.


The use of an approved scientific calculator is expected, where appropriate.

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This paper consists of **17** printed pages

NJC Preliminary Examination 9729/01/18

**Instructions on how to fill in the Optical Mark Sheet**

1. Enter your NAME ( as in NRIC ). <u>TAN AH TECK</u> 2. Enter the SUBJECT TITLE. <u>CHEMISTRY</u> 3. Enter the TEST NAME. <u>SH2 Prelim</u> 4. Enter the CLASS. <u>cmA</u>	<p><b>RUB OUT ERRORS THOROUGHLY</b></p> <p><b>USE PENCIL ONLY FOR ALL ENTRIES ON THIS SHEET</b> </p> <table border="1"> <tr> <td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td> </tr> <tr> <td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input checked="" type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td> </tr> <tr> <td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td> </tr> <tr> <td><input type="checkbox"/></td><td><input checked="" type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td> </tr> <tr> <td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td> </tr> <tr> <td><input checked="" type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td><td><input type="checkbox"/></td> </tr> </table>	0	1	2	3	4	5	6	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	1	2	3	4	5	6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	1	2	3	4	5	6	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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Student	Examples of Registration No.	Shade:
	<b>1705648</b>	<b>75648</b>

*Example:*

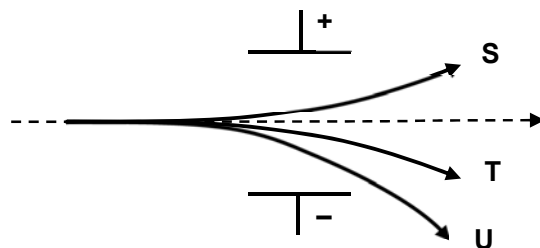
Shade the index number in a 5 digit format on the optical mark sheet:

2<sup>nd</sup> digit and the last 4 digits of the Registration Number.

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

- 1 Use of the Data Booklet is relevant to this question.

The following are flight paths of charged particles when accelerated in an electric field.



Which correctly identifies **S**, **T** and **U**?

	<b>S</b>	<b>T</b>	<b>U</b>
<b>A</b>	$^{15}\text{O}^+$	$^{14}\text{C}^+$	$^{14}\text{N}^+$
<b>B</b>	$^{15}\text{O}^-$	$^{15}\text{O}^+$	$^{28}\text{Si}^+$
<b>C</b>	$^{14}\text{N}^-$	$^{28}\text{Si}^{2+}$	$^{14}\text{C}^{2+}$
<b>D</b>	$^{14}\text{N}^-$	$^{14}\text{C}^+$	$^{28}\text{Si}^{2+}$

- 2 In which sequence is the molecules listed in the order of increasing dipole moment?

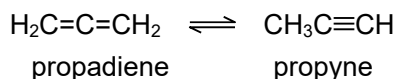
- A**  $\text{SO}_3$ ,  $\text{CO}_2$ ,  $\text{AlCl}_3$                       **B**  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{S}$ ,  $\text{HBr}$   
**C**  $\text{CF}_4$ ,  $\text{CO}$ ,  $\text{HF}$                       **D**  $\text{NH}_3$ ,  $\text{HF}$ ,  $\text{BeCl}_2$

- 3 In which row are the molecules arranged in order of increasing bond angle?

- 1**  $\text{CH}_4$ ,  $\text{AlCl}_3$ ,  $\text{XeF}_2$   
**2**  $\text{H}_2\text{S}$ ,  $\text{PH}_3$ ,  $\text{NH}_3$ ,  
**3**  $\text{NF}_3$ ,  $\text{NCl}_3$ ,  $\text{SO}_3$

- A** 1, 2 and 3                      **B** 1 and 2  
**C** 2 and 3                      **D** 1 only

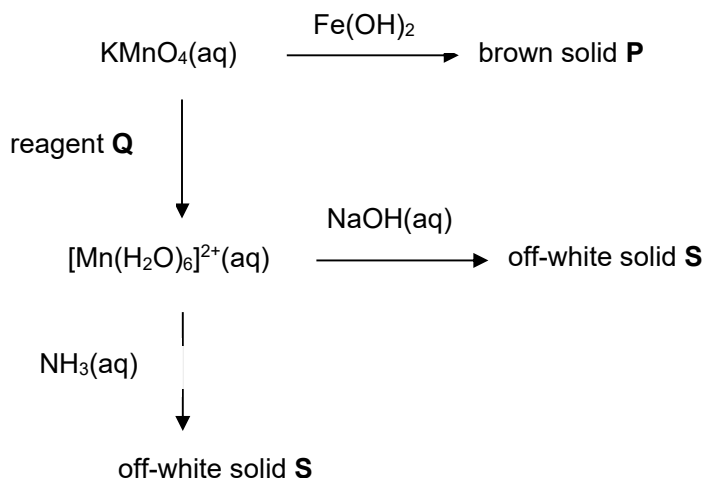
- 4 Propadiene and propyne both have the same molecular formula,  $C_3H_4$ . They exist in equilibrium as shown:



Which bond is present in propadiene but **not** present in propyne?

- A a  $\sigma$  bond formed by s – sp overlap  
 B a  $\pi$  bond formed by p – p overlap  
 C a  $\sigma$  bond formed by sp –  $sp^2$  overlap  
 D a  $\sigma$  bond formed by  $sp^2$  –  $sp^2$  overlap
- 5 *Use of the Data Booklet is relevant to this question.*

A reaction scheme regarding manganese compounds is shown below.



Which statements are true?

- 1 Off-white solid **S** is able to dissolve in excess of  $NH_3(aq)$ .  
 2 Manganese in brown solid **P** has an oxidation state of +4.  
 3 Reagent **Q** can be acidified  $[V(H_2O)_6]^{3+}(aq)$ .  
 4 Off white solid **S** turns brown upon standing.
- A 1, 2 and 4  
 B 2, 3 and 4  
 C 2 and 3  
 D All correct

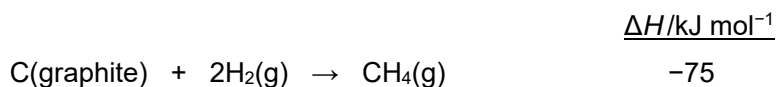
- 6 In which chemical reaction does the transition metal compound or element behave as the described catalyst?

	Reaction	Catalyst
1	Formation of ethanal from ethanol, using acidified potassium dichromate	Homogeneous
2	Formation of oxygen from hydrogen peroxide, using iron(III) hydroxide	Heterogeneous
3	Chlorination of benzene, using chlorine and iron(III) chloride	Homogeneous
4	Removal of air pollutants in exhaust systems of cars, using nickel	Heterogeneous

- A 1, 2 and 4                                      B 2 and 3  
C 3 and 4    D 2, 3 and 4

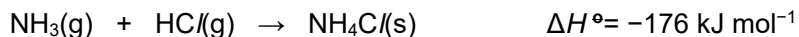
- 7 *Use of the Data Booklet is relevant to this question.*

Given the following standard enthalpy changes,



What is the standard enthalpy change of atomisation of graphite?

- A +693 kJ mol<sup>-1</sup>  
B +1129 kJ mol<sup>-1</sup>  
C -2151 kJ mol<sup>-1</sup>  
D -2587 kJ mol<sup>-1</sup>
- 8 Ammonia gas and hydrogen chloride gas react to form ammonium chloride as shown in the equation below:



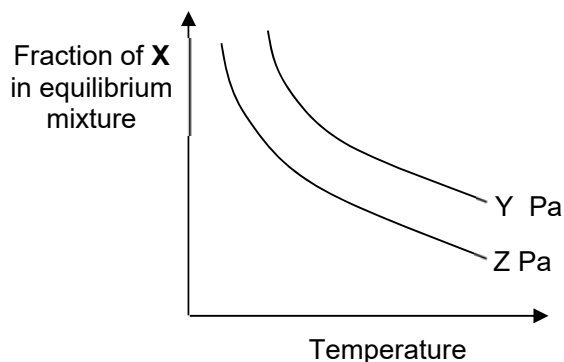
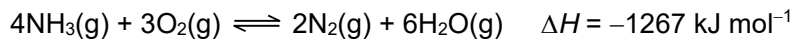
The magnitude of standard entropy change of this reaction is 284 J K<sup>-1</sup> mol<sup>-1</sup>.

Which statements are correct?

- 1  $\Delta G^\circ = -261 \text{ kJ mol}^{-1}$ .  
2 The reaction becomes non-spontaneous at temperatures higher than 620 K.  
3 There is an increase in order as strong hydrogen bonding between NH<sub>3</sub> and HCl hold the particles in NH<sub>4</sub>Cl in fixed positions and close to each other.

- A 1 only                                      B 1 and 2                                      C 2 only                                      D 2 and 3

- 9 The graph below shows how the fraction of **X**, which represents one of the following compounds in the given equilibrium mixture, varies with temperature at pressures of Y Pa and Z Pa.



Identify **X** and the correct relative magnitudes of Y and Z.

	<b>X</b>	<b>Pressure</b>
<b>A</b>	N <sub>2</sub>	Z > Y
<b>B</b>	O <sub>2</sub>	Y > Z
<b>C</b>	H <sub>2</sub> O	Y > Z
<b>D</b>	NH <sub>3</sub>	Z > Y

- 10 One of the key production stages in the Contact Process is the production of sulfur trioxide.

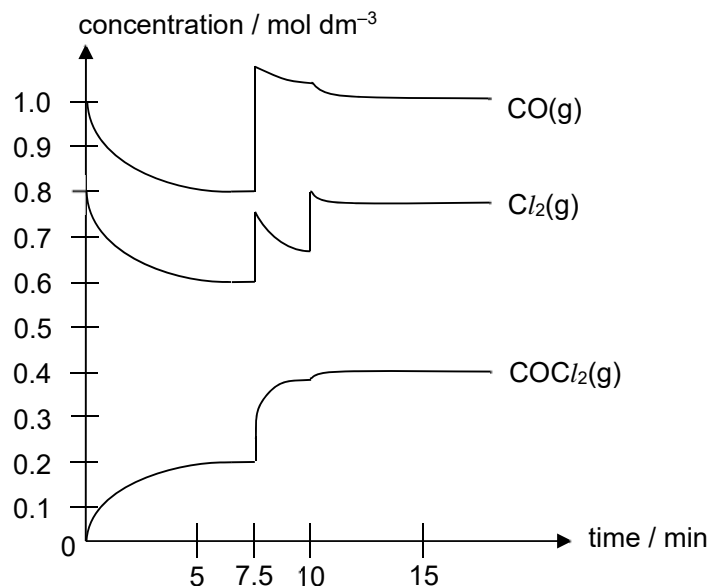
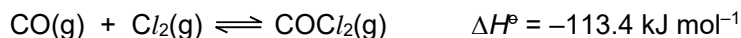


The rate constants of the forward and backward reactions are given as  $k_1$  and  $k_{-1}$  respectively.

What happens to  $k_1$ ,  $k_{-1}$  and  $K_c$  if the temperature of the reaction is increased?

	$k_1$	$k_{-1}$	$K_c$
<b>A</b>	increase	increase	increase
<b>B</b>	increase	decrease	increase
<b>C</b>	decrease	increase	decrease
<b>D</b>	increase	increase	decrease

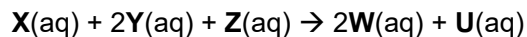
- 11 The reaction between carbon monoxide and chlorine was studied in an experiment by mixing the two gases and changing the reaction conditions inside the reaction vessel at different times during the experiment. The concentrations of the gases in the vessel were followed with time, and the following graph is obtained.



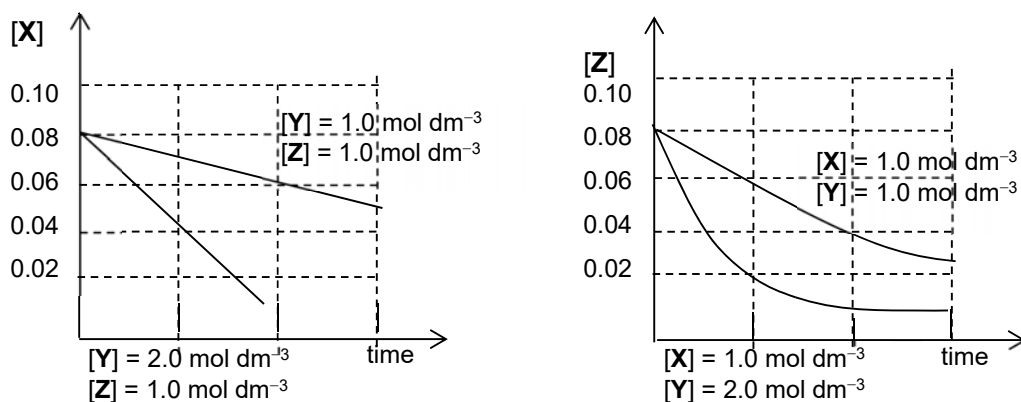
Which conclusion deduced from the graph is **incorrect**?

- A The rate of forward reaction equals the rate of backward reaction at 7 min.
- B The change in concentration from 7.5 min to 10 min was produced by an increase in volume at constant temperature.
- C The equilibrium constant,  $K_c$ , for the system when determined at 7 min is  $0.417 \text{ mol}^{-1} \text{ dm}^3$ .
- D The change in concentration from 10 min to 15 min was produced by the addition of more chlorine.

- 12 Substances **X**, **Y** and **Z** react according to the following equation:



To find the rate equation for the above reaction, two sets of separate experiments were performed, in which the initial concentrations of each of the reactants **X**, **Y** and **Z** were varied while the other two were kept constant. The results are shown below.

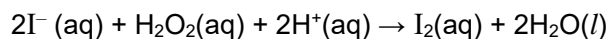


Which rate equations represent the experimental results?

- |   |   |
|---|---|
| <b>A</b> rate = $k[\text{Y}]^2$           | <b>B</b> rate = $k[\text{Y}][\text{Z}]$           |
| <b>C</b> rate = $k[\text{Y}]^2[\text{Z}]$ | <b>D</b> rate = $k[\text{X}][\text{Y}][\text{Z}]$ |

- 13 *Use of the Data Booklet is relevant to this question.*

The reaction of acidified aqueous potassium iodide with hydrogen peroxide is represented by the following equation.



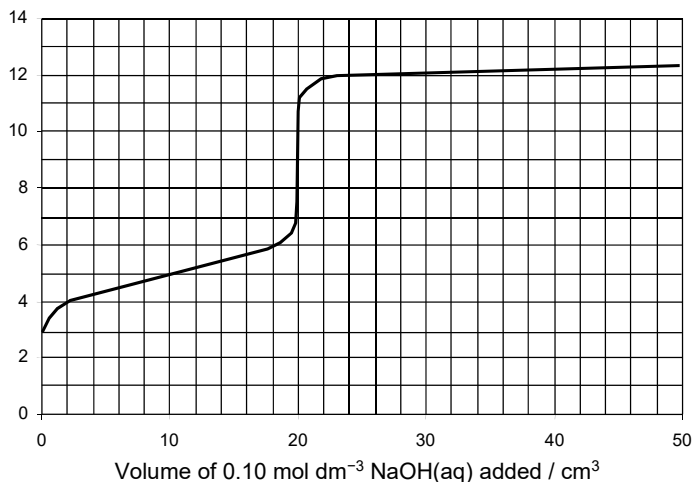
Which statements about the reaction are true?

- 1  $E^{\ominus}_{\text{cell}} = +1.23 \text{ V}$ .
- 2  $E_{\text{cell}}$  becomes more negative when  $\text{Br}_2(\text{aq})$  is added to the anode.
- 3  $E_{\text{cell}}$  becomes more positive when a few drops of  $\text{AgNO}_3(\text{aq})$  is added to the anode.

- |                  |                     |
|------------------|---------------------|
| <b>A</b> 1 only  | <b>B</b> 1 and 2    |
| <b>C</b> 2 and 3 | <b>D</b> 1, 2 and 3 |



- 14 The titration curve below shows the reaction between a monoprotic acid, **HX**, and aqueous sodium hydroxide.



Given the following data:

Indicator	Colour change (acidic to basic medium)	pH range in which colour change occurs
Methyl red	red to yellow	4.2 – 6.3
Bromothymol blue	yellow to blue	6.0 – 7.6
Thymolphthalein	colourless to blue	8.3 – 10.5

What statements are correct?

- 1 Methyl red will indicate an endpoint at a value lower than 20.0 cm<sup>3</sup>.
- 2  $K_a$  value of HX is  $1.0 \times 10^{-5}$
- 3 Buffer at maximum buffer capacity is formed at 25.0 cm<sup>3</sup> since the pH change in that region is relatively constant.
- 4 Alkaline hydrolysis of salt takes place after the equivalence point accounting for the alkaline pH value of the reaction mixture.

- A** 1,2 and 3      **B** 2,3 and 4      **C** 1 and 2      **D** 3 and 4

- 15 Given the following data,

$$K_a \text{ of } \text{CH}_3\text{COOH} = 1.8 \times 10^{-5}$$

Reaction mixture **X**:

25.0 cm<sup>3</sup> of  $2.0 \times 10^{-5} \text{ mol dm}^{-3}$  CH<sub>3</sub>COOH and 25.0 cm<sup>3</sup> water

Reaction mixture **Y**:

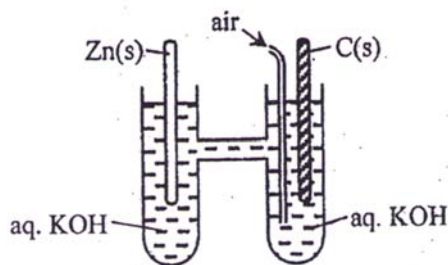
25.0 cm<sup>3</sup> of  $0.02 \text{ mol dm}^{-3}$  CH<sub>3</sub>COOH and 25.0 cm<sup>3</sup> of  $0.01 \text{ mol dm}^{-3}$  NaOH

Reaction mixture **Z**:

25.0 cm<sup>3</sup> of  $0.01 \text{ mol dm}^{-3}$  CH<sub>3</sub>COOH and 25.0 cm<sup>3</sup> of  $0.02 \text{ mol dm}^{-3}$  NaOH

Which is the correct order of pH values of the above reaction mixture?

- A**  $Z > Y > X$   
**B**  $Z > X > Y$   
**C**  $Y > X > Z$   
**D**  $X > Y > Z$
- 16 A cell is constructed with zinc and carbon electrodes, each weighing 50 g, partly immersed in aqueous KOH.

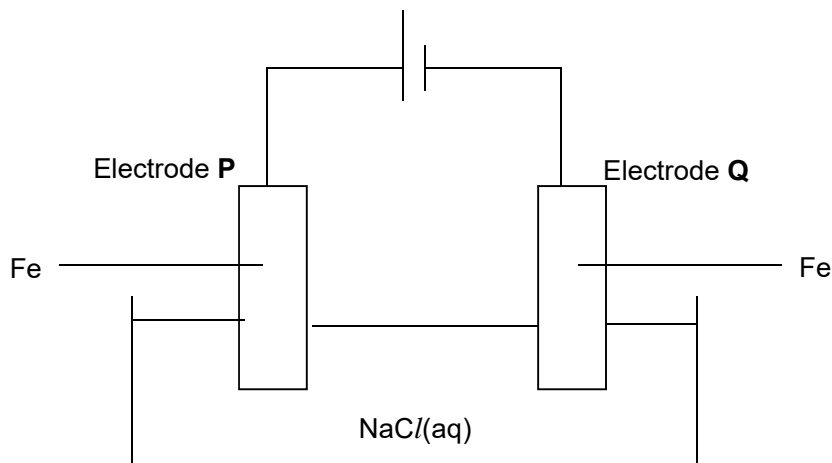


When connected in a circuit, some zinc passes into solution as zincate(II) ions,  $\text{ZnO}_2^{2-}(\text{aq})$ . The cell delivers a current of  $1.68 \times 10^{-2} \text{ A}$ . The zinc electrode is replaced once 60% of it is used up.

What is the time taken, in seconds, before replacement of zinc electrode becomes necessary?

- A**  $2.63 \times 10^6$                       **B**  $4.39 \times 10^6$   
**C**  $5.27 \times 10^6$                       **D**  $8.78 \times 10^6$

- 17 An experiment is set up as shown below to study the corrosion of iron.

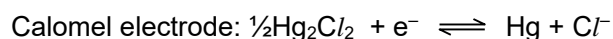


What will occur at electrodes **P** and **Q**?

	Electrode <b>P</b>	Electrode <b>Q</b>
<b>A</b>	No corrosion of Fe	Corrosion of Fe ; H <sub>2</sub> gas evolved
<b>B</b>	No corrosion of Fe	Corrosion of Fe ; O <sub>2</sub> gas evolved
<b>C</b>	Corrosion of Fe	No corrosion of Fe ; Na deposited
<b>D</b>	Corrosion of Fe	No corrosion of Fe ; H <sub>2</sub> gas evolved

- 18 *Use of Data Booklet is relevant to this question.*

The calomel electrode was used extensively as a reference electrode in the past. However, it has since been replaced by safer options such as the standard hydrogen electrode (S.H.E.).

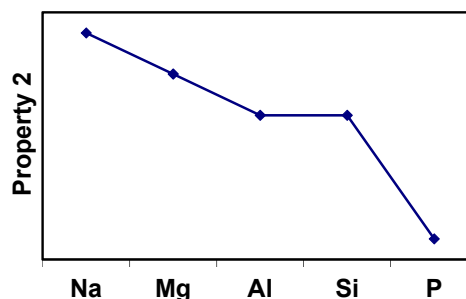
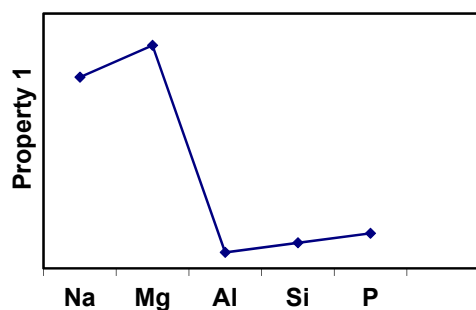


When measured with reference to the calomel electrode, a half-cell containing Zn<sup>2+</sup>/Zn has a change in Gibbs' free energy of +199 kJ per mole of Zn<sup>2+</sup>.

What is the standard electrode potential of the calomel electrode?

- A** +0.27 V      **B** +1.30 V      **C** -1.79 V      **D** -2.82 V

- 19 The graphs below show the variation of two properties of some period 3 elements and/or their compounds.



Which correctly describes properties 1 and 2?

**Property 1**

- A atomic radius of the elements
- B boiling point of the chlorides at the highest oxidation states
- C melting point of the oxides
- D electrical conductivity of elements

**Property 2**

- electrical conductivity of the elements
- pH of the oxides when added to water
- first ionisation energies of the elements
- pH of the chlorides at the highest oxidation states when added to water

- 20 What mass of sodium ethanedioate,  $\text{Na}_2\text{C}_2\text{O}_4$ , should be added to  $250 \text{ cm}^3$  of a  $2.2 \times 10^{-3} \text{ mol dm}^{-3}$  solution of calcium nitrate before a precipitate is formed?  
 $[\text{K}_{\text{sp}} \text{ of } \text{CaC}_2\text{O}_4 = 2.27 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}]$

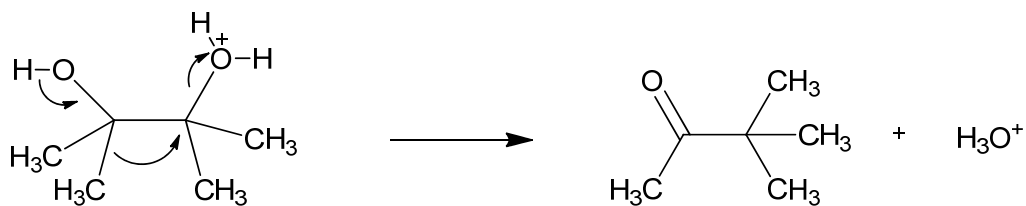
- A  $3.5 \times 10^{-5} \text{ g}$
- B  $1.0 \times 10^{-6} \text{ g}$
- C  $2.5 \times 10^{-7} \text{ g}$
- D  $2.3 \times 10^{-9} \text{ g}$

- 21 Benzylamine has the formula  $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$  and is a common precursor in organic synthesis.

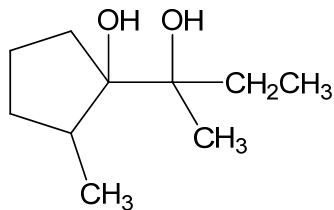
Which statements about benzylamine is correct?

- A It can be formed by the reduction of  $\text{C}_6\text{H}_5\text{CH}_2\text{CN}$ .
- B It reacts with  $\text{CH}_3\text{CO}_2\text{H}$  to form  $\text{C}_6\text{H}_5\text{CH}_2\text{NHCOCH}_3$ .
- C It is formed by the reaction between  $\text{C}_6\text{H}_5\text{NO}_2$  and tin in concentrated  $\text{HCl}$ , followed by  $\text{NaOH}$ .
- D It reacts with excess  $\text{CH}_3\text{CH}_2\text{Cl}$  under heat to form the compound,  $\text{C}_{13}\text{H}_{22}\text{NCl}$ .

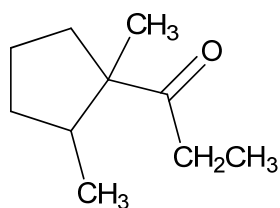
- 22 When a 1,2-diol is treated with a dilute acid, the protonated diol undergoes the following pinacol rearrangement.



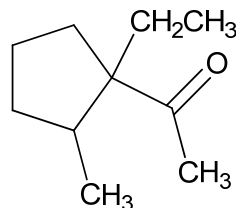
Which structure is **not** formed when diol **Z** undergoes pinacol rearrangement?



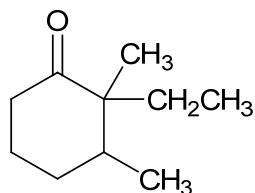
A



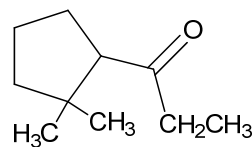
B



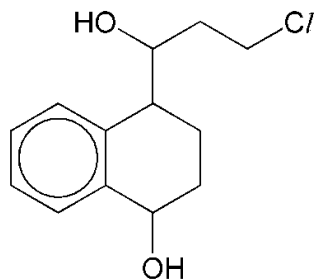
C



D



- 23 What is the total number of possible stereoisomers exhibited by the products when the following compound reacts with excess concentrated  $\text{H}_2\text{SO}_4$ ?



A 2

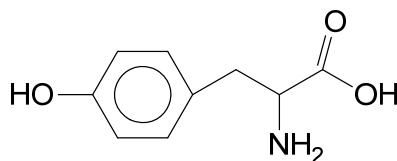
B 4

C 6

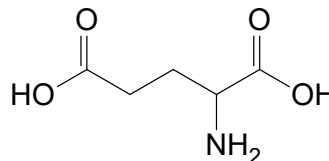
D 8

- 24** Electrophoresis is a technique of separating and identifying amino acids. A solution of amino acids is absorbed into paper that is moistened with a buffer solution and stretched between two electrodes. Positively charged species move towards the cathode, negatively charged species move towards the anode.

With a buffer at pH 4, which statement is true?



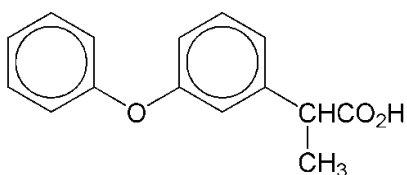
Tyrosine (pI = 5.7)



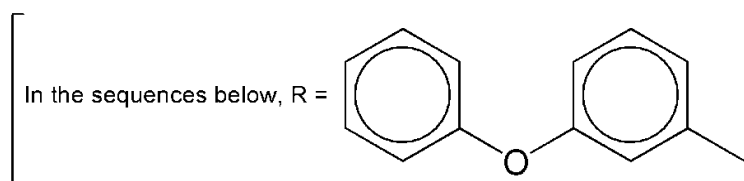
Glutamic acid (pI = 3.2)

- A** Both species move towards the anode
- B** Both species move towards the cathode.
- C** Tyrosine moves towards the anode, glutamic acid moves towards the cathode.
- D** Tyrosine moves towards the cathode, glutamic acid moves towards the anode.

- 25 *Fenoprofen* is an anti-arthritic agent.



Which of the following could be part of a reaction sequence for synthesising *Fenoprofen*?



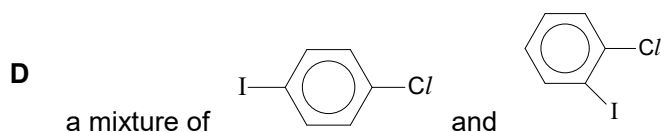
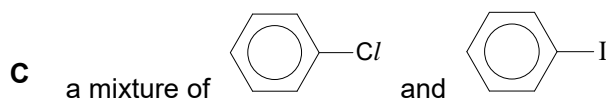
- A**  $\text{RCHBrCH}_3 \xrightarrow[\text{heat}]{\text{NaCN(ethanolic)}} \text{Intermediate} \xrightarrow[\text{heat}]{\text{H}^+(\text{aq})} \text{Fenoprofen}$
- B**  $\text{RCH(CH}_3)_2 \xrightarrow[\text{heat}]{\text{KMnO}_4, \text{OH}^-(\text{aq})} \text{Intermediate} \xrightarrow{\text{H}^+(\text{aq})} \text{Fenoprofen}$
- C**  $\text{RCHOCOC(CH}_3)_3 \xrightarrow[\text{warm}]{\text{I}_2, \text{OH}^-(\text{aq})} \text{Intermediate} \xrightarrow{\text{H}^+(\text{aq})} \text{Fenoprofen}$
- D**  $\text{RCH(OH)CH}_3 \xrightarrow[\text{heat}]{\text{KMnO}_4, \text{OH}^-(\text{aq})} \text{Intermediate} \xrightarrow{\text{H}^+(\text{aq})} \text{Fenoprofen}$

- 26 Chlorofluorocarbons (CFCs) are commonly used as aerosols, propellants and refrigerants. However in the stratosphere, CFCs can damage the ozone layer through a radical chain reaction.

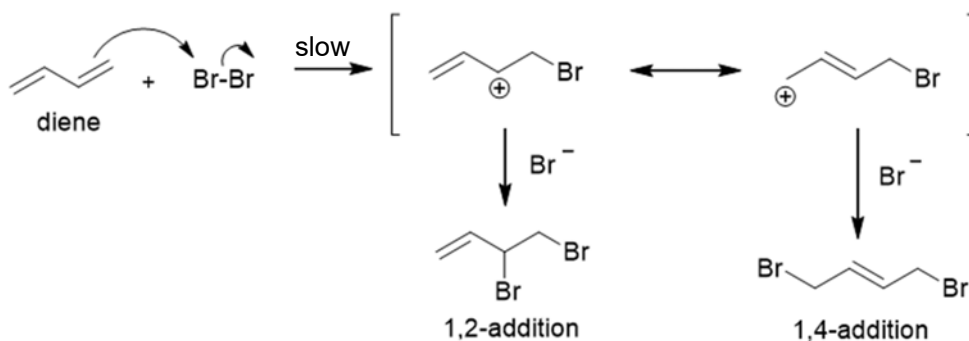
In which sequence are the following compounds listed in increasing order of their ability to destroy ozone?

- A**  $\text{CHCl}_3 < \text{CCl}_2\text{F}_2 < \text{CHCl}_2\text{F}$
- B**  $\text{CCl}_2\text{F}_2 < \text{CHCl}_2\text{F} < \text{CHCl}_3$
- C**  $\text{CHCl}_3 < \text{CCl}_2\text{F}_2 < \text{CHCl}_2\text{F}$
- D**  $\text{CHCl}_3 < \text{CHCl}_2\text{F} < \text{CCl}_2\text{F}_2$

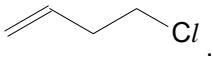
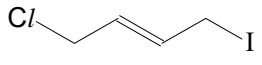
- 27 Which is the product formed when benzene reacts with iodine chloride,  $ICl$  in the presence of a suitable catalyst?



- 28 When a conjugated diene undergoes electrophilic addition with  $Br_2$ , it forms two products through the 1,2-addition and the 1,4-addition, which is shown in the mechanism below.

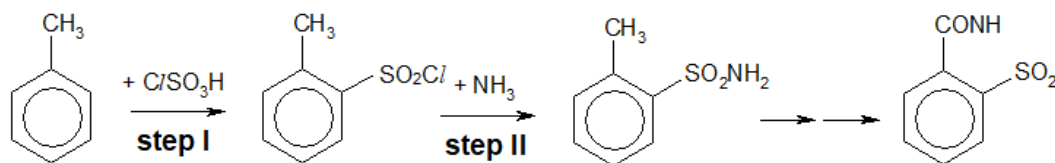


Which statement is **not** correct?

- A The overall rate law is second order.
- B The carbocation intermediates are resonance stabilised.
- C The 1,2-addition product formed when  $HCl$  is used is .
- D The 1,4-addition product formed when  $ICl$  is used is .



- 29 Saccharin is an artificial sweetening agent used in some soft drinks and is manufactured from methylbenzene through a four-step synthesis. Part of the reaction scheme is shown below.

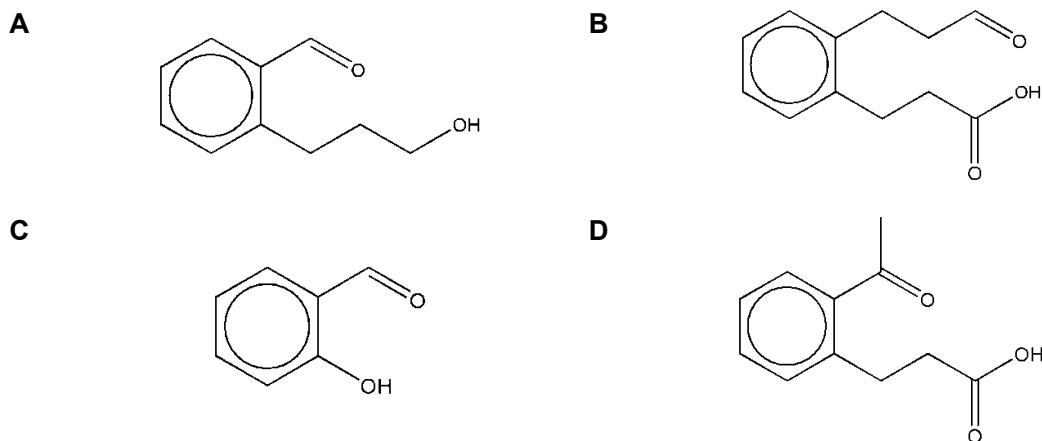


What type of reaction do steps I and II illustrate?

	Step I	Step II
A	Electrophilic addition	Nucleophilic addition
B	Electrophilic substitution	Nucleophilic substitution
C	Nucleophilic addition	Elimination
D	Electrophilic substitution	Neutralisation

- 30 Compound **X** gives a positive result when treated with  $[\text{Ag}(\text{NH}_3)_2]^+$  and  $\text{PCl}_5$  respectively but a negative result when treated with alkaline  $\text{Cu}(\text{II})$  complex.

What could **X** be?

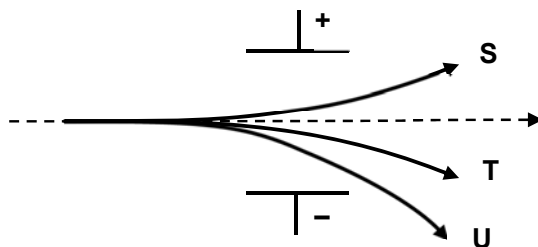


END of PAPER

**NJC 2018 SH2 H2 Chemistry Paper 1 Solutions:**

- 1 Use of the Data Booklet is relevant to this question.

The following are flight paths of charged particles when accelerated in an electric field.



Which correctly identifies **S**, **T** and **U**?

	<b>S</b>	<b>T</b>	<b>U</b>
<b>A</b>	$^{15}\text{O}^+$	$^{14}\text{C}^+$	$^{14}\text{N}^+$
<b>B</b>	$^{15}\text{O}^-$	$^{15}\text{O}^+$	$^{28}\text{Si}^+$
<b>C</b>	$^{14}\text{N}^-$	$^{28}\text{Si}^{2+}$	$^{14}\text{C}^{2+}$
<b>D</b>	$^{14}\text{N}^-$	$^{14}\text{C}^+$	$^{28}\text{Si}^{2+}$

**C:** Negatively charged ions attracted to positive plate, positive ions to negative plate.

particles	$^{14}\text{N}^-$	$^{14}\text{C}^{2+}$	$^{14}\text{C}^+$	$^{28}\text{Si}^{2+}$
Charge /mass	1/14	2/14 = 1/7	1/14	2/28 = 1/14

Since angle of deflection is charge/mass ratio, **S** and **T** have roughly the same angle of deflection but different polarity, while **U** has almost double the angle of deflection as **T**.

- 2 In which sequence is the molecules listed in the order of increasing dipole moment?

**A**  $\text{SO}_3$ ,  $\text{CO}_2$ ,  $\text{AlCl}_3$

All non-polar. Dipole moments cancel out due to shape of molecule.

**B**  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{S}$ ,  $\text{HBr}$

$\text{H}_2\text{O}$  and  $\text{H}_2\text{S}$  have bent shape.  **$\text{H}_2\text{O}$  is more polar than  $\text{H}_2\text{S}$**  as O is more electronegative than S.

**C**  $\text{CF}_4$ ,  $\text{CO}$ ,  $\text{HF}$

$\text{CF}_4$  is non-polar, dipole moments cancel out due to tetrahedral shape of molecule.

$\text{CO}$  and  $\text{HF}$  are linear.  $\text{HF}$  is more polar than  $\text{CO}$ , as electronegativity difference is greater between H and F than between C and O.

**D**  $\text{NH}_3$ ,  $\text{HF}$ ,  $\text{BeCl}_2$

$\text{NH}_3$  and  $\text{HF}$  are polar but  $\text{BeCl}_2$  is non-polar, dipole moments cancel out due to linear shape of molecule.

3 In which row are the molecules arranged in order of increasing bond angle?

1  $\text{CH}_4$ ,  $\text{AlCl}_3$ ,  $\text{XeF}_2$

$\text{CH}_4$  (tetrahedral, 109 degrees)

$\text{AlCl}_3$  (trigonal planar, 120 degrees)

$\text{XeF}_2$  (linear, 180 degrees)

2  $\text{H}_2\text{S}$ ,  $\text{PH}_3$ ,  $\text{NH}_3$ ,

$\text{H}_2\text{S}$  (tetrahedral, 109 degrees)

$\text{PH}_3$  and  $\text{NH}_3$  (trigonal pyramidal, around 107 degrees)

$\text{NH}_3$  has a larger bond angle than  $\text{PH}_3$  as

1) N is more electronegative than P, N pulls electron density of bond pairs more towards itself, leading to greater bond-pair bond-pair repulsion.

2) N has a smaller lone pair region than P (N is above P in group 15). Lone-pair bond-pair repulsion is smaller, leading to a larger bond angle.

3  $\text{NF}_3$ ,  $\text{NCl}_3$ ,  $\text{SO}_3$

$\text{NF}_3$ ,  $\text{NCl}_3$  (trigonal pyramidal, around 107 degrees)

$\text{NF}_3$  has a smaller bond angle than  $\text{NCl}_3$ . F is more electronegative than N and N is more electronegative than Cl). F pulls electron density of bond pairs more towards itself/ away from central N atom, leading to smaller bond-pair bond-pair repulsion.

$\text{SO}_3$  (trigonal planar, 120 degrees)

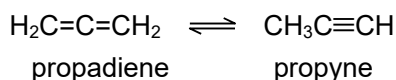
**A** 1, 2 and 3

**B** 1 and 2

**C** 2 and 3

**D** 1 only

4 Propadiene and propyne both have the same molecular formula,  $\text{C}_3\text{H}_4$ . They exist in equilibrium as shown:



Which bond is present in propadiene but **not** present in propyne?

**A** a  $\sigma$  bond formed by s – sp overlap

**B** a  $\pi$  bond formed by p – p overlap

**C** a  $\sigma$  bond formed by sp –  $\text{sp}^2$  overlap

**D** a  $\sigma$  bond formed by  $\text{sp}^2$  –  $\text{sp}^2$  overlap

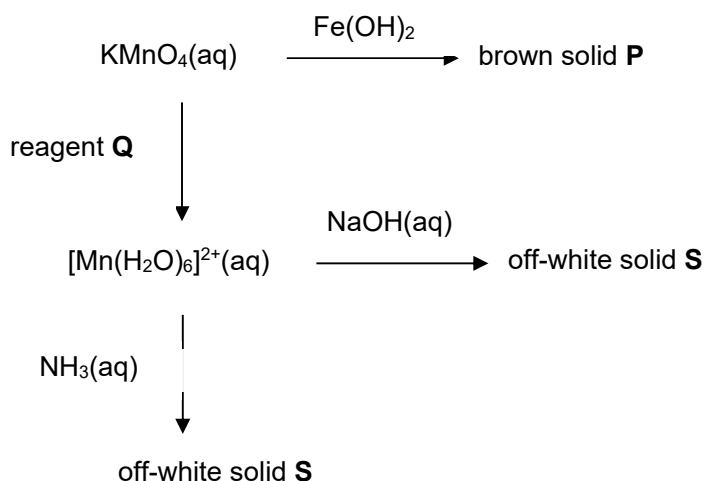
propadiene  $\text{H}_2\text{C}=\text{C}=\text{CH}_2$   
hybridisation:  $\text{sp}^2$  sp  $\text{sp}^2$

propyne  $\text{CH}_3\text{C}\equiv\text{CH}$   
hybridisation:  $\text{sp}^3$  sp sp

- A** a  $\sigma$  bond formed by s – sp overlap: in propyne  $\text{CH}_3\text{C}\equiv\text{C}-\text{H}$ , not in propadiene
- B** a  $\pi$  bond formed by p – p overlap: present in both molecules
- C** a  $\sigma$  bond formed by sp – sp<sup>2</sup> overlap: in propadiene  $\text{H}_2\text{C}=\text{C}=\text{CH}_2$ , not in propyne
- D** a  $\sigma$  bond formed by sp<sup>2</sup> – sp<sup>2</sup> overlap :absent in both

**5** Use of the Data Booklet is relevant to this question.

A reaction scheme regarding manganese compounds is shown below.



Which statements are true?

- 1** Off-white solid **S** is able to dissolve in excess of  $\text{NH}_3(\text{aq})$ .
- 2** Manganese in brown solid **P** has an oxidation state of +4.
- 3** Reagent **Q** can be acidified  $[\text{V}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ .
- 4** Off white solid **S** turns brown upon standing.

- |                     |                      |
|---------------------|----------------------|
| <b>A</b> 1, 2 and 4 | <b>B</b> 2, 3 and 4  |
| <b>C</b> 2 and 3    | <b>D</b> All correct |

**1** off-white solid **S** is  $\text{Mn}(\text{OH})_2$ . It is insoluble in excess of  $\text{NH}_3(\text{aq})$ . Check Data Booklet.

**2** Brown solid **P** is  $\text{MnO}_2$ . Oxidation state of Mn in  $\text{MnO}_2$  is +4.  $\text{KMnO}_4(\text{aq})$  oxidises  $\text{Fe}(\text{OH})_2$ , itself is reduced to  $\text{MnO}_2$ .

**3** Reagent **Q** can be acidified  $[\text{V}(\text{H}_2\text{O})_6]^{3+}$  as the  $E_{\text{cell}} > 0$ .

$$(E_{\text{cell}} = (+1.52) + (-0.34) = +1.18\text{V})$$

**4** off-white solid **S** turns brown upon standing. Check Data Booklet.  $\text{Mn}(\text{OH})_2$  is further oxidised by air.

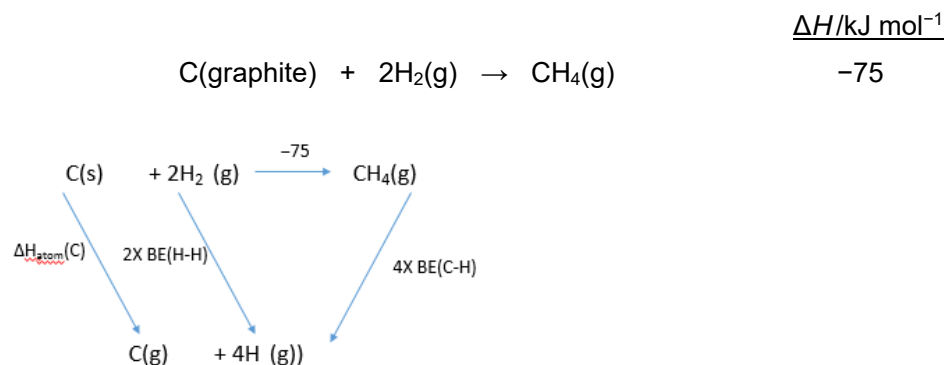
- 6 In which chemical reaction does the transition metal compound or element behave as the described catalyst?

	Reaction	Catalyst
1	Formation of ethanal from ethanol, using acidified potassium dichromate <i>K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> is an oxidising agent, not a catalyst.</i>	Homogeneous
2	Formation of oxygen from hydrogen peroxide, using iron(III) hydroxide <i>Fe(OH)<sub>3</sub> is a solid catalyst used in the decomposition of hydrogen peroxide, due to the slow rate of reaction.</i>	Heterogeneous
3	Chlorination of benzene, using chlorine and iron(III) chloride <i>FeCl<sub>3</sub> is a catalyst as well as a halogen carrier, is regenerated in the last step of the electrophilic substitution.</i>	Homogeneous
4	Removal of air pollutants in exhaust systems of cars, using nickel <i>Nickel is a catalyst in the catalytic converter and is in solid phase, a different phase from the gaseous reactant</i>	Heterogeneous

- A 1, 2 and 4                      B 2 and 3  
C 3 and 4                      D 2, 3 and 4

- 7 Use of the Data Booklet is relevant to this question.

Given the following standard enthalpy changes,



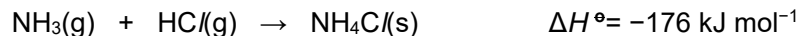
$$a + (2 \times 436) - (4 \times 410) = -75$$

$$a = +693 \text{ kJ mol}^{-1}$$

What is the standard enthalpy change of atomisation of graphite?

- A +693 kJ mol<sup>-1</sup>  
B +1129 kJ mol<sup>-1</sup>  
C -2151 kJ mol<sup>-1</sup>  
D -2587 kJ mol<sup>-1</sup>

- 8 Ammonia gas and hydrogen chloride gas react to form ammonium chloride as shown in the equation below:



The magnitude of standard entropy change of this reaction is  $284 \text{ J K}^{-1} \text{ mol}^{-1}$ .

Which statements are correct?

- 1  $\Delta G^\circ = -261 \text{ kJ mol}^{-1}$ .

No of mol of gas decreases  $\Rightarrow \Delta S^\circ = -284 \text{ J K}^{-1} \text{ mol}^{-1}$   
 $\Delta G^\circ = -176 - 298(-0.284) = -91.4 \text{ kJ mol}^{-1}$ .

- 2 The reaction becomes non-spontaneous at temperatures higher than 620 K.

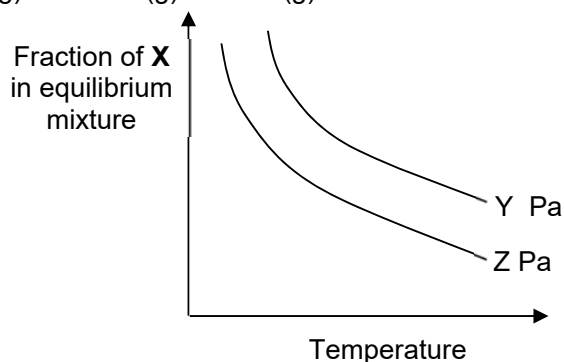
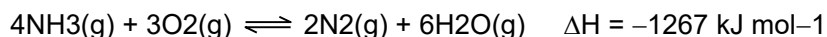
Crossover temperature occurs when  $\Delta G^\circ = 0$   
 $\Delta H^\circ = T\Delta S^\circ$   
 $T = -176000 / -284 = 620 \text{ K}$

- 3 There is an increase in order as strong hydrogen bonding between  $\text{NH}_3$  and  $\text{HCl}$  hold the particles in  $\text{NH}_4\text{Cl}$  in fixed positions and close to each other.

$\text{NH}_4\text{Cl}$  is ionic lattice with strong ionic bonds between  $\text{NH}_4^+$  and  $\text{Cl}^-$ , not strong H bonding between the  $\text{NH}_3$  and  $\text{HCl}$  molecules.

- A 1 only      B 1 and 2      C 2 only      D 2 and 3

- 9 The graph below shows how the fraction of X, which represents one of the following compounds in the given equilibrium mixture, varies with temperature at pressures of Y Pa and Z Pa.



Identify X and the correct relative magnitudes of Y and Z.

- |   | X                    | Pressure |
|---|----------------------|----------|
| A | $\text{N}_2$         | $Z > Y$  |
| B | $\text{O}_2$         | $Y > Z$  |
| C | $\text{H}_2\text{O}$ | $Y > Z$  |
| D | $\text{NH}_3$        | $Z > Y$  |

**Shape of graph:**

- (i) As temperature increase, fraction of X decrease.
- (ii) As temperature increase, as forward reaction is exothermic, fraction of product should decrease.

Matching (i) and (ii): X should be the product of the reaction => either N<sub>2</sub> or H<sub>2</sub>O.

**Comparison of the two graphs:**

- (i) 7 mol of gaseous reactants vs 8 mol of gaseous products => decrease pressure will favour the forward reaction, to partially increase pressure.
- (ii) Decrease pressure increase the fraction of X (since X is the product)

Matching (i) and (ii): Fraction of X is higher for Y Pa than Z Pa (Y Pa < Z Pa)

- 10** One of the key production stages in the Contact Process is the production of sulfur trioxide.



The rate constants of the forward and backward reactions are given as  $k_1$  and  $k_{-1}$  respectively.

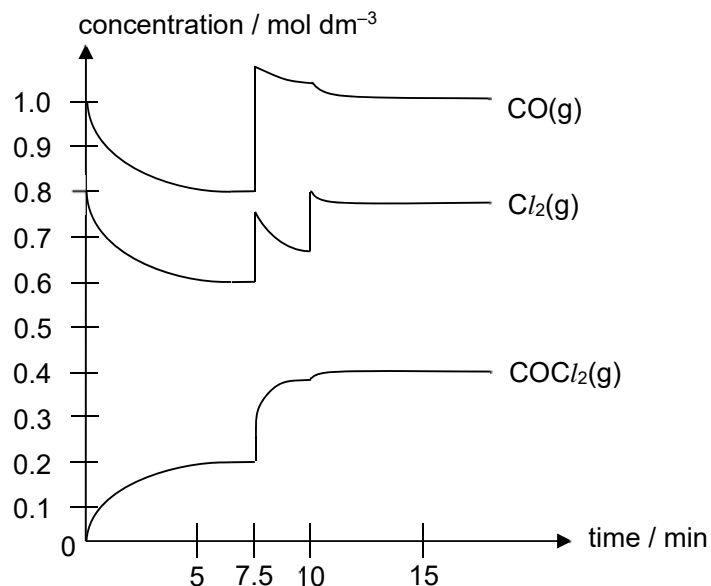
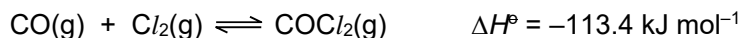
What happens to  $k_1$ ,  $k_{-1}$  and  $K_c$  if the temperature of the reaction is increased?

	$k_1$	$k_{-1}$	$K_c$
<b>A</b>	increase	increase	increase
<b>B</b>	increase	decrease	increase
<b>C</b>	decrease	increase	decrease
<b>D</b>	increase	increase	decrease

When temperature increased, no of molecules with energy greater than activation energy increases, frequency of effective collision increased, rate of reaction increases as rate constant increased.  $k_1$  and  $k_{-1}$  increase.

As reaction is exothermic, as temperature increase, equilibrium shift backward to partially absorb the excess heat. Hence,  $K_c$  decrease as  $[\text{product}]/[\text{reactant}]$  decrease.

- 11 The reaction between carbon monoxide and chlorine was studied in an experiment by mixing the two gases and changing the reaction conditions inside the reaction vessel at different times during the experiment. The concentrations of the gases in the vessel were followed with time, and the following graph is obtained.

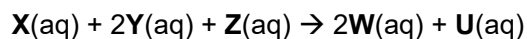


Which conclusion deduced from the graph is **incorrect**?

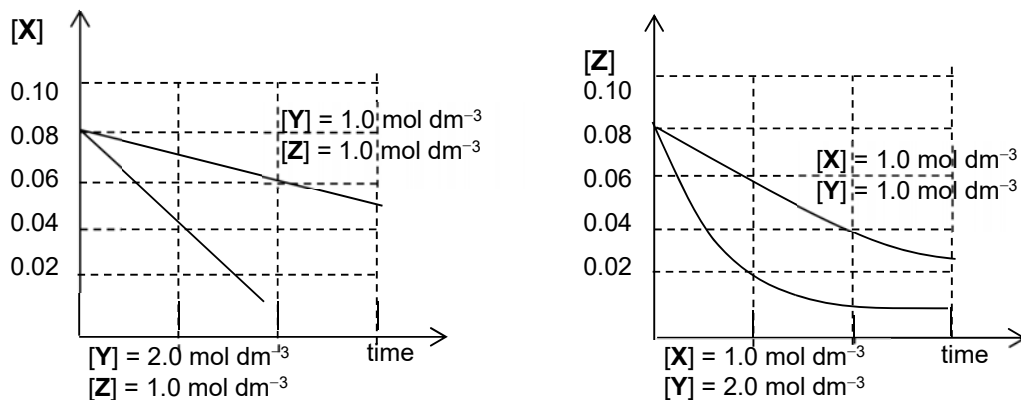
- A** The rate of forward reaction equals the rate of backward reaction at 7 min.  
**Correct:** At 7 min, the system is in dynamic equilibrium and hence the rate of forward reaction is equal to the rate of backward reaction.
- B** The change in concentration from 7.5 min to 10 min was produced by an increase in volume at constant temperature.  
**Incorrect:** Increase in volume at constant temperature will cause the concentration to decrease.
- C** The equilibrium constant,  $K_c$ , for the system when determined at 7 min is  $0.417 \text{ mol}^{-1} \text{ dm}^3$ .  
**Correct:** Using  $K_c = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]}$  and calculate
- D** The change in concentration from 10 min to 15 min was produced by the addition of more chlorine.  
**Correct:** When chlorine is added, the concentration of chlorine will increase instantaneously as shown in the graph.



- 12 Substances **X**, **Y** and **Z** react according to the following equation:



To find the rate equation for the above reaction, two sets of separate experiments were performed, in which the initial concentrations of each of the reactants **X**, **Y** and **Z** were varied while the other two were kept constant. The results are shown below.



Which rate equations represent the experimental results?

**A** rate =  $k[\text{Y}]^2$

**B** rate =  $k[\text{Y}][\text{Z}]$

**C** rate =  $k[\text{Y}]^2[\text{Z}]$

**D** rate =  $k[\text{X}][\text{Y}][\text{Z}]$

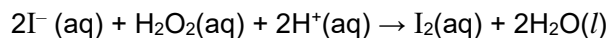
From the [X] versus time graph, a straight line indicates that the rate is constant with respect to any changes in [X]. Therefore order of reaction with respect to X is zero.

From the [Z] versus time graph, a constant half-time is obtained which indicates that the reaction is first order with respect to Z.

From the [Z] versus time graph, the time taken when [Y] is 2.0 mol dm<sup>-3</sup> is  $\frac{1}{4}$  of the time taken when [Y] is 1.0 mol dm<sup>-3</sup> for [Z] to drop from 0.08 mol dm<sup>-3</sup> to 0.04 mol dm<sup>-3</sup>. Therefore order of reaction with respect to Y is 2.

- 13 Use of the Data Booklet is relevant to this question.

The reaction of acidified aqueous potassium iodide with hydrogen peroxide is represented by the following equation.



Which statements about the reaction are true?

- 1  $E^{\circ}_{\text{cell}} = +1.23 \text{ V}$ .

**True:**  $E^{\circ}_{\text{cell}} = (-0.54) + (+1.77) = +1.23 \text{ V}$

- 2  $E^{\circ}_{\text{cell}}$  becomes more negative when  $\text{Br}_2(\text{aq})$  is added to the anode.

**True:**  $\text{Br}_2(\text{aq})$  added will remove  $\text{I}^{-}$  causing  $E^{\circ}_{\text{oxidation}}$  of  $\text{I}^{-}$  to be more negative when will cause  $E^{\circ}_{\text{cell}}$  becomes more negative

- 3  $E^{\circ}_{\text{cell}}$  becomes more positive when a few drops of  $\text{AgNO}_3(\text{aq})$  is added to the anode.

**False:**  $\text{AgNO}_3(\text{aq})$  added with remove  $\text{I}^{-}$  causing  $E^{\circ}_{\text{oxidation}}$  of  $\text{I}^{-}$  to be more negative when will cause  $E^{\circ}_{\text{cell}}$  becomes more negative

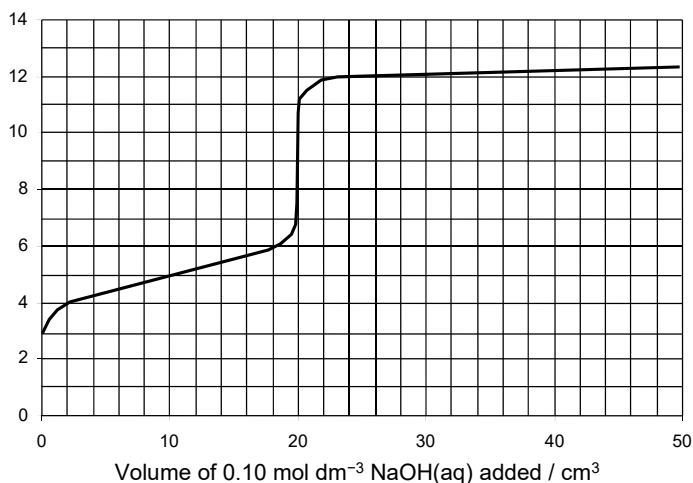
- A 1 only

- B** 1 and 2

- C 2 and 3

- D 1, 2 and 3

- 14 The titration curve below shows the reaction between a monoprotic acid, **HX**, and aqueous sodium hydroxide.



Given the following data:

Indicator	Colour change (acidic to basic medium)	pH range in which colour change occurs
Methyl red	red to yellow	4.2 – 6.3
Bromothymol blue	yellow to blue	6.0 – 7.6
Thymolphthalein	colourless to blue	8.3 – 10.5

What statements are correct?

- 1 Methyl red will indicate an endpoint at a value lower than 20.0 cm<sup>3</sup>.  
**Correct:** At a value lower than 20.0 cm<sup>3</sup>, the pH is less than 6.5 which coincide with the working range of methyl red.
- 2 K<sub>a</sub> value of HX is 1.0 × 10<sup>-5</sup>  
**Correct:** At max buffer capacity, pH = pK<sub>a</sub> = 5  
K<sub>a</sub> = 1.0 × 10<sup>-5</sup>
- 3 Buffer at maximum buffer capacity is formed at 25.0 cm<sup>3</sup> since the pH change in that region is relatively constant.  
**Incorrect:** Maximum buffer capacity is formed at 10.0 cm<sup>3</sup> where [HX] = [NaX]
- 4 Alkaline hydrolysis of salt takes place after the equivalence point accounting for the alkaline pH value of the reaction mixture.  
**Incorrect:** Alkaline hydrolysis of salt takes place **AT** equivalence point accounting for the alkaline pH value of the reaction mixture.

**A** 1,2 and 3      **B** 2,3 and 4      **C** 1 and 2      **D** 3 and 4

15 Given the following data,

$$K_a \text{ of } \text{CH}_3\text{COOH} = 1.8 \times 10^{-5}$$

Reaction mixture **X**:

25.0 cm<sup>3</sup> of 2.0 × 10<sup>-5</sup> mol dm<sup>-3</sup> CH<sub>3</sub>COOH and 25.0 cm<sup>3</sup> water

Reaction mixture **Y**:

25.0 cm<sup>3</sup> of 0.02 mol dm<sup>-3</sup> CH<sub>3</sub>COOH and 25.0 cm<sup>3</sup> of 0.01 mol dm<sup>-3</sup> NaOH

Reaction mixture **Z**:

25.0 cm<sup>3</sup> of 0.01 mol dm<sup>-3</sup> CH<sub>3</sub>COOH and 25.0 cm<sup>3</sup> of 0.02 mol dm<sup>-3</sup> NaOH

Which is the correct order of pH values of the above reaction mixture?

- A** Z > Y > X  
**B** Z > X > Y  
**C** Y > X > Z

**D X > Y > Z**

For reaction mixture X,  $[\text{CH}_3\text{COOH}]_{\text{new}} = 0.5 \times 2.0 \times 10^{-5} = 1.0 \times 10^{-5} \text{ mol dm}^{-3}$

$$[\text{H}^+] = \sqrt{(1.0 \times 10^{-5} \times 1.8 \times 10^{-5})} = 1.3416 \times 10^{-5} \text{ mol dm}^{-3}$$

$$\text{pH} = -\lg(1.3416 \times 10^{-5}) = 4.87$$

For reaction mixture Y,

	CH <sub>3</sub> COOH	+	NaOH	→	CH <sub>3</sub> COONa	+	H <sub>2</sub> O
Initial / mol	0.0005		0.00025		0		-
Change / mol	- 0.00025		- 0.00025		+ 0.00025		-
Final / mol	0.00025		0		0.00025		-

An acidic buffer is formed.

$$\text{pH} = \text{pK}_a \text{ since } [\text{CH}_3\text{COOH}]_{\text{new}} = [\text{CH}_3\text{COONa}]_{\text{new}}$$

$$\text{pH} = -\lg(1.8 \times 10^{-5}) = 4.74$$

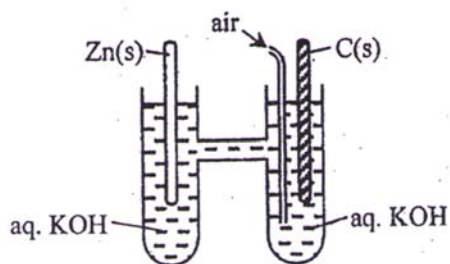
For reaction mixture Z,

	CH <sub>3</sub> COOH	+	NaOH	→	CH <sub>3</sub> COONa	+	H <sub>2</sub> O
Initial / mol	0.00025		0.0005		0		-
Change / mol	- 0.00025		- 0.00025		+ 0.00025		-
Final / mol	0		0.00025		0.00025		-

Salt hydrolysis is not considered as presence of strong base will suppress the salt's dissociation

$$\text{pH} = 14 - \text{pOH} = 14 + \lg(0.00025 / \frac{25.0+25.0}{1000}) = 11.70$$

**Answer is B**



What is the time taken, in seconds, before replacement of zinc electrode becomes necessary?

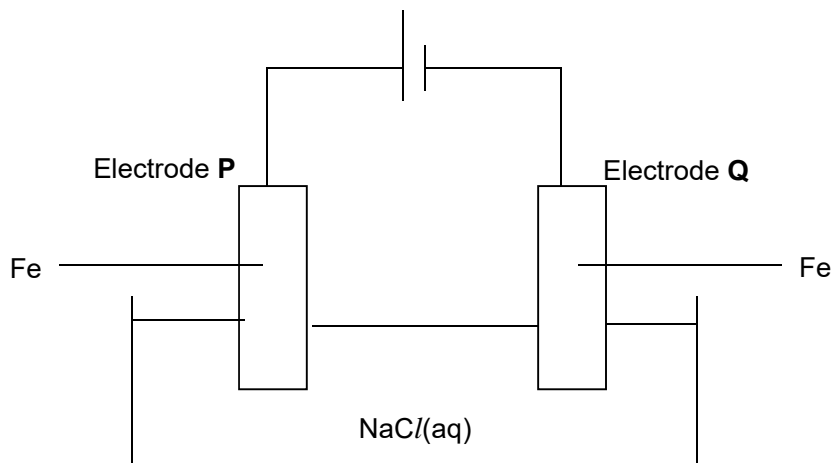
- |          |                    |          |                    |
|----------|--------------------|----------|--------------------|
| <b>A</b> | $2.63 \times 10^6$ | <b>B</b> | $4.39 \times 10^6$ |
| <b>C</b> | $5.27 \times 10^6$ | <b>D</b> | $8.78 \times 10^6$ |

$$\text{Amount of Zn used up} = \frac{60}{100} \times \frac{50}{65.4} = 0.4587 \text{ mol}$$

$$(1.68 \times 10^{-2})t = 0.9174 \times 96500$$

**Answer is C**

- 17 An experiment is set up as shown below to study the corrosion of iron.



What will occur at electrodes **P** and **Q**?

	Electrode <b>P</b>	Electrode <b>Q</b>
<b>A</b>	No corrosion of Fe	Corrosion of Fe ; H <sub>2</sub> gas evolved
<b>B</b>	No corrosion of Fe	Corrosion of Fe ; O <sub>2</sub> gas evolved
<b>C</b>	Corrosion of Fe	No corrosion of Fe ; Na deposited
<b>D</b>	Corrosion of Fe	No corrosion of Fe ; H <sub>2</sub> gas evolved

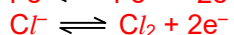
Electrode **P** is the positive anode, while electrode **Q** is the negative cathode

Since oxidation occurs at the anode, while reduction occurs at the cathode,

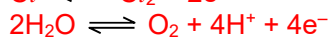
At the anode:



$$E^{\circ}_{\text{ox}} = +0.44 \text{ V}$$



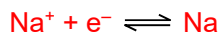
$$E^{\circ}_{\text{ox}} = -1.36 \text{ V}$$



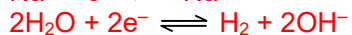
$$E^{\circ}_{\text{ox}} = -1.23 \text{ V}$$

Corrosion of Fe will occur at electrode **P** since first  $E^{\circ}_{\text{ox}}$  is the most positive

At the cathode:



$$E^{\circ} = -2.71 \text{ V}$$



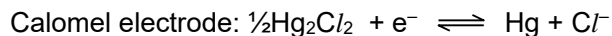
$$E^{\circ} = -0.83 \text{ V}$$

No corrosion of Fe will occur, since Fe cannot be reduced. H<sub>2</sub> gas will be evolved since second  $E^{\circ}$  is the most positive

**Answer is D**

- 18 Use of Data Booklet is relevant to this question.

The calomel electrode was used extensively a reference electrode in the past. However, it has since been replaced by safer options such as the standard hydrogen electrode (S.H.E.).



When measured with reference to the calomel electrode, a half-cell containing  $\text{Zn}^{2+}/\text{Zn}$  has a change in Gibbs' free energy of +199 kJ per mole of  $\text{Zn}^{2+}$ .

What is the standard electrode potential of the calomel electrode?

- A** +0.27 V                      **B** +1.30 V                      **C** -1.79 V                      **D** -2.82 V

A change in Gibbs' free energy of +199 kJ per mole of  $\text{Zn}^{2+}$  being reduced is equivalent to a change in Gibbs' free energy of -199 kJ per mole of Zn being oxidised

$$\Delta G^\ominus = -nFE^\ominus_{\text{cell}}$$

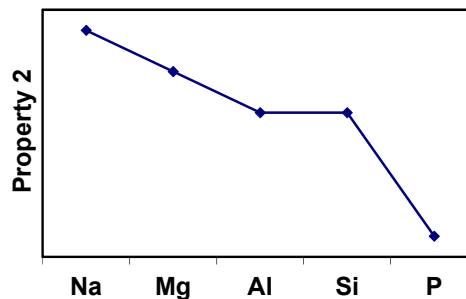
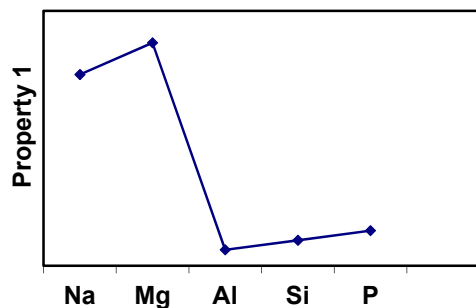
$$-199 \times 1000 = -(2)(96500)E^\ominus_{\text{cell}}$$

$$E^\ominus_{\text{cell}} = +1.03 \text{ V} = E^\ominus + E^\ominus_{\text{ox}}(\text{Zn} / \text{Zn}^{2+}) = E^\ominus + 0.76 \text{ V}$$

$$E^\ominus = +0.27 \text{ V}$$

**Answer is A**

- 19 The graphs below show the variation of two properties of some period 3 elements and/or their compounds.



Which correctly describes properties 1 and 2?

- |          | Property 1   | Property 2  |
|----------|--|---|
| <b>A</b> | atomic radius of the elements                          | electrical conductivity of the elements                         |
| <b>B</b> | boiling point of the highest oxidation state chlorides | pH of the oxides when added to water                            |
| <b>C</b> | melting point of oxides                                | first ionisation energies of the elements                       |
| <b>D</b> | electrical conductivity of elements                    | pH of the highest oxidation state chlorides when added to water |

<p><b>For option A</b></p> <p>Property 1 cannot be atomic radii as it should be a continuous decrease across the period due to increase in nuclear attraction for the outermost electron. This is because of increase in nuclear charge but constant shielding caused by the same number of inner electrons.</p>	<p>Property 2: Electrical conductivity should increase from Mg to Al due to increase in number of mobile charged carriers (more electrons in the sea of delocalised electrons). Electrical conductivity should be very low for Si while P exhibit zero electrical conductivity. Hence graph shows a wrong trend for electrical conductivity.</p>
<p><b>For option B</b></p> <p>Boiling point of chloride compounds decreases from NaCl to <math>\text{AlCl}_3</math> as <math>\text{AlCl}_3</math> is a simple covalent molecule therefore easier to overcome the intermolecular temporary dipole induced dipole than ionic bonds in giant ionic lattice of NaCl and <math>\text{MgCl}_2</math>.</p> <p>From <math>\text{AlCl}_3</math> to <math>\text{PCl}_5</math>, they have the structure of simple covalent molecules with Mr of <math>\text{AlCl}_3</math> (133.5) &lt; <math>\text{SiCl}_4</math> (170.1) &lt; <math>\text{PCl}_5</math> (208.5). B.pt increases with increasing ease of distortion of the electron cloud of the chloride compound.</p> <p>Hence property1 shows the correct trend in the b.pt of chlorides across period 3 element.</p>	<p>Property 2: <b>acid base property of oxide</b> depends on the <b>nature of bonds present in the oxide</b> compound. While ionic oxide tends to be basic and covalent oxide is acidic; ionic oxides with significant covalent character will be amphoteric, this is usually observed when cation has high charge/size ratio.</p> <p><b>pH of oxides in aqueous medium</b> not only depends on the nature of the bonds, <b>solubility</b> also matters.</p> <p><math>\text{Na}_2\text{O}</math> is <b>basic and fully soluble</b> in water, therefore pH very high (highly alkaline). Solubility of <math>\text{MgO}</math> less than <math>\text{Na}_2\text{O}</math> but more than <math>\text{Al}_2\text{O}_3</math>, hence pH of <math>\text{MgO}</math> &gt; <math>\text{Al}_2\text{O}_3</math>.</p> <p><b>pH of <math>\text{Al}_2\text{O}_3</math> and <math>\text{SiO}_2</math> are both equal to 7 because both are insoluble in water</b> but <math>\text{Al}_2\text{O}_3</math> is an amphoteric oxide while <math>\text{SiO}_2</math> is an acidic oxide.</p> <p>Oxides of P dissolves in water to give phosphoric acid therefore pH is very low.</p> <p>Hence property 2 shows the correct trend for pH of aqueous oxides across period 3.</p>
<p><b>For option C</b></p> <p>Melting points of oxides across the period should peak at <math>\text{SiO}_2</math> since it has a very strong giant covalent lattice.</p> <p>Phosphoric oxide is a simple covalent molecule, therefore there should be a drastic drop of m.pt from <math>\text{SiO}_2</math> to <math>\text{P}_4\text{O}_{10}</math>.</p> <p>Hence property 1 cannot be m.pt of oxides across period 3 elements.</p>	<p>First ionisation energy of elements across period should exhibit a general increasing trend due to increasing nuclear attraction for the most loosely held electron. This is due to increase in nuclear charge but constant shielding effect by the same number of inner shell electrons.</p> <p>Hence property 2 cannot be first ionisation energy.</p>
<p><b>For option D</b></p> <p>Electrical conductivity should increase from Na to Mg to Al due to increase in number of mobile charged carriers (more electrons in the sea of delocalised electrons). Electrical conductivity should be very low for Si while P exhibit zero</p>	<p>For chlorides across period 3 element, they are all soluble in aqueous medium. For chlorides that dissociates into ions in aq medium, cation hydrolysis gives rise to acidic solution. Extent of cation hydrolysis increases with charge/size ratio of the cation. Hence <math>\text{AlCl}_3</math> (aq) more acidic than <math>\text{MgCl}_2</math>(aq) while NaCl is neutral (pH =7)</p>



electrical conductivity. Hence graph shows a wrong trend for electrical conductivity.	On the other hand, covalent chlorides react with water to form HCl therefore the pH value should be low for both $\text{SiCl}_4$ and $\text{PCl}_5$ .  Hence graph of property 2 do not agree with the pH trend of aqueous chlorides across the period.
---	---

- 20 What mass of sodium ethanedioate,  $\text{Na}_2\text{C}_2\text{O}_4$ , should be added to  $250 \text{ cm}^3$  of a  $2.2 \times 10^{-3} \text{ mol dm}^{-3}$  solution of calcium nitrate before a precipitate is formed?  
[ $K_{\text{sp}}$  of  $\text{CaC}_2\text{O}_4 = 2.27 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}$ ]

In order for precipitate to take place, ionic product  $> K_{\text{sp}}$ .

Expression for ionic product and  $K_{\text{sp}}$  is the same.

$$K_{\text{sp}} = [\text{Ca}^{2+}][\text{C}_2\text{O}_4^{2-}]$$

Magnitude of Ionic product =  $K_{\text{sp}}$  when solution is saturated with  $\text{Na}_2\text{C}_2\text{O}_4$ .

$$\left( \frac{\text{mass}}{(23.0 \times 2 + 24.0 + 64.0)} \times \frac{1000}{250} \right) (2.2 \times 10^{-3}) = 2.27 \times 10^{-9}$$

Min mass of  $\text{Na}_2\text{C}_2\text{O}_4 = 3.46 \times 10^{-5} \text{ g}$

**A**  $3.5 \times 10^{-5} \text{ g}$

**B**  $1.0 \times 10^{-6} \text{ g}$

**C**  $2.5 \times 10^{-7} \text{ g}$

**D**  $2.3 \times 10^{-9} \text{ g}$

- 21 Benzylamine has the formula  $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$  and is a common precursor in organic synthesis.

Which statements about benzylamine is correct?

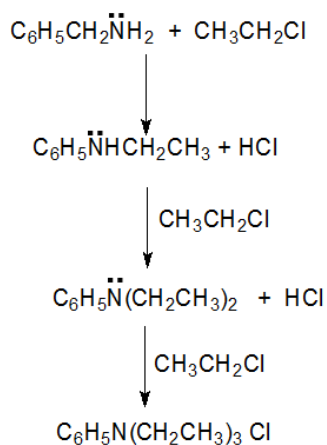
- A** It can be formed by the reduction of  $\text{C}_6\text{H}_5\text{CH}_2\text{CN}$ .  
**B** It reacts with  $\text{CH}_3\text{CO}_2\text{H}$  to form  $\text{C}_6\text{H}_5\text{CH}_2\text{NHCOCH}_3$ .  
**C** It is formed by the reaction between  $\text{C}_6\text{H}_5\text{NO}_2$  and tin in concentrated  $\text{HCl}$  followed by  $\text{NaOH}$ .  
**D** It reacts with excess  $\text{CH}_3\text{CH}_2\text{Cl}$  under heat to form the compound,  $\text{C}_{13}\text{H}_{22}\text{NCl}$ .

**Option A:** reduction of  $\text{C}_6\text{H}_5\text{CH}_2\text{CN}$  gives  $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{NH}_2$  with 1 C more than  $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$ . Hence it is not the correct answer.

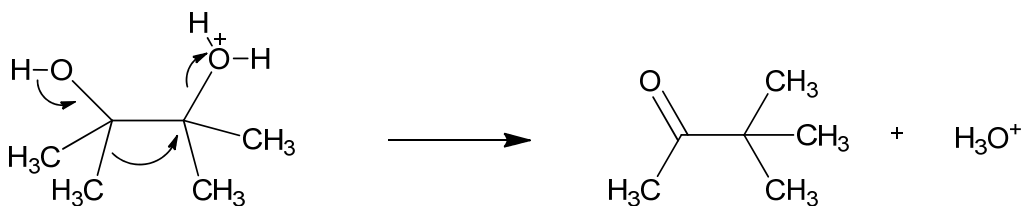
**Option B:** N in  $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$  uses its lone pair to accept  $\text{H}^+$  from  $\text{CH}_3\text{COOH}$  (acid base reaction instead of nucleophilic acyl substitution (condensation)). Hence  $(\text{CH}_3\text{COO}^-)(\text{C}_6\text{H}_5\text{CH}_2\text{NH}_3)^+$  is formed instead of  $\text{C}_6\text{H}_5\text{CH}_2\text{NHCOCH}_3$ .

**Option C:**  $\text{C}_6\text{H}_5\text{NO}_2$  will be reduced to  $\text{C}_6\text{H}_5\text{NH}_2$  which is isolated as  $\text{C}_6\text{H}_5\text{NH}_3\text{Cl}$  due to acidic medium.  $\text{C}_6\text{H}_5\text{NO}_2$  has 1 less C than  $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$  after reduction, hence not the answer.

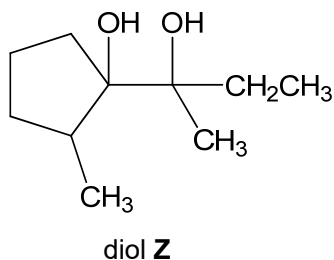
**Option D:** Correct answer. A quaternary ammonium salt is formed when  $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$  reacts with excess  $\text{CH}_3\text{CH}_2\text{Cl}$ .



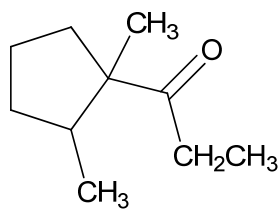
- 22 When a 1,2-diol is treated with a dilute acid, the protonated diol undergoes the following pinacol rearrangement.



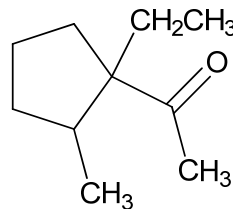
Which structure is **not** formed when diol **Z** undergoes pinacol rearrangement?



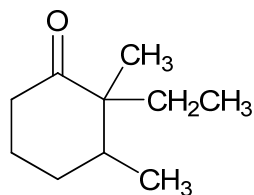
A



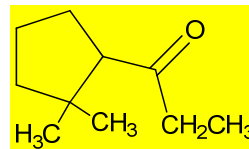
B

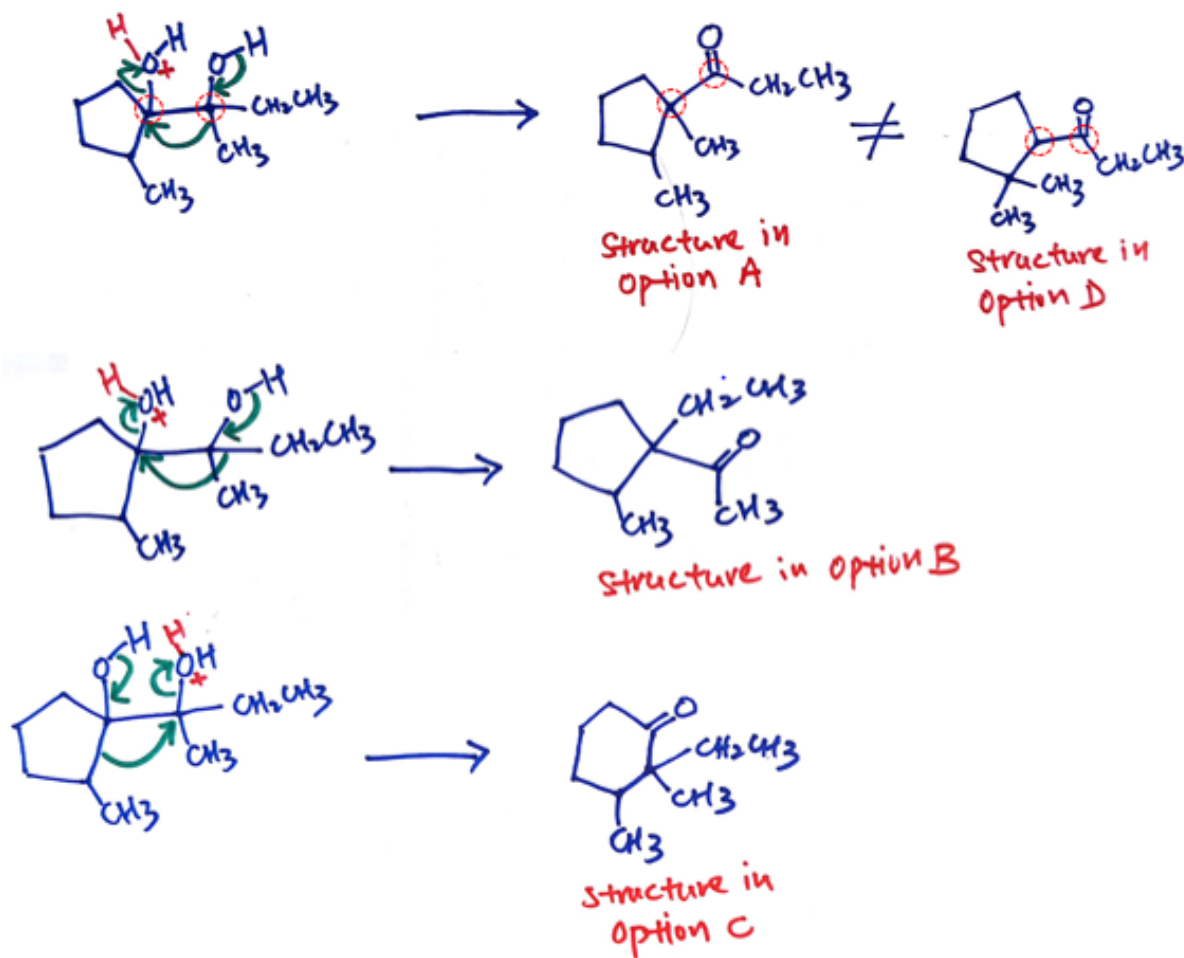


C

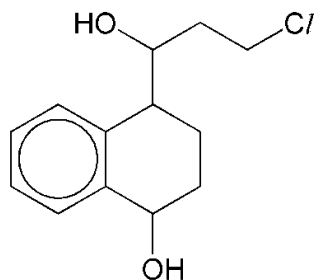


D





- 23 What is the total number of possible stereoisomers exhibited by the products when the following compound reacts with excess concentrated  $\text{H}_2\text{SO}_4$ ?



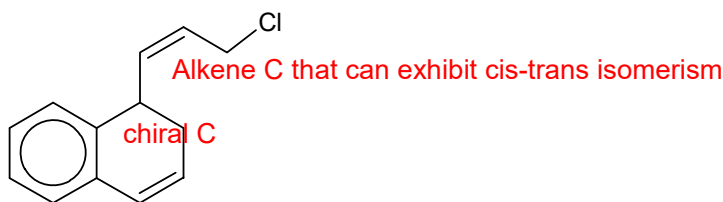
A 2

B 4

**C 6**

D 8

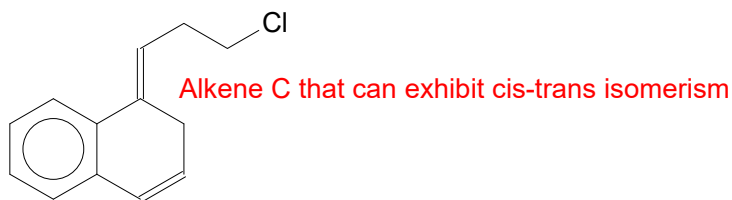
The molecule undergoes elimination of  $\text{H}_2\text{O}$  with excess concentrated  $\text{H}_2\text{SO}_4$  to give alkene. The product is



Using the formula,

No of stereoisomers =  $2^{n+m}$  where  $n$  = no of chiral C and  $m$  = no of alkene C that can exhibit cis-trans isomerism, this alkene has  $2^{1+1} = 4$  isomers.

Another possible products of elimination:

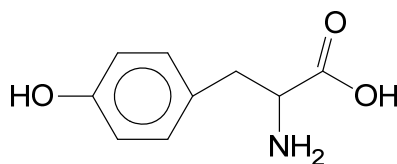


No of stereoisomers:  $2^1 = 2$  isomers

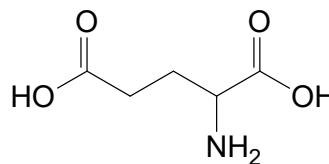
Total no of stereoisomers =  $2^2 + 2 = 6$

- 24 Electrophoresis is a technique of separating and identifying amino acids. A solution of amino acids is absorbed into paper that is moistened with a buffer solution and stretched between two electrodes. Positively charged species move towards the cathode, negatively charged species move towards the anode.

With a buffer at pH 4, which statement is true?



Tyrosine ( $\text{pI} = 5.7$ )



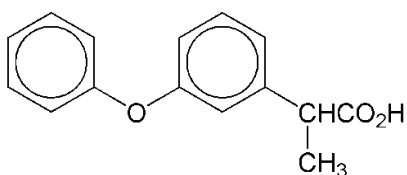
Glutamic acid ( $\text{pI} = 3.2$ )

- A Both species move towards the anode
- B Both species move towards the cathode.
- C Tyrosine moves towards the anode, glutamic acid moves towards the cathode.
- D Tyrosine moves towards the cathode, glutamic acid moves towards the anode.**

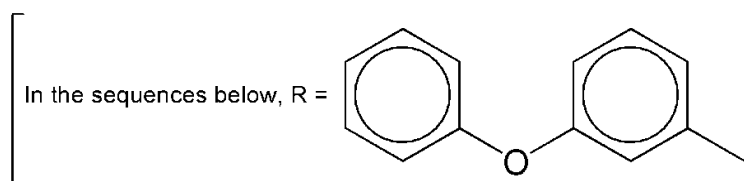
Since  $\text{pH} < \text{pI}$  of Tyrosine, the  $-\text{NH}_2$  grp will get protonated  $\Rightarrow$  Overall positively charged, hence move towards cathode.

Since  $\text{pH} > \text{pI}$  of Glutamic acid, both the  $-\text{COOH}$  grps will get deprotonated  $\Rightarrow$  Overall negatively charged, hence move towards anode. Answer is (D).

- 25 *Fenoprofen* is an anti-arthritic agent.



Which of the following could be part of a reaction sequence for synthesising *Fenoprofen*?



- A**  $\text{RCHBrCH}_3 \xrightarrow[\text{heat}]{\text{NaCN(ethanolic)}} \text{Intermediate} \xrightarrow[\text{heat}]{\text{H}^+(\text{aq})} \text{Fenoprofen}$
- B**  $\text{RCH(CH}_3)_2 \xrightarrow[\text{heat}]{\text{KMnO}_4, \text{OH}^-(\text{aq})} \text{Intermediate} \xrightarrow{\text{H}^+(\text{aq})} \text{Fenoprofen}$
- C**  $\text{RCHOC(=O)CH}_3 \xrightarrow[\text{warm}]{\text{I}_2, \text{OH}^-(\text{aq})} \text{Intermediate} \xrightarrow{\text{H}^+(\text{aq})} \text{Fenoprofen}$
- D**  $\text{RCH(OH)CH}_3 \xrightarrow[\text{heat}]{\text{KMnO}_4, \text{OH}^-(\text{aq})} \text{Intermediate} \xrightarrow{\text{H}^+(\text{aq})} \text{Fenoprofen}$

For option (A), the halogenoalkane  $\text{RCHBrCH}_3$  undergoes nucleophilic substitution when heated with ethanolic NaCN, forming  $\text{RCH(CN)CH}_3$  as the intermediate, which then undergoes acidic hydrolysis of the  $-\text{CN}$  group to form  $-\text{COOH}$ .

For option (B),  $\text{RCH(CH}_3)_2$  does not undergo oxidation when heated with alkaline  $\text{KMnO}_4$ .

For option (C),  $\text{RCH(=O)CH}_3$  has methyl carbonyl which is part of the ester functional grp, hence does not undergo iodoform reaction when warmed with alkaline iodine.

For option (D), secondary alcohol  $\text{RCH(OH)CH}_3$  undergoes oxidation to form ketone intermediate,  $\text{RCOCH}_3$ , which does not react with  $\text{H}^+$ .

- 26 Chlorofluorocarbons (CFCs) are commonly used as aerosols, propellants and refrigerants. However in the stratosphere, CFCs can damage the ozone layer through a radical chain reaction.

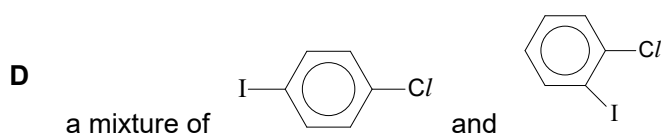
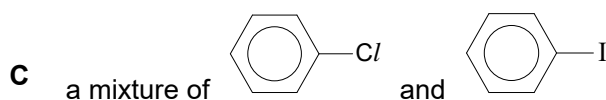
In which sequence are the following compounds listed in increasing order of their ability to destroy ozone?

- A  $\text{CHCl}_3/\text{FCCl}_2\text{F}_2 < \text{CCl}_2\text{FCCl}_2\text{F} < \text{CHCl}_3/\text{F}_2$   
 B  $\text{CCl}_2\text{FCCl}_2\text{F} < \text{CHCl}_3/\text{F}_2 < \text{CHCl}_3/\text{FCCl}_2\text{F}_2$   
 C  $\text{CHCl}_3/\text{F}_2 < \text{CCl}_2\text{FCCl}_2\text{F} < \text{CHCl}_3/\text{FCCl}_2\text{F}_2$   
 D  $\text{CHCl}_3/\text{F}_2 < \text{CHCl}_3/\text{FCCl}_2\text{F}_2 < \text{CCl}_2\text{FCCl}_2\text{F}$

C-F bond is much stronger than C-Cl, it does not break easily to form F radicals => does not damage ozone layer.

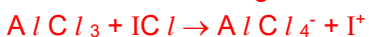
All four options (A), (B), (C) and (D) comprise of molecules containing C-F and C-Cl bonds. The molecule with more C-Cl bonds will have higher ability to destroy ozone due to more Cl radicals it is able to produce. Hence, answer is (D).

- 27 Which is the product formed when benzene reacts with iodine chloride,  $\text{ICl}$  in the presence of a suitable catalyst?



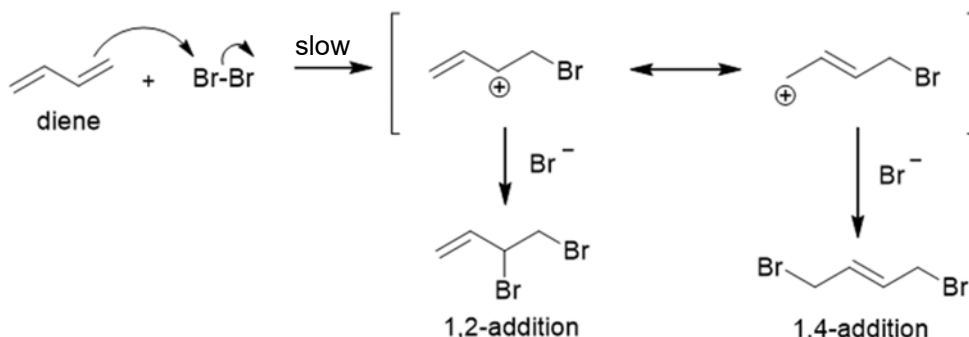
Answer:

$\text{Cl}$  is more electronegative than  $\text{I}$ , hence only  $\text{I}^+$  electrophile forms for reaction.




Hence only 1 electrophilic substitution product is possible.

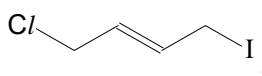
- 28 When a conjugated diene undergoes electrophilic addition with  $\text{Br}_2$ , it forms two products through the 1,2-addition and the 1,4-addition, which is shown in the mechanism below.



Which statement is **not** correct?

- A The overall rate law is second order.
- B The carbocation intermediates are resonance stabilised.

**C** The 1,2-addition product formed when  $\text{HCl}$  is used is .

D The 1,4-addition product formed when  $\text{ICl}$  is used is .

Answer:

A is correct.

Step 1 can be determined to be the slow step as bond breaking occurs. 1 mole of diene and 1 mole of bromine are involved and hence the overall order is 2.

B is correct.

The presence of the pi bond stabilises the positive charge on the cations.

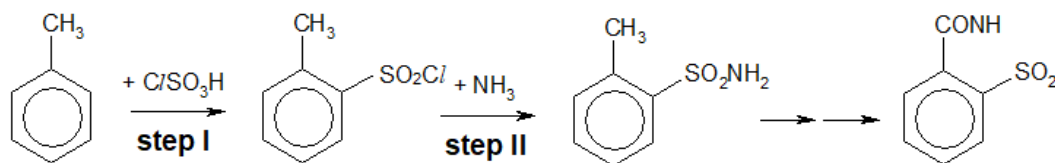
C is incorrect.

For the 1,2-addition product, the positive charge is on the 2<sup>nd</sup> carbon and hence  $\text{Cl}^-$  should be on the 2<sup>nd</sup> carbon instead.

D is correct.

$\text{Cl}^-$  is more electronegative than I, hence in step 1, the I which is  $\delta^+$  will function as the electrophile and  $\text{Cl}^-$  is generated which then attacks the carbocation.

- 29 Saccharin is an artificial sweetening agent used in some soft drinks and is manufactured from methylbenzene through a four-step synthesis. Part of the reaction scheme is shown below.



What type of reaction do steps I and II illustrate?

	Step I	Step II
A	Electrophilic addition	Nucleophilic addition
B	Electrophilic substitution	Nucleophilic substitution
C	Nucleophilic addition	Elimination
D	Electrophilic substitution	Neutralisation

Answer:

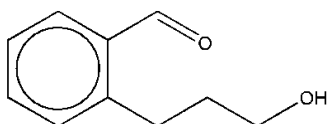
Step 1: Benzene ring is electron rich: Electrophilic Substitution

Step 2: S is  $\delta^+$  due to the electronegative atoms attached to it;  $-\text{Cl}$  replaced by  $-\text{NH}_2$  : Nucleophilic Substitution

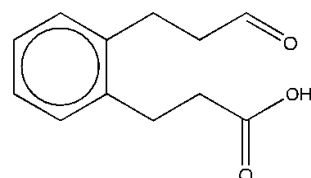
- 30 Compound **X** gives a positive result when treated with  $[\text{Ag}(\text{NH}_3)_2]^+$  and  $\text{PCl}_5$  respectively but a negative result when treated with alkaline  $\text{Cu}(\text{II})$  complex.

What could **X** be?

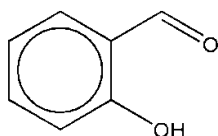
A



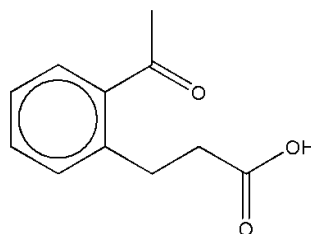
B



C



D

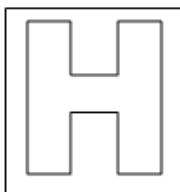


Reacts with $[\text{Ag}(\text{NH}_3)_2]^+$ (Tollen's)	Aldehyde
Reacts with $\text{PCl}_5$	$-\text{OH}$ which can undergo substitution present (not phenol)
No reaction with alkaline $\text{Cu}(\text{II})$ complex (Fehlings)	Aromatic aldehyde

END of PAPER



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



**NATIONAL JUNIOR COLLEGE  
SH 2 PRELIMINARY EXAMINATION**

Higher 2

CANDIDATE  
NAME

SUBJECT  
CLASS

REGISTRATION  
NUMBER

**CHEMISTRY**

Paper 2 Structured Questions

**9729/02**

**Tues 21 Aug 2018  
2 hours**

Candidates answer **all** questions on the Question Paper.  
Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen.

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

Do not use staples, paper clips, glue or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

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

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

For Examiner's Use			
1	/8		
2	/14		
3	/13		
4	/11		
5	/14		
6	/15		
Penalty units			
Penalty sf			
Paper 2	/75		

Answer **ALL** questions on the space provided.

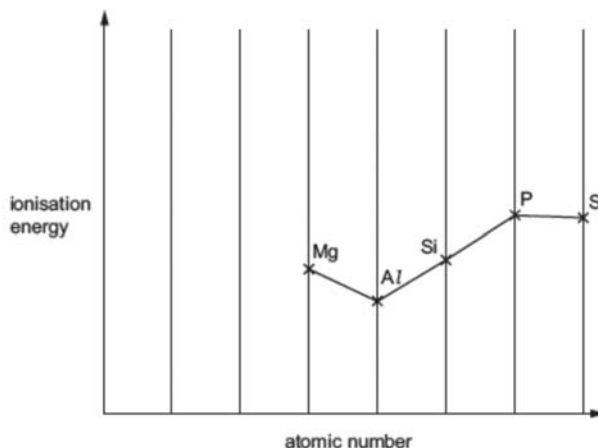
This paper consists of **18** printed pages.



- 1 The properties of elements and their compounds show similarities, differences and trends depending on the positions of the elements.

- (a) The elements in the third period, and their compounds, show trends in their physical and chemical properties.

A sketch graph of the first ionisation energies of five successive elements in the third period is shown.



- (i) Sketch on the graph, the position of the ionisation energy of the two elements that come before Mg in this sequence.

[1]

- (ii) Explain, with reference to electronic arrangements, the decreases in first ionisation energy between Mg and Al and between P and S.

Mg and Al: .....

.....  
 .....

P and S: .....

.....  
 .....

[2]

- (b) The chlorides of the elements in the third period behave in different ways when added to water, depending on their structure and bonding.

**L** is a chloride of an element in Period 3. A student investigated **L** and the results are as given below.

- **L** is a white crystalline solid with a melting point of 987 K.
- **L** dissolves in water to form a weakly acidic solution.
- Addition of NaOH(aq) to an aqueous solution of **L** produces a white precipitate, **M**.

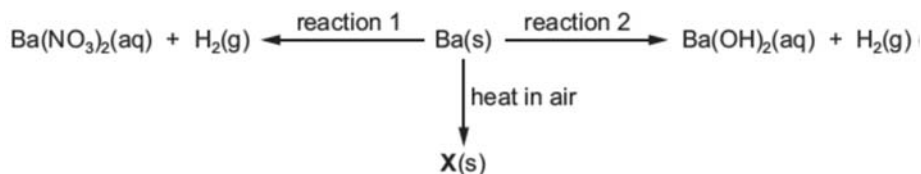
- (i) Identify **L** and **M**.

**L**: ..... **M**: ..... [1]

- (ii) Write an equation to illustrate the formation of the weakly acidic solution.

..... [1]

- (c) Some reactions based on the Group 2 metal barium, Ba, are shown below.



- (i) State the reagent needed for each of reactions 1 and 2.

Reaction 1 .....

Reaction 2 .....

[2]

- (ii) Write an equation for the formation of **X**.

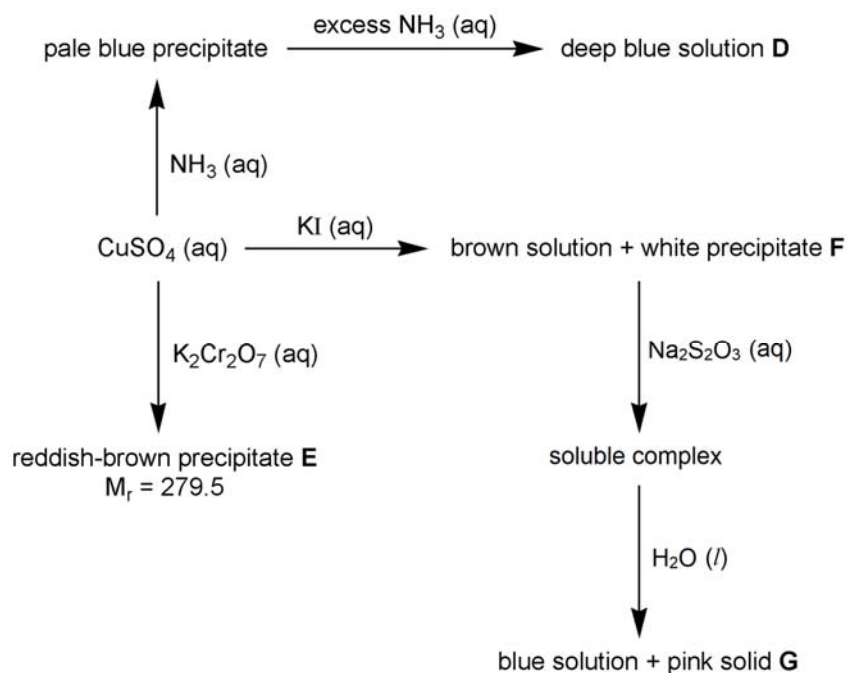
.....

[1]

[Total: 8]

2 The use of *Data Booklet* is relevant to this question.

- (a) Copper(II) sulfate, an inorganic compound that has wide uses in organic syntheses and in engraving of zinc plates for intaglio printmaking, can undergo a series of reactions as shown below.



- (i) Identify **D**, **E**, **F** and **G**.

**D**: ..... **E**: .....  
**F**: ..... **G**: .....

[4]

- (ii) With the aid of relevant equations, account for the formation of the deep blue solution **D** from the pale blue precipitate.

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

[2]

- (b) (i) By quoting relevant data, account for the trend in the thermal stabilities from  $\text{HCl}$  to  $\text{HI}$ .

.....

.....

.....

[2]

- (ii) Identify a transition metal cation that can be used to differentiate the oxidising abilities of  $\text{Br}_2$  and  $\text{I}_2$ . Explain your answer with appropriate workings.

[3]

- (iii) Suggest a series of steps to verify the presence of chloride and iodide ions in a mixture, given the following reagents:

- Aqueous silver nitrate
- Aqueous ammonia
- Aqueous nitric acid
- Filter paper
- Filter funnel

.....

.....

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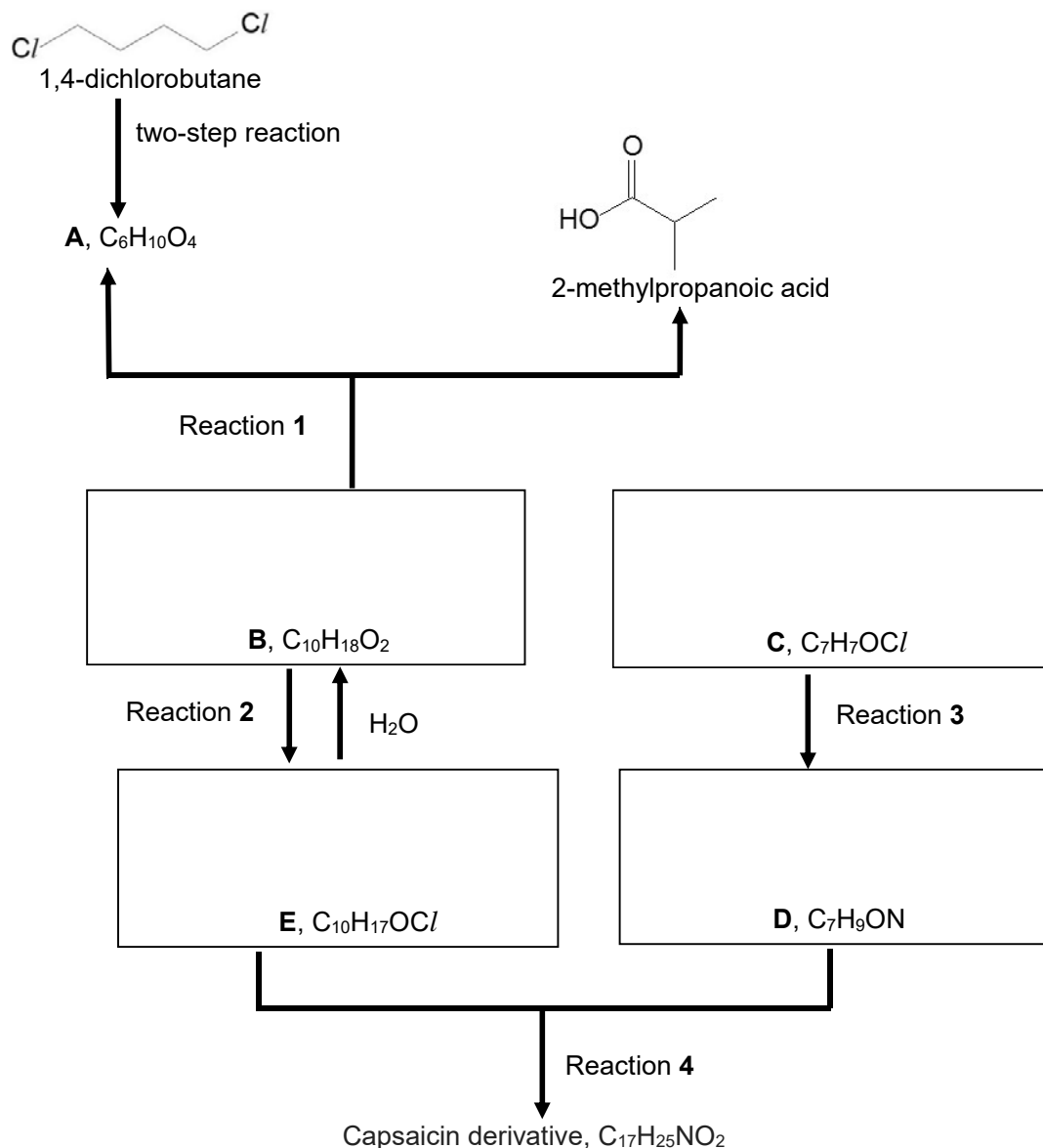
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[3]

[Total: 14]

- 3 Capsaicin is an active component of chili peppers. The reaction scheme involving the formation of a derivative of Capsaicin,  $C_{17}H_{25}NO_2$ , is shown below.



Compounds **A** to **D** react with sodium metal.

Compounds **A** and **B** react with aqueous sodium carbonate.

Compound **C**, Compound **D** and the capsaicin derivative reacts with aqueous sodium hydroxide but does not react with aqueous sodium carbonate.

Compounds **B** and **E** also react with cold acidified  $KMnO_4$ .

- (a) Name the functional group common to compounds **A** and **B**.

..... [1]



- (b) Compound **A** can be synthesised from 1,4-dichlorobutane in two steps. Suggest reagents and conditions for the synthesis, and the intermediate product for the reaction.

Step 1: .....

Step 2: .....

Intermediate product:

[3]

- (c) There are two functional groups in compound **B**. Suggest the identity of the functional group in **B** that reacts with cold acidified  $\text{KMnO}_4$ .

Functional group that reacts with cold acidified  $\text{KMnO}_4$ : .....

[1]

- (d) Hence, draw the structure of compound **B** in the box on pg 6 and state the reagents and conditions for reaction 1.

Reagents and conditions for reaction 1: .....

[2]

- (e) Compound **C** reacts with hot ethanolic silver nitrate to produce a white ppt. Draw the structure of Compounds **C** and **D** in the box on pg 6. Name the type of reaction for reaction 3.

Type of reaction for reaction 3: .....

[3]

- (f) Compound **E** readily hydrolyses in water to produce Compound **B**.

Draw the structure of compound **E** in the box on pg 6, and hence state the reagents and conditions for reaction 2.

Reagents and conditions for reaction 2: .....

[2]

- (g) Compounds **D** and **E** react to produce the Capsaicin derivative.

Draw the structure of the Capsaicin derivative.

[1]

[Total: 13]

- 4 On 11 May 2018, Mount Merapi on Central Java, Indonesia erupted, causing the local airport to be closed. The eruption was reported to be caused by accumulation of volcanic gases. The volcanic ash and gases spewed can be dangerous to planes passing through the plume. The most abundant volcanic gas is harmless water vapour. However, significant amounts of carbon dioxide, sulfur dioxide, hydrogen sulfide and hydrogen halides are also emitted.

When carbon dioxide is emitted from volcanoes, it typically becomes diluted to low concentrations very quickly and is not life threatening. However, cold carbon dioxide gas can flow into low-lying areas where it can reach much higher concentrations. Breathing air with more than 3% CO<sub>2</sub> can quickly lead to headaches, dizziness, increased heart rate and difficulty breathing. At about 15%, unconsciousness and death can result quickly.

**Table 1.1:** Volcanic gas composition in area A

Gas	Volume Percentage
Water vapour, H <sub>2</sub> O	87.1
Carbon dioxide, CO <sub>2</sub>	Rapidly increasing
Sulfur dioxide, SO <sub>2</sub>	0.5
Hydrogen, H <sub>2</sub>	0.7
Carbon monoxide, CO	0.01
Hydrogen sulfide, H <sub>2</sub> S	0.23
Hydrochloric acid, HCl	2.89
Hydrofluoric acid, HF	2.55

Composition of the volcanic gases are typically expressed in terms of volume percentage, which can be calculated as follows

$$\text{volume percentage} = \frac{\text{volume of gas}}{\text{Total volume}}$$

However, percentages are only additive for ideal gases.

- (a) (i) State **two** assumptions of the kinetic theory of gases.

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

[2]

- (ii) Under what conditions of temperature and pressure would you expect the behaviour of carbon dioxide to be most like that of an ideal gas?

.....  
 [1]

- (iii) Suggest a reason why at low temperature, carbon dioxide would sink rapidly and accumulate to high concentrations.

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

[2]

- (iv) People living in area A were evacuated as the level of carbon dioxide and temperature of surroundings were increasing rapidly.  
Given that 0.30 mg of  $\text{CO}_2$  was present in  $10 \text{ cm}^3$  of gas mixture at  $43^\circ\text{C}$  and 11.2 kPa, determine the volume percentage of carbon dioxide present.

Hence comment on the possible danger if people remained in the area.

Volume percentage of carbon dioxide = .....

.....  
.....

[3]

- (b) Hydrogen sulfide can react with methane in the following equation.

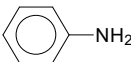
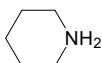
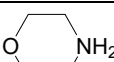
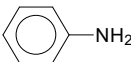
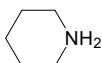
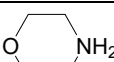
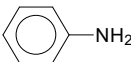
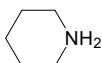
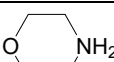


1 mol of  $\text{CH}_4$ , 2 mol of  $\text{H}_2\text{S}$ , 1 mol of  $\text{CS}_2$  and 1 mol of  $\text{H}_2$  was allowed to reach equilibrium at a constant temperature and pressure of  $960^\circ\text{C}$  and 2 atm.

Given that partial pressure of  $\text{CS}_2$  was found to be 0.5 atm at equilibrium, determine the value of  $K_p$ , giving its units.

[3]

[Total: 11]

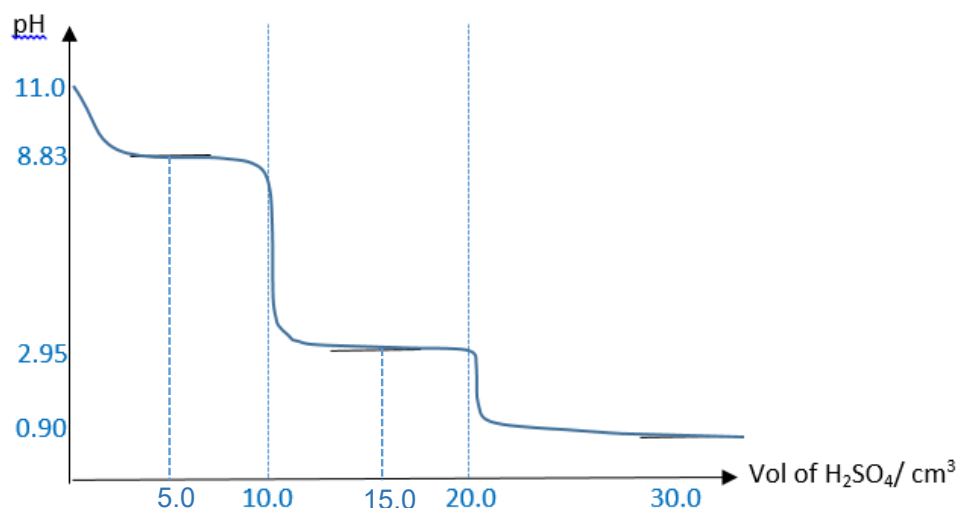
5	(a)	The following table contains the $pK_b$ values of different nitrogen organic compounds.													
		<table><tr><th>Compound</th><th><math>pK_b</math></th></tr><tr><td><math>(CH_3)_3CNH_2</math> 2-amino-2-methylpropane</td><td>3.19</td></tr><tr><td> phenylamine</td><td>9.38</td></tr><tr><td> piperidine</td><td>2.88</td></tr><tr><td> morpholine</td><td>5.17</td></tr><tr><td><math>N_2H_4</math> hydrazine</td><td>5.17, 11.05</td></tr></table>		Compound	$pK_b$	$(CH_3)_3CNH_2$ 2-amino-2-methylpropane	3.19	 phenylamine	9.38	 piperidine	2.88	 morpholine	5.17	$N_2H_4$ hydrazine	5.17, 11.05
Compound	$pK_b$														
$(CH_3)_3CNH_2$ 2-amino-2-methylpropane	3.19														
 phenylamine	9.38														
 piperidine	2.88														
 morpholine	5.17														
$N_2H_4$ hydrazine	5.17, 11.05														
		(i)	Suggest a reason why $pK_b$ of morpholine is higher than piperidine.												
			<p>Morpholine has an electronegative O that exert <b>electron withdrawing effect</b>, it reduces the availability of lone pair on N to accept <math>H^+</math>, therefore Morpholine is a weaker base hence a higher <math>pK_b</math> value.</p> <p><b>Examiners Comments:</b> Most students are able to identify that O is electronegative and hence able to exert electron withdrawing effect. There are a handful who thought that the lone pair will delocalise into O. This is impossible as the 2 atoms are not adjacent to each other and no orbital overlap exists.</p>												
		(ii)	Suggest a reason why $pK_b$ of phenylamine is so much higher than 2-amino-2-methylpropane.												
			<p>Lone pair on N of phenylamine is delocalised into the benzene ring, making lone pair much less available to receive <math>H^+</math> than lone pair of N in <math>(CH_3)_3CNH_2</math>, phenylamine is a weaker base hence a higher <math>pK_b</math> value than <math>(CH_3)_3CNH_2</math>.</p> <p><b>Examiners Comments:</b> Most students are able to recognise that the lone pair on N can delocalise into the ring and hence a reduction in availability of lone pair for donation to a proton. Do use the correct key word "delocalisation" as some students will use terms like "dissociate" or "diffuse" into the ring which is not very accurate.</p>												
			[2]												

- (b) 10.0 cm<sup>3</sup> of an aqueous mixture containing 0.5 mol dm<sup>-3</sup> of hydrazine was placed in a conical flask and the initial pH was found to be 11.0.

Sketch the pH–volume graph on the axis provided when 10.0 cm<sup>3</sup> of the aqueous mixture was titrated with 0.25 mol dm<sup>-3</sup> dilute sulfuric acid until a total volume of 30.0 cm<sup>3</sup> of dilute sulfuric acid was added.

Your sketch should include the following points

- Initial pH of hydrazine
- pH of the reaction mixture when 30.0 cm<sup>3</sup> of H<sub>2</sub>SO<sub>4</sub> is added.
- Maximum buffer points (if any)



Initial pH = 11.0 given in question

volume of H<sub>2</sub>SO<sub>4</sub> required for the 1<sup>st</sup> equiv point = 10.0 cm<sup>3</sup>  
total vol of H<sub>2</sub>SO<sub>4</sub> required for 2<sup>nd</sup> equiv point = 20.0 cm<sup>3</sup>

Max buffer points occur at 5 and 15 cm<sup>3</sup>.

pOH = pK<sub>b</sub> at max buffer pts

pH = 14 - pOH

pH are 14 - 5.17 = 8.83 and 14 - 11.05 = 2.95 respectively.

Final pH

Amt of unreacted H<sup>+</sup> = (2 × 10/1000 × 0.25) = 0.005 mol (since H<sub>2</sub>SO<sub>4</sub> is diprotic)

[H<sup>+</sup>] = 0.005 × 1000 / 40 = 0.125 mol dm<sup>-3</sup>

pH = 0.90

### Examiners Comments:

Students did badly for this question.

Most students did not manage to recognise two equivalence point (represented by 2 steep slope).

To identify how many equivalence point(s) there is, students need to **focus on the analyte**. If the analyte is (1) weak **and** (2) multi-protic, then it will have multiple equivalence points.

		<p>Most students also could not calculate the volume of <math>\text{H}_2\text{SO}_4</math> used correctly. To do so, since both acid and base are diprotic,</p> <p><math>\text{N}_2\text{H}_4 + \text{H}_2\text{A} \rightarrow \text{N}_2\text{H}_6^{2+} + \text{A}^{2-}</math></p> <p>Mol ratio is 1:1</p> <p>Hence <b>total volume</b> of acid required is <math>20 \text{ cm}^3</math></p> <p>[3]</p>		
	(c)	<p>Student <b>M</b> suggested a 2-step process as shown, to synthesise 2-amino-2-methylpropane from a suitable alkane.</p> <p><math display="block">\begin{array}{ccccc} \text{C}_4\text{H}_{10} &amp; \xrightarrow{\text{step 1}} &amp; \text{C}_4\text{H}_9\text{Cl} &amp; \xrightarrow{\text{step 2}} &amp; \text{C}_4\text{H}_{11}\text{N} \\ \mathbf{A} &amp; &amp; \mathbf{B} &amp; &amp; \end{array}</math></p>		
	(i)	<p>Identify the structures of compounds <b>A</b> and <b>B</b>, and suggest reagents and conditions for each of the two steps.</p> <table border="1"><tr><td><p><math>(\text{CH}_3)_3\text{CH}</math></p><p>Structure of <b>A</b></p></td><td><p><math>(\text{CH}_3)_3\text{CCl}</math></p><p>Structure of <b>B</b></p></td></tr></table> <p>Step 1: limited <math>\text{Cl}_2</math>, UV. light</p> <p>Step 2: excess <math>\text{NH}_3</math> in ethanol, heat in sealed tube</p> <p>[4]</p>	<p><math>(\text{CH}_3)_3\text{CH}</math></p> <p>Structure of <b>A</b></p>	<p><math>(\text{CH}_3)_3\text{CCl}</math></p> <p>Structure of <b>B</b></p>
<p><math>(\text{CH}_3)_3\text{CH}</math></p> <p>Structure of <b>A</b></p>	<p><math>(\text{CH}_3)_3\text{CCl}</math></p> <p>Structure of <b>B</b></p>			
	(ii)	<p>Outline the mechanism for step 1.</p>		



			[3]

- (iii) A student **N** suggested an alternative synthetic route for the synthesis of 2-amino-2-methylpropane, using an alkene as a starting material.

Explain why this synthetic route will give a higher yield as compared to the suggested route in **c(ii)**.

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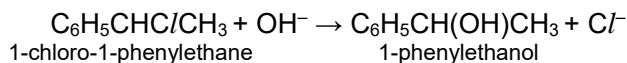
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[2]

[Total: 14]

- 6 1-chloro-1-phenylethane undergoes hydrolysis with hydroxide ions to produce 1-phenylethanol, as shown in the equation below.



- (a) The rate of this reaction can be studied by measuring the amount of hydroxide ions that remain in the solution at a given time after the reaction has been quenched.

- (i) Suggest a suitable quenching agent that can be used to stop the reaction effectively.

..... [1]

- (ii) Using your answer in (i), describe a suitable method for determining the order of reaction with respect to  $\text{OH}^-$ , given the following.

- Solution **A**, 1.0 mol dm<sup>-3</sup> 1-chloro-1-phenylethane
- Solution **B**, 0.10 mol dm<sup>-3</sup> sodium hydroxide
- 0.10 mol dm<sup>-3</sup> hydrochloric acid
- Quenching agent [as suggested in (i)]
- Stopwatch
- Standard laboratory equipment

Specific details of volumes and time is not required.

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- (b) The rate of this reaction was measured using different initial concentrations of the two reagents and the results are shown below. [3]

Experiment	$[\text{C}_6\text{H}_5\text{CHC}/\text{CH}_3] / \text{mol dm}^{-3}$	$[\text{OH}^-] / \text{mol dm}^{-3}$	Relative rate
1	0.05	0.10	1.0
2	0.10	0.20	2.0
3	0.15	0.10	3.0

- (i) Deduce the order of reaction with respect to each of the reagents. Explain your reasoning.

Order with respect to  $\text{C}_6\text{H}_5\text{CHC}/\text{CH}_3 = \dots\dots\dots$

Order with respect to  $\text{OH}^- = \dots\dots\dots$  [2]

- (ii) Write the rate equation for this reaction, stating the units of the rate constant,  $k$ .

rate =  $\dots\dots\dots \text{mol dm}^{-3} \text{s}^{-1}$

units of  $k = \dots\dots\dots$

[2]

- (c) (i) By making use of your answer in (b)(i), describe the mechanism for the reaction of 1-chloro-1-phenylethane with hydroxide ions. In your answer, you should show relevant charges, lone pairs, dipoles and show movement of electrons by curly arrow.

[3]

- (ii) This reaction was carried out using a single optical isomer of 1-chloro-1-phenylethane. Use your mechanism in (i) to predict whether the product will be a single optical isomer or a mixture of two optical isomers. Explain your answer.

.....

.....

.....

[2]

- (iii) 1-chloro-2-ethyl benzene,  $\text{C}_6\text{H}_4\text{C}/\text{CH}_2\text{CH}_3$ , is an isomer of 1-chloro-1-phenylethane,  $\text{C}_6\text{H}_5\text{CHC}/\text{CH}_3$ . The ease of hydrolysis for each of the 2 compounds is different. Explain why.

.....

.....

.....

[2]

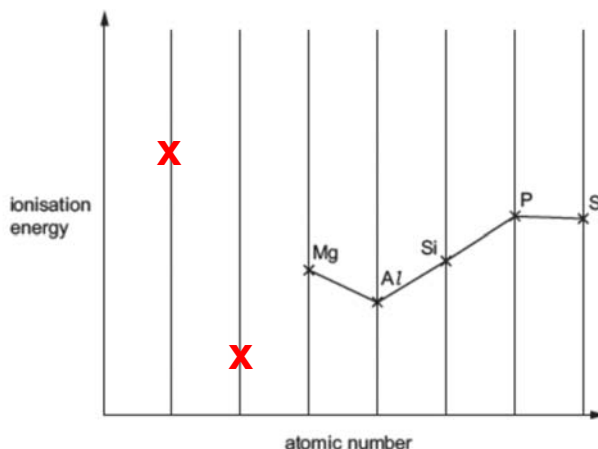
[Total: 15]

**NJC SH2 H2 Chemistry P2 Solutions**

- 1 The properties of elements and their compounds show similarities, differences and trends depending on the positions of the elements.

- (a) The elements in the third period, and their compounds, show trends in their physical and chemical properties.

A sketch graph of the first ionisation energies of five successive elements in the third period is shown.



- (i) Sketch on the graph, the position of the ionisation energy of the two elements that come before Mg in this sequence.

Cross shown on first vertical line from the y-axis (group 0/Ne) is clearly higher than all shown.

Cross shown on second vertical line from the y-axis (group 1/Na) is clearly lower than all shown.

[1]

- (ii) Explain, with reference to electronic arrangements, the decreases in first ionisation energy between Mg and Al and between P and S.

Mg and Al:

The most loosely held electron in Al is in the **higher energy 3p subshell** while that of Mg is in the **lower energy 3s subshell**.

This **outweighs the effect of the increase in nuclear charge** from Mg to Al.

Hence **nuclear attraction for the most loosely held electron in Al is**

**weaker**, i.e. Al has a lower 1<sup>st</sup> IE.

[1]

P and S:

The most loosely held electron in S is **one of the paired electrons in 3p orbital** while that of P is in the **singly filled 3p orbital**.

**Inter-electronic repulsion** between the paired electrons in the same p orbital **outweighs the effect of an increase in nuclear charge**.

Hence, **nuclear attraction for the most loosely held electrons is weaker in S**, i.e. S has a lower first IE.

[1]

[2]

- (b) The chlorides of the elements in the third period behave in different ways when added to water, depending on their structure and bonding.

**L** is a chloride of an element in Period 3. A student investigated **L** and the results are as given below.

- **L** is a white crystalline solid with a melting point of 987 K.
- **L** dissolves in water to form a weakly acidic solution.
- Addition of NaOH(aq) to an aqueous solution of **L** produces a white precipitate, **M**.

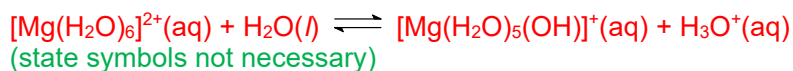
(i) Identify **L** and **M**.

**L:**  $\text{MgCl}_2$

**M:**  $\text{Mg(OH)}_2$

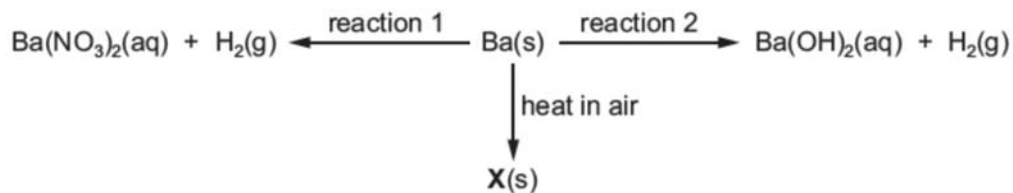
[1]

(ii) Write an equation to illustrate the formation of the weakly acidic solution.



[1]

(c) Some reactions based on the Group 2 metal barium, Ba, are shown below.

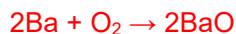


(i) State the reagent needed for each of reactions 1 and 2.

Reaction 1:  $\text{HNO}_3$  [1]

Reaction 2:  $\text{H}_2\text{O}$  [1]

(ii) Write an equation for the formation of **X**.

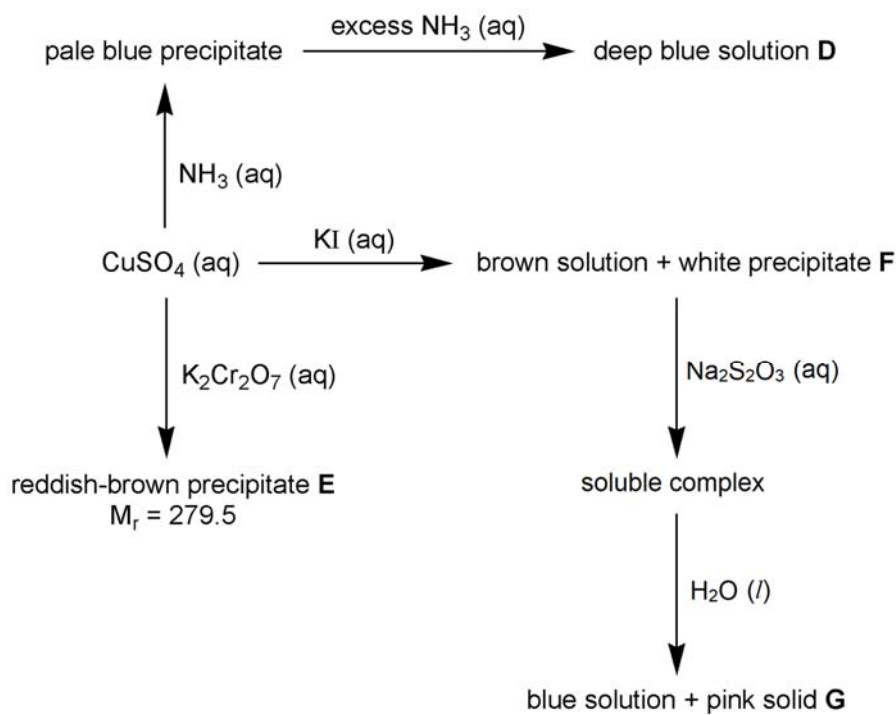


[1]

[Total: 8]

2 The use of *Data Booklet* is relevant to this question.

- (a) Copper(II) sulfate, an inorganic compound that has wide uses in organic syntheses and in engraving of zinc plates for intaglio printmaking, can undergo a series of reactions as shown below.



- (i) Identify **D**, **E**, **F** and **G**.

**D:**  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$  or  $[\text{Cu}(\text{NH}_3)_4]^{2+}$       **E:**  $\text{CuCr}_2\text{O}_7$

**F:**  $\text{CuI}$       **G:**  $\text{Cu}$

- (ii) With the aid of relevant equations, account for the formation of the deep blue solution **D** from the pale blue precipitate.



Formation of  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  complex lowers  $[\text{Cu}^{2+}]$ . This causes the ionic product of  $\text{Cu}(\text{OH})_2$  to become less than  $K_{\text{sp}}$  of  $\text{Cu}(\text{OH})_2$ , and hence the pale blue  $\text{Cu}(\text{OH})_2$  precipitate dissolves to form the deep blue solution.

OR

Formation of  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  complex lowers  $[\text{Cu}^{2+}]$ . By Le Chatelier's Principle, the position of equilibrium (2) shifts to the right to partially increase  $[\text{Cu}^{2+}]$ . Hence the pale blue  $\text{Cu}(\text{OH})_2$  precipitate dissolves to form the deep blue solution.

[2]



- (b) (i) By quoting relevant data, account for the trend in the thermal stabilities from HCl to HI.



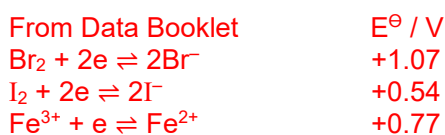
Down the group, less energy is needed to break the weaker H-X bond, resulting in decreasing thermal stability of HX.

[2]

- (ii) Identify a transition metal cation that can be used to differentiate the oxidising abilities of Br<sub>2</sub> and I<sub>2</sub>. Explain your answer with appropriate workings.

[3]

The transition metal cation is Fe<sup>2+</sup>.



Br<sub>2</sub> can oxidise Fe<sup>2+</sup> to Fe<sup>3+</sup> since the reaction is spontaneous.



I<sub>2</sub> cannot oxidise Fe<sup>2+</sup> to Fe<sup>3+</sup> since the reaction is non-spontaneous.

- (iii) Suggest a series of steps to verify the presence of chloride and iodide ions in a mixture, given the following reagents:

- |                          |                 |
|--------------------------|-----------------|
| • Aqueous silver nitrate | • Filter paper  |
| • Aqueous ammonia        | • Filter funnel |
| • Aqueous nitric acid    |                 |

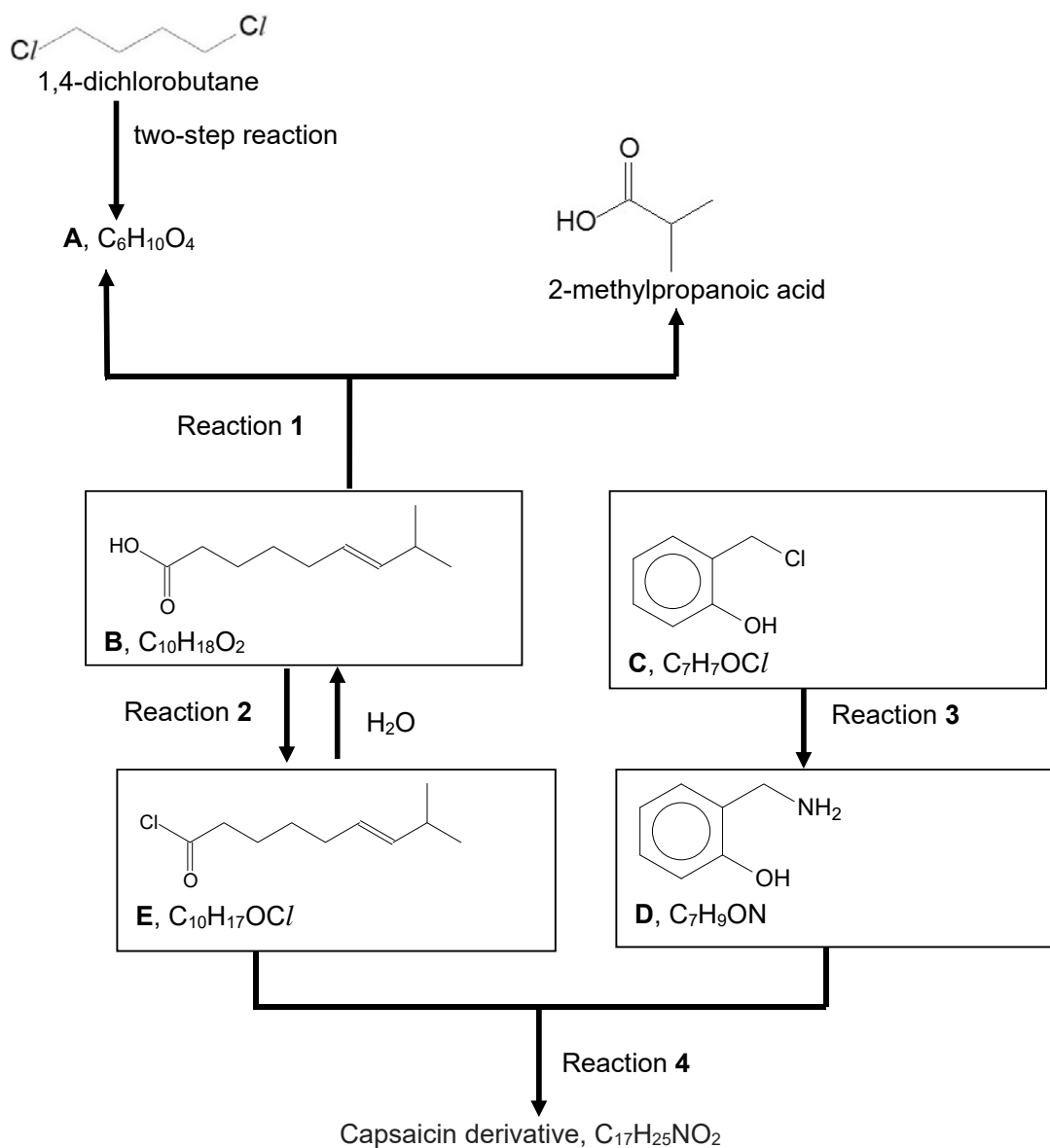
1. Add excess aqueous silver nitrate to the mixture. Yellowish-white precipitate is formed.
2. Next, add excess aqueous ammonia. Some of the precipitate will dissolve and only a yellow precipitate remains.
3. Filter the mixture with filter paper and filter funnel. Yellow residue indicates the presence of iodide ions.
4. To the colourless filtrate, add excess aqueous nitric acid. White precipitate formed indicates the presence of chloride ions.

[3]

[Total: 14]

- 3 Capsaicin is an active component of chili peppers. The reaction scheme involving the formation of a derivative of Capsaicin,  $C_{17}H_{25}NO_2$ , is shown below.

Information on compounds **A** to **D** are given on pages 6 and 7.



Compounds **A** to **D** react with sodium metal.

Compounds **A** and **B** react with aqueous sodium carbonate.

Compound **C**, Compound **D** and the capsaicin derivative reacts with aqueous sodium hydroxide but does not react with aqueous sodium carbonate.

Compounds **B** and **E** also react with cold acidified  $KMnO_4$ .

- (a) Name the functional group common to compounds **A** and **B**.

Carboxylic acid

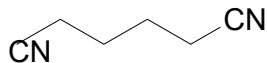
[1]

- (b) Compound **A** can be synthesised from 1,4-dichlorobutane in two steps. Suggest reagents and conditions for the synthesis, and the intermediate product for the reaction.

Step 1: **ethanolic NaCN, heat**

Step 2: **dil H<sub>2</sub>SO<sub>4</sub>, heat**

Intermediate product:



[3]

- (c) There are two functional groups in compound **B**. Suggest the identity of the functional group in **B** that reacts with cold acidified KMnO<sub>4</sub>.

Functional group that reacts with cold acidified KMnO<sub>4</sub>: **alkene**

[1]

- (d) Hence, draw the structure of compound **B** in the box on pg 6 and state the reagents and conditions for reaction 1.

Reagents and conditions for reaction 1: **KMnO<sub>4</sub>, dil H<sub>2</sub>SO<sub>4</sub>, heat**

[2]

- (e) Compound **C** reacts with hot ethanolic silver nitrate to produce a white ppt. Draw the structure of Compounds **C** and **D** in the box on pg 6. Name the type of reaction for reaction 3.

Type of reaction for reaction 3: **nucleophilic substitution**

[3]

- (f) Compound **E** readily hydrolyses in water to produce Compound **B**.

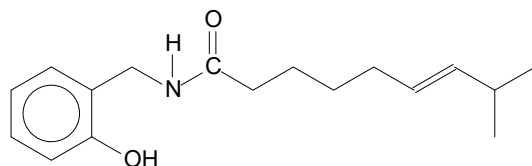
Draw the structure of compound **E** in the box on pg 6, and hence state the reagents and conditions for reaction 2.

Reagents and conditions for reaction 2: **PCl<sub>5</sub> (s), anhydrous**

[2]

- (g) Compounds **D** and **E** react to produce the Capsaicin derivative.

Draw the structure of the Capsaicin derivative.



[1]

[Total: 13]

- 4 On 11 May 2018, Mount Merapi on Central Java, Indonesia erupted, causing the local airport to be closed. The eruption was reported to be caused by accumulation of volcanic gases. The volcanic ash and gases spewed can be dangerous to planes passing through the plume. The most abundant volcanic gas is harmless water vapour. However, significant amounts of carbon dioxide, sulfur dioxide, hydrogen sulfide and hydrogen halides are also emitted.

When carbon dioxide is emitted from volcanoes, it typically becomes diluted to low concentrations very quickly and is not life threatening. However, cold carbon dioxide gas can flow into low-lying areas where it can reach much higher concentrations. Breathing air with more than 3% CO<sub>2</sub> can quickly lead to headaches, dizziness, increased heart rate and difficulty breathing. At about 15%, unconsciousness and death can result quickly.

**Table 1.1:** Volcanic gas composition in area A

Gas	Volume Percentage
Water vapour, H <sub>2</sub> O	87.1
Carbon dioxide, CO <sub>2</sub>	unknown
Sulfur dioxide, SO <sub>2</sub>	0.5
Hydrogen, H <sub>2</sub>	0.7
Carbon monoxide, CO	0.01
Hydrogen sulfide, H <sub>2</sub> S	0.23
Hydrochloric acid, HCl	2.89
Hydrofluoric acid, HF	2.55

Composition of the volcanic gases are typically expressed in terms of volume percentage, which can be calculated as follows

$$\text{volume percentage} = \frac{\text{volume of gas}}{\text{Total volume}} \times 100\%$$

However, percentages are only additive for ideal gases.

- (a) (i) State **two** assumptions of the kinetic theory of gases.

- 1) Negligible attractive or repulsive forces between gas particles
- 2) Negligible volume of gas particles compared to the volume they are moving in/ volume of the container they are in.

[2]

- (ii) Under what conditions of temperature and pressure would you expect the behaviour of carbon dioxide to be most like that of an ideal gas?

Low pressure and high temperature.

[1]

- (iii) Suggest a reason why at low temperature, carbon dioxide would sink rapidly and accumulate to high concentrations.

At low temperatures, there is insufficient energy to overcome the strong temporary dipole induced dipole (tdid) interactions between CO<sub>2</sub> molecules. Hence CO<sub>2</sub> would aggregate together/ more CO<sub>2</sub> molecules in a smaller volume and have a higher density thus sink down.

[2]

- (iv) People living in area A were evacuated as the level of carbon dioxide and temperature of surroundings were increasing rapidly.

Given that 0.30 mg of CO<sub>2</sub> was present in 10 cm<sup>3</sup> of gas mixture at 43 °C and 11.2 kPa, determine the volume percentage of carbon dioxide present.

Hence comment on the possible danger if people remained in the area.

$$\text{Amt of CO}_2 = \frac{0.30 \times 0.001}{44.0} = 6.818 \times 10^{-6} \text{ mol}$$

$$pV = nRT$$

$$(11200)(V) = (6.818 \times 10^{-6})(8.31)(273 + 43)$$

$$V = 1.598 \times 10^{-6} \text{ m}^3$$

$$\text{volume percentage of CO}_2 = \frac{1.598 \times 10^{-6}}{10 \times 10^{-6}} \times 100\% = 16.0\%$$

Ans: 16.0% unconsciousness and death can result quickly.

[3]

- (b) Hydrogen sulfide can react with methane in the following equation.



1 mol of CH<sub>4</sub>, 2 mol of H<sub>2</sub>S, 1 mol of CS<sub>2</sub> and 1 mol of H<sub>2</sub> was allowed to reach equilibrium at a constant temperature and pressure of 960°C and 2 atm.

Given that partial pressure of  $\text{CS}_2$  was found to be 0.5 atm at equilibrium, determine the value of  $K_p$ , giving its units.

[3]

Q says to reach equilibrium at  $960^\circ\text{C}$  and 2 atm, i.e. Total P initially and Total P at eqm is same, 2 atm.

	$\text{CH}_4(\text{g})$	$+ 2 \text{H}_2\text{S}(\text{g})$	$\rightleftharpoons$	$\text{CS}_2(\text{g})$	$+ 4 \text{H}_2(\text{g})$
Initial/ mol	1	2		1	1
Eqm/ mol	$1-x$	$2-2x$		$1+x$	$1+4x$

Total mol at eqm =  $5 + 2x$

partial pressure of  $\text{CS}_2 = 2 \left( \frac{1+x}{5+2x} \right) = 0.5 \text{ atm}$

solve for  $x$ ,  $x = 0.5$

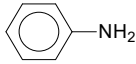
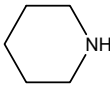
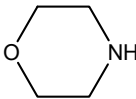
	$\text{CH}_4(\text{g})$	$+ 2 \text{H}_2\text{S}(\text{g})$	$\rightleftharpoons$	$\text{CS}_2(\text{g})$	$+ 4 \text{H}_2(\text{g})$
Eqm/ mol	0.5	1		1.5	3
	Total amt of gas at eqm = 6				
Eqm / atm	$\frac{0.5}{6} \times 2 = \frac{1}{6}$	$\frac{1}{6} \times 2 = \frac{1}{3}$		0.5	$\frac{3}{6} \times 2 = 1$

$$K_p = \frac{(P_{\text{H}_2})^4 \cdot P_{\text{CS}_2}}{P_{\text{CH}_4} \cdot (P_{\text{H}_2\text{S}})^2}$$

$$K_p = \frac{1^4(0.5)}{(1/6) \cdot (1/3)^2} = 27.0 \text{ atm}^2$$

[Total: 11]

- 5 (a) The following table contains the  $pK_b$  values of different nitrogen organic compounds.

Compound	$pK_b$
$(CH_3)_3CNH_2$ 2-amino-2-methylpropane	3.19
 phenylamine	9.38
 piperidine	2.88
 morpholine	5.17
$N_2H_4$ hydrazine	5.17, 11.05

- (i) Suggest a reason why  $pK_b$  of morpholine is higher than piperidine.

Morpholine has an electronegative O that exert **electron withdrawing effect**, it reduces the availability of lone pair on N to accept  $H^+$ , therefore Morpholine is a weaker base hence a higher  $pK_b$  value.

- (ii) Suggest a reason why  $pK_b$  of phenylamine is so much higher than 2-amino-2-methylpropane.

Lone pair on N of phenylamine is delocalised into the benzene ring, making lone pair much less available to receive  $H^+$  than lone pair of N in  $(CH_3)_3CNH_2$ , phenylamine is a weaker base hence a higher  $pK_b$  value than  $(CH_3)_3CNH_2$ .

[2]

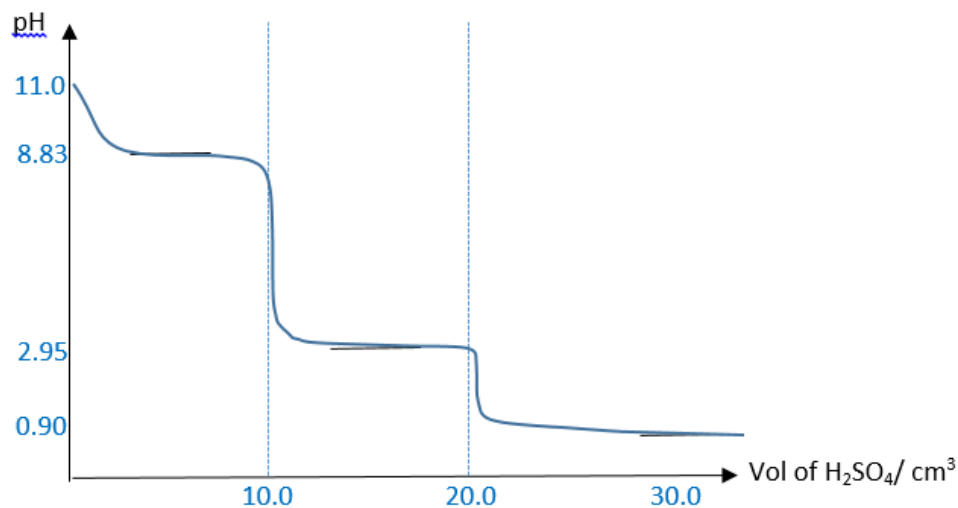
- (b)  $10.0\text{ cm}^3$  of an aqueous mixture containing  $0.5\text{ mol dm}^{-3}$  of hydrazine was placed in a conical flask and the initial pH was found to be 11.0.

Sketch the  $pH$ -volume graph on the axis provided when  $10.0\text{ cm}^3$  of the aqueous mixture was titrated with  $0.25\text{ mol dm}^{-3}$  dilute sulfuric acid until a total volume of  $30.0\text{ cm}^3$  of dilute sulfuric acid was added.

Your sketch should include the following points

- Initial pH of hydrazine
- $pH$  of the reaction mixture when  $30.0\text{ cm}^3$  of  $H_2SO_4$  is added.

- Maximum buffer points (if any)



Initial pH = 11.0 given in question

volume of  $\text{H}_2\text{SO}_4$  required for the 1<sup>st</sup> equiv point = 10.0  $\text{cm}^3$

total vol of  $\text{H}_2\text{SO}_4$  required for 2<sup>nd</sup> equiv point = 20.0  $\text{cm}^3$

Max buffer points occur at 5 and 15  $\text{cm}^3$ .

$\text{pOH} = \text{p}K_b$  at max buffer pts

$\text{pH} = 14 - \text{pOH}$

$\text{pH}$  are  $14 - 5.17 = 8.83$  and  $14 - 11.05 = 2.95$  respectively.

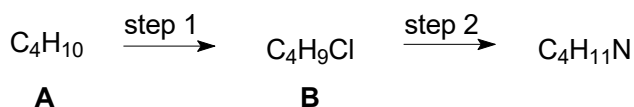
Final pH

Amt of unreacted  $\text{H}^+ = (2 \times 10/1000 \times 0.25) = 0.005 \text{ mol}$  (since  $\text{H}_2\text{SO}_4$  is diprotic)

$[\text{H}^+] = 0.005 \times 1000 / 40 = 0.125 \text{ mol dm}^{-3} \Rightarrow \text{pH} = 0.90$

[3]

- (c) Student **M** suggested a 2-step process as shown, to synthesise 2-amino-2-methylpropane from a suitable alkane.



- (i) Identify the structures of compounds **A** and **B**, and suggest reagents and conditions for each of the two steps.

$(\text{CH}_3)_3\text{CH}$ Structure of <b>A</b>	$(\text{CH}_3)_3\text{CCl}$ Structure of <b>B</b>
---	--

Step 1: limited  $\text{Cl}_2$ , UV. light



Step 2: excess  $\text{NH}_3$  in ethanol, heat in sealed tube

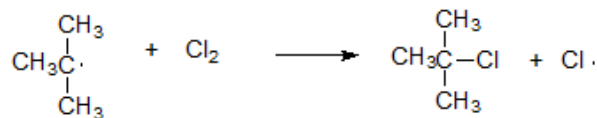
[4]

- (ii) Outline the mechanism for step 1.

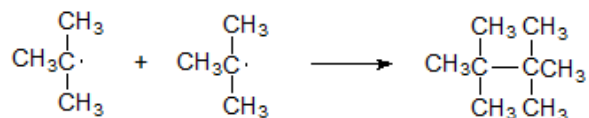
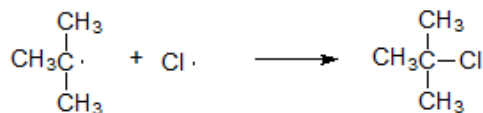
### Free radical substitution



### propagation



### Termination



[3]

- (iii) A student **N** suggested an alternative synthetic route for the synthesis of 2-amino-2-methylpropane, using an alkene as a starting material.

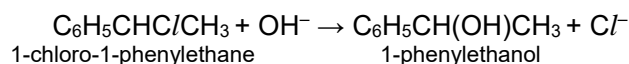
Explain why this synthetic route will give a higher yield as compared to the suggested route in (c) (ii).

Electrophilic addition via alkene can only give two possible products and the tertiary carbocation is formed at a greater rate that forms the major product 2-amino-2-methylpropane, while free radical substitution of alkane gives rise to a variety of reactive intermediates that lead to multiple products being formed.

[2]

[Total: 14]

- 6 1-chloro-1-phenylethane undergoes hydrolysis with hydroxide ions to produce 1-phenylethanol, as shown in the equation below.



- (a) The rate of this reaction can be studied by measuring the amount of hydroxide ions that remain in the solution at a given time after the reaction has been quenched.
- (i) Suggest a suitable quenching agent that can be used to stop the reaction effectively.

cold water

[1]

- (ii) Using your answer in (i), describe a suitable method for determining the order of reaction with respect to  $\text{OH}^-$ , given the following.

- Solution **A**, 1.0 mol dm<sup>-3</sup> 1-chloro-1-phenylethane
- Solution **B**, 0.10 mol dm<sup>-3</sup> sodium hydroxide
- 0.10 mol dm<sup>-3</sup> hydrochloric acid
- Quenching agent [as suggested in (i)]
- Stopwatch
- Standard laboratory equipment

Specific details of volumes and time is not required.

Continuous Method:

1. Mix Solution **A** & **B**, swirl the beaker and start the stopwatch.
2. At a certain time, withdraw a fixed volume of mixture into a conical flask, add fixed volume of cold water to the mixture to quench the reaction.
3. Titrate against hydrochloric acid, using phenolphthalein as indicator.
4. Titrate until colour of mixture turns from pink to colourless.
5. Repeat steps 2 - 4 at fixed time intervals (eg, 6 min, 9 min, 12 min)
6. Plot graph of volume of HCl against time.
7. If straight-line graph, it means that reaction is 0 order wrt  $\text{OH}^-$   
If constant half-life, it means that reaction is 1<sup>st</sup> order wrt  $\text{OH}^-$   
If increasing half-life, it means that reaction is 2<sup>nd</sup> order wrt  $\text{OH}^-$

- (b) The rate of this reaction was measured using different initial concentrations of the two reagents and the results are shown below.

Experiment	$[\text{C}_6\text{H}_5\text{CHCl/CH}_3] / \text{mol dm}^{-3}$	$[\text{OH}^-] / \text{mol dm}^{-3}$	Relative rate
1	0.05	0.10	1.0
2	0.10	0.20	2.0
3	0.15	0.10	3.0

- (i) Deduce the order of reaction with respect to each of the reagents. Explain your reasoning.

Comparing experiment 1 & 3, when  $[\text{OH}^-]$  is constant,  $[\text{C}_6\text{H}_5\text{CHCl}/\text{CH}_3]$  is tripled, relative rate is tripled. Hence, reaction is 1<sup>st</sup> order with respect to  $\text{C}_6\text{H}_5\text{CHCl}/\text{CH}_3$ . [1]

Comparing experiment 1 & 2, when both  $[\text{OH}^-]$  and  $[\text{C}_6\text{H}_5\text{CHCl}/\text{CH}_3]$  are doubled, relative rate is doubled. Since reaction is 1<sup>st</sup> order with respect to  $\text{C}_6\text{H}_5\text{CHCl}/\text{CH}_3$ , the doubling of  $[\text{OH}^-]$  has no effect on rate, so reaction is zero order with respect to  $\text{OH}^-$ . [1]

\* Accept if student write conc / rate increases by 3 times.

Order with respect to  $\text{C}_6\text{H}_5\text{CHCl}/\text{CH}_3$  = **first order**

Order with respect to  $\text{OH}^-$  = **zero order**

- (ii) Write the rate equation for this reaction, stating the units of the rate constant,  $k$ .

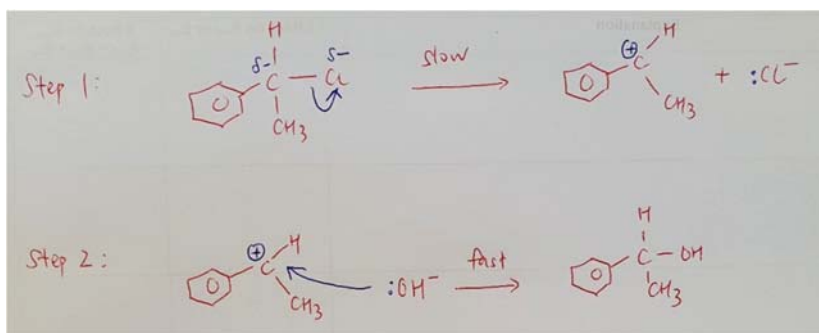
$$\text{rate} = k[\text{C}_6\text{H}_5\text{CHCl}/\text{CH}_3] \text{ mol dm}^{-3}\text{s}^{-1}$$

$$\text{units of } k = \text{s}^{-1}$$

[2]

- (c) (i) By making use of your answer in (b)(i), describe the mechanism for the reaction of 1-chloro-1-phenylethane with hydroxide ions. In your answer, you should show relevant charges, lone pairs, dipoles and show movement of electrons by curly arrow.

Nucleophilic substitution ( $\text{S}_{\text{N}}1$ )



- (ii) This reaction was carried out using a single optical isomer of 1-chloro-1-phenylethane. Use your mechanism in (i) to predict whether the product will be a single optical isomer or a mixture of two optical isomers. Explain your answer.

A mixture of 2 optical isomers (racemic mixture) will be formed because the nucleophile can attack the trigonal planar intermediate from top or bottom of the plane with equal probability.

If  $S_N2$  in c(i),

A single optical isomer will be formed as the nucleophile attack the molecule from the opposite side of the leaving chloride, resulting in an inversion of configuration. [2]

- (iii) 1-chloro-2-ethyl benzene,  $C_6H_4C/CH_2CH_3$ , is an isomer of 1-chloro-1-phenylethane,  $C_6H_5CHC/CH_3$ . The ease of hydrolysis for each of the 2 compounds is different. Explain why.

In 1-chloro-2-ethyl benzene, the p-orbital of C/ overlaps with the  $\pi$ -electron cloud of benzene, resulting in delocalisation of electrons, strengthening the C-C/ bond, giving it a partial double bond character.

Hence, the C-C/ bond does not break easily and the ease of hydrolysis will be much lower than that of 1-chloro-1-phenylethane.

[Total: 15]



**NATIONAL JUNIOR COLLEGE**  
**SH2 PRELIMINARY EXAMINATION**

Higher 2

CANDIDATE  
NAME

SUBJECT  
CLASS

REGISTRATION  
NUMBER

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**CHEMISTRY**

Paper 3 Free Response

**9729/03**

**Monday 10 Sep 2018**  
**2 hours**

Candidates answer on separate paper.

Additional Materials: Data Booklet  
Answer Paper

---

**READ THESE INSTRUCTIONS FIRST**

Write your subject class, registration number and name on all the work you hand in.  
Write in dark blue or black pen.

You may use a soft pencil for any diagrams or graphs.  
Do not use paper clips, highlighters, glue or correction fluid/tape.

**Section A**

Answers **all** questions.

**Section B**

Answers **one** question.

The use of an approved scientific calculator is expected, where appropriate.  
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

## Section A

Answer **all** the questions in this section.

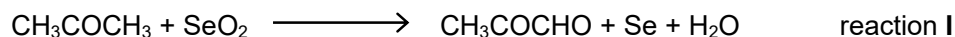
- 1 (a) The melting points of some compounds are given

Substance	Octan-1-ol	Iodine	Fullerene	Graphite
Formula	$\text{CH}_3(\text{CH}_2)_7\text{OH}$	$\text{I}_2$	$\text{C}_{60}$	$\text{C}$
Melting point/ K	277	286	873	>3000

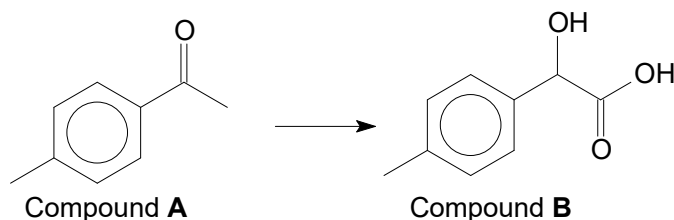
(i) Explain why the melting points of octan-1-ol and iodine are comparable. [2]

(ii) Explain why the melting point of graphite is higher than that of fullerene. [2]

- (b) In 1932, Harry Lister Riley and coworkers published their findings on the use of selenium dioxide,  $\text{SeO}_2$ , in the synthesis of aldehyde and ketone functional groups. One of such reactions is shown below.



Using the synthetic method above in one of your steps, devise a three-stage synthesis of compound **B** from compound **A**.



[5]

- (c) The most common source of acidity in water is dissolved carbon dioxide.

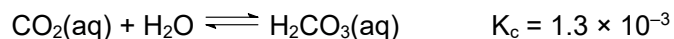
Carbon dioxide enters the water through equilibrium with the atmosphere.



where  $K_{\text{H}}$  is known as the Henry's Law constant given by the equation:

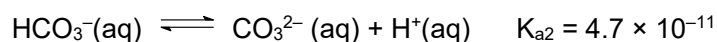
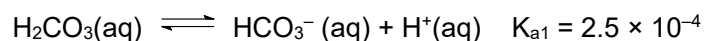
$$[\text{CO}_2(\text{aq})] = K_{\text{H}} \times P_{\text{CO}_2}$$

Carbon dioxide can react with water to form carbonic acid as shown in the following reaction.



- (i) Calculate  $[\text{CO}_2(\text{aq})]$  at a pressure of 101.3 kPa, given that air contains 0.035% by volume of carbon dioxide. [2]
- (ii) Using your answer from (i), calculate  $[\text{H}_2\text{CO}_3]$ . [1]

Carbonic acid will further dissociate in the following reactions.



(iii) The pH of the carbonic acid is largely contributed by  $K_{a1}$ . Explain why. [1]

(iv) Hence, calculate pH of carbonic acid. [1]

(c) Many organic compounds that occur naturally have molecules that can show stereoisomerism, that is cis-trans or optical isomerism.

Draw the structures of all the possible stereoisomers which have the following features.

- They are acyclic.
- They have molecular formula  $\text{C}_4\text{H}_{10}\text{N}_2$ .
- No nitrogen atom is attached to any carbon atom which is involved in a double bond.
- No carbon atom has more than one nitrogen atom joined to it.

For **each** structure you draw, state the type of stereoisomerism it shows.

[4]

[Total:18]

- 2 Electric or hybrid vehicles are expected to reach 27 million by 2027. Copper is used as a major component in the windings and copper rotors of electric vehicles.

Crude copper was obtained when a particular copper ore was reduced. Crude copper contains cobalt and silver as minor impurities. It contained no other metal. In order to purify it, crude copper was made the anode of an electrolysis cell, with a pure copper cathode and aqueous  $\text{CuSO}_4$  as electrolyte.

- (a) Explain, with reference to relevant  $E^\circ$  values, what happens to the cobalt and silver impurities during this purification process.

[3]

An experiment was carried out to determine the percentage purity of the crude copper obtained from reduction of copper ore. A current of 2.15 A was passed through the cell described in (a) for 28.0 minutes, and the electrodes removed and weighed. It was found that the anode has lost 1.25 g.

After filtering it off, the deposit underneath the anode weighed 0.07 g. On adding an excess of dimethylglyoxime to the electrolyte, the highly insoluble red complex with the formula  $\text{Co}(\text{C}_4\text{H}_7\text{N}_2\text{O}_2)_2$  was precipitated. Its mass was 0.55 g.

- (b) (i) Calculate the *actual mass of copper* removed from the crude copper.

[2]

- (ii) Hence determine the percentage purity of the crude copper produced in (a), assuming that the crude copper is of uniform mixture.

[1]

- (iii) Suggest how the procedure can be improved to increase the reliability of results.

[1]

- (iv) Calculate the *expected increase* in mass of the cathode.

[2]

- (c)  $\text{Co}(\text{C}_4\text{H}_7\text{N}_2\text{O}_2)_2$  has a solubility of  $1.23 \times 10^{-4} \text{ mol dm}^{-3}$ .

Calculate its solubility product.

[2]



Lithium is a scavenger for hydrogen, hence it is able to prevent the reaction between hydrogen and copper during pure copper casting. Reaction with hydrogen makes the copper brittle, causing it to fall apart under very light stress.

**Table 1**

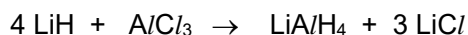
	Enthalpy / kJ mol <sup>-1</sup>
Enthalpy change of formation of LiH(s)	-90.5
Enthalpy change of formation of LiAlH <sub>4</sub> (l)	-152.5
Enthalpy change of formation of Li <sub>3</sub> AlH <sub>6</sub> (s)	-454
Enthalpy change of atomisation of Li(s)	+159.5
Electron affinity of hydrogen atoms	-73.0

(d) Heating lithium in a stream of hydrogen gas produces white, crystalline, ionic lithium hydride, LiH.

(i) With the help of a suitable energy level diagram, calculate the lattice energy of LiH using relevant data from **Table 1** and the *Data Booklet*. [3]

(ii) By quoting relevant data from the *Data Booklet*, suggest and explain how the magnitude of the lattice energy of LiCl would compare to LiH. [2]

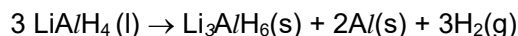
(e) When lithium hydride is heated with anhydrous aluminium chloride, lithium aluminium hydride, LiAlH<sub>4</sub> and lithium chloride are produced.



When 5 g each of AlCl<sub>3</sub> and LiH are reacted in a bomb calorimeter, the temperature rise is 8.4 °C. Given that the heat capacity of the bomb calorimeter is 1.24 kJ K<sup>-1</sup>, determine the enthalpy change of this reaction per mole of LiAlH<sub>4</sub>.

[3]

(f) Just above its melting point, LiAlH<sub>4</sub> decomposes according to the following equation.



(i) Use relevant data in **Table 1**, calculate the standard enthalpy change of this reaction. [1]

(ii) Given that  $\Delta G^\circ = -27.7 \text{ kJ mol}^{-1}$ , calculate  $\Delta S^\circ$  for this reaction at 298K, and comment on its sign with respect to the equation for this reaction. [2]

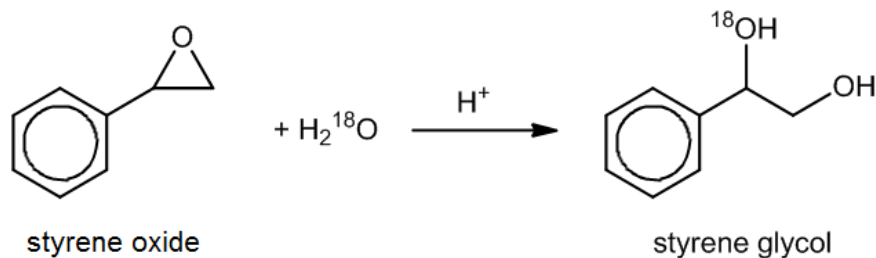
(iii) Hence calculate the melting point of LiAlH<sub>4</sub>. [1]

[Total: 23]

- 3 (a) Epoxides are a class of organic compounds with a three-membered ring structure. The three-membered ring in epoxides makes them highly reactive and susceptible to “ring-opening reactions” whereby one of the C–O bonds breaks.

- (i) An example of an epoxide ring-opening reaction is the hydrolysis of styrene oxide in the presence of a strong acid catalyst to form styrene glycol.

To determine the reaction mechanism, isotopic labelling was used. The hydrolysis was carried out using “heavy-oxygen water”,  $\text{H}_2^{18}\text{O}$ .



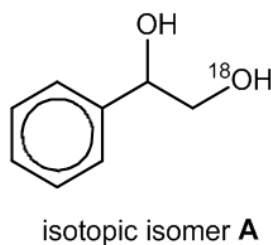
Some details of the mechanism are as given.

1. Protonation of the oxygen atom by a strong acid catalyst
2. Heterolytic fission of the C–O bond to generate a carbocation intermediate, which is a slow step
3. Attack of the carbocation by one molecule of  $\text{H}_2^{18}\text{O}$  to form a new C–O bond
4. Loss of a proton to form styrene glycol and regenerate the acid catalyst

Describe steps 1 to 4 of the unimolecular nucleophilic substitution mechanism, showing all relevant charges, lone pairs, dipoles and movement of electrons by curly arrows. You are to label the  $^{18}\text{O}$  atom in all necessary species.

[3]

- (ii) Trace amounts of an isotopic isomer **A** are also detected upon analysis of the styrene glycol product formed from the hydrolysis.



Explain why **A** was formed only in trace amounts.

[2]

- (iii) Draw the structure of a side product formed if the same reaction is carried out in the presence of aqueous sodium chloride.

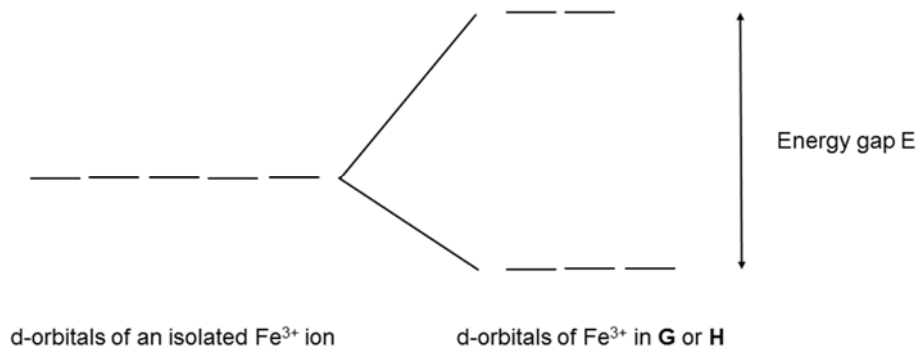
[1]

- (b) In 2012, a group of scientists synthesised two ligands, N,N-diethylethylenediamine and N-ethylethylenediamine, and reacted each with  $\text{Fe}^{3+}$  to form two complexes, **G** and **H**, with different colours respectively.

(i) Explain why iron(III) complexes are usually coloured.

[3]

The following diagram shows how the d-orbitals are split in an octahedral environment.



When the ligand in **H** is substituted with N,N-diethylethylenediamine ligand to form **G**, the  $\text{Fe}^{3+}$  ion changes its electronic configuration from a 'high spin' state to a 'low spin' state.

In a 'high spin' state, the electrons occupy all the d-orbitals singly, before starting to pair up in the lower energy d-orbitals.

In a 'low spin' state, the lower energy d-orbitals are filled first, by pairing up if necessary, before the higher energy d-orbitals are used.

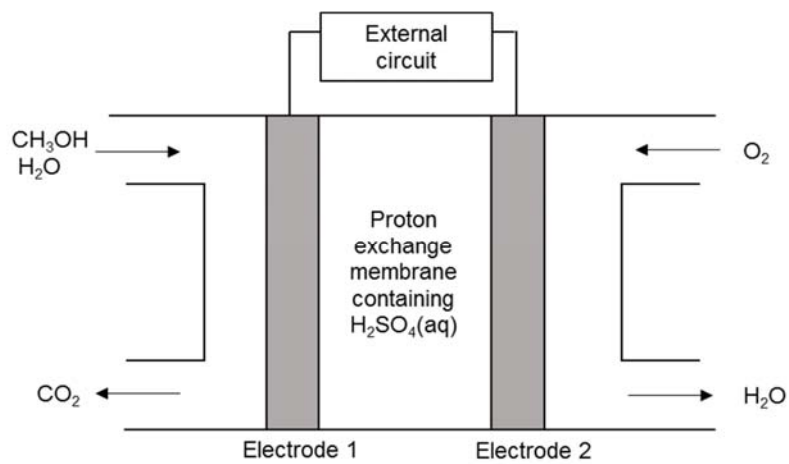
(ii) Use diagrams like the one above to show the electronic distribution of a  $\text{Fe}^{3+}$  ion in a high spin state, and in a low spin state.

[2]

(iii) By using the information provided thus far and your answer in (ii), state and explain which of the two complexes will contain the larger energy gap, E, between its d-orbitals.

[2]

- (c) The following diagram illustrates the parts of a type of fuel cell, Direct methanol fuel cell (DMFC). Methanol is supplied to Electrode 1 where methanol and water react to form carbon dioxide. Oxygen is supplied to Electrode 2 simultaneously and reacts with the protons at the cathode to form water.



- (i) Determine the oxidation number of carbon in carbon dioxide and methanol. [1]
- (ii) Write half equations for the reactions which take place at Electrode 1 and Electrode 2. Hence, construct an equation for the overall reaction. [2]
- (iii) The cell is capable of producing an e.m.f. of 1.62 V.  
Predict how the voltage of this cell would change if the concentration of methanol was reduced. [2]
- (iv) Suggest a possible advantage of using DMFC as compared to a hydrogen-oxygen fuel cell. [1]

[Total: 19]

## Section B

Answer **one** question from this section.

- 4 (a) Proteins are diverse groups of polypeptides required by the human body for growth and maintenance. Human serum albumin, HSA is an important protein that transports hydrophobic molecules in the blood stream.

Four of the most common amino acids in the HSA molecule are listed below.

Amino acid	Formula of side chain (R in $\text{RCH}(\text{NH}_2)\text{CO}_2\text{H}$ )
Glutamic acid	$-\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
Leucine	$-\text{CH}_2\text{CH}(\text{CH}_3)_2$
Lysine	$-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
Valine	$-\text{CH}(\text{CH}_3)_2$

- (i) Use the above amino acids to draw the structural formula of a section of the polypeptide chain of HSA, consisting of 3 amino acid residues.

[2]

- (ii) The ability of a protein to carry out its function lies in its unique structure that is a result of interactions within the polypeptide chain.

Given that the secondary structure occurs due to interactions between the peptide linkages, state the type of interaction in the secondary structure and illustrate it with a simple diagram.

[2]

- (iii) The hydrophobic groups are transported in the inside of the spherical HSA molecule.

Which 2 amino acids from the above table are likely to be responsible for this? Explain your answer.

[2]

- (b) (i) Amino acids exist as zwitterions. Using leucine as an example, suggest what is meant by the term *zwitterion*.

[1]

- (ii) How would you expect the melting point and the solubility in water, of an unionised form of leucine to compare with the actual properties of the zwitterionic form?

[3]

- (c) Compound **A**,  $C_8H_{10}O_2$ , reacts with aqueous bromine to form a white precipitate, compound **B** with molecular formula,  $C_8H_7O_2Br_3$ .

Compound **A** also reacts with dilute nitric acid to give compound **C**,  $C_8H_9NO_4$ . Treatment of compound **C** with tin in concentrated hydrochloric acid, followed by hot aqueous sodium hydroxide gives compound **D**,  $C_8H_{10}NO_2Na$ .

Compound **D** turns hot acidified potassium dichromate solution green and forms compound **E**,  $C_8H_9NO_3$ . 1 mole of compound **E** reacts with 2 moles of aqueous sodium hydroxide.

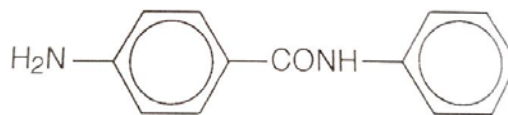
Compound **E** reacts with phosphorus pentachloride to give compound **F**,  $C_8H_7NO_2$ .

Deduce the structures of compounds **A**, **B**, **C**, **D**, **E** and **F** and explain the chemistry of the reactions described.

[10]

[Total:20]

- 5 (a) The structure of 4-amino-N-phenylbenzamide, used in the treatment of epilepsy, is given below. It forms interactions with water but has low solubility in water.



- (i) State the type of interaction occurring between water molecules and 4-amino-N-phenylbenzamide. Illustrate it with a simple diagram involving a water molecule.

[2]

- (ii) Explain the low solubility of 4-amino-N-phenylbenzamide in water.

[2]

- (b) 4-amino-N-phenylbenzamide is warmed with aqueous sodium hydroxide. Distillation was carried out to separate the products.

- (i) Draw the structures of the products formed when 4-amino-N-phenylbenzamide is warmed with aqueous sodium hydroxide.

[2]

- (ii) Suggest and explain the identity of the distillate.

[2]

- (iii) When the other product is carefully neutralised, a compound that can be used to maintain the pH of systems at a desired value is obtained.

By means of equations, show how this is achieved when small amounts of

- I. dilute HCl,
- II. dilute NaOH,

is added to a solution of the compound.

[2]

- (c) **G**,  $C_6H_9O_2N$ , is a neutral compound with the ability to rotate plane polarized light.

On heating **G** with aqueous NaOH, a pungent gas **H** that turned moist red litmus blue was liberated. Upon acidification of the reaction mixture, **J**,  $C_5H_8O_4$ , was formed.

**J** reacts with LiAlH<sub>4</sub> to form **K**,  $C_5H_{12}O_2$ . On heating with excess concentrated H<sub>2</sub>SO<sub>4</sub>, **K** forms **L**,  $C_5H_8$ . **L** does not exhibit cis-trans isomerism. When **L** is heated with acidified KMnO<sub>4</sub> solution, **M**,  $C_3H_4O_3$  is formed.

**M** reacts with aqueous Na<sub>2</sub>CO<sub>3</sub> to produce effervescence that forms a white precipitate in limewater. **M** also forms a yellow precipitate when warmed with alkaline aqueous I<sub>2</sub>.

Deduce the structures of compounds **G**, **H**, **J**, **K**, **L** and **M**, and explain the chemistry of the reactions described.

[10]

[Total:20]

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## NATIONAL JUNIOR COLLEGE SENIOR HIGH 2 PRELIM EXAMINATION

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## NATIONAL JUNIOR COLLEGE SENIOR HIGH 2 PRELIM EXAMINATION

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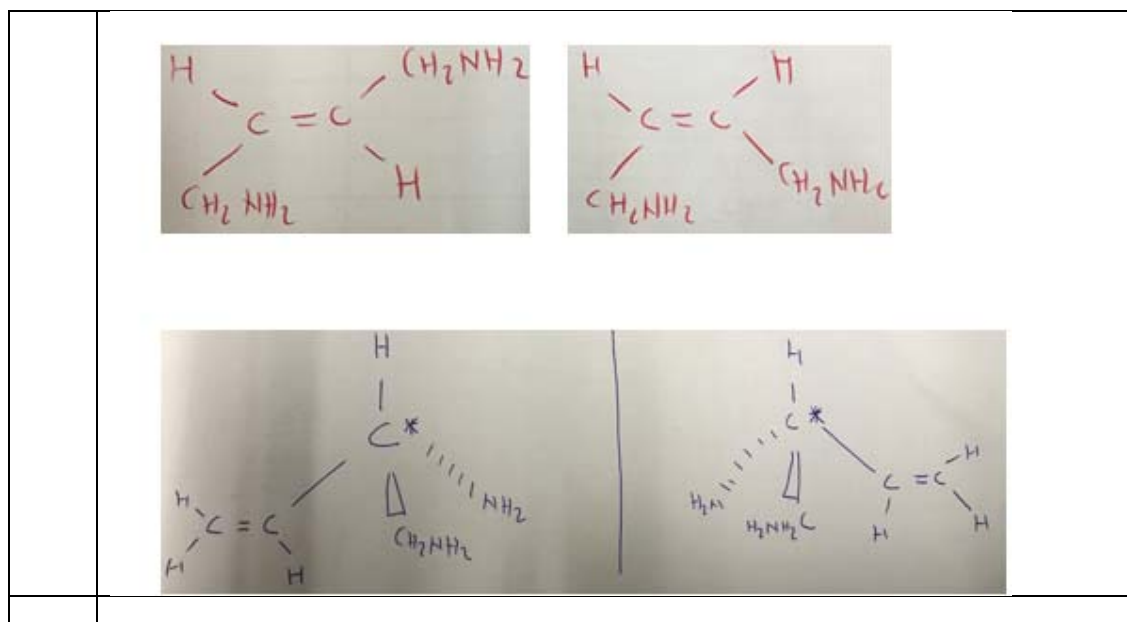
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**NJC 2018 SH2 H2 Chemistry Prelim Paper 3 Solutions:**

<b>Question 1</b>	
<b>(a)(i)</b>	<b>Suggested solution</b>  Both octan-1-ol and iodine have simple covalent structure Strength of Td-Id in iodine due to its large electron cloud size is comparable to the stronger hydrogen bonding between octan-1-ol molecules.
<b>(ii)</b>	<b>Suggested solution</b>  Graphite has a giant molecular structure with strong covalent bonds between carbon atoms to be overcome during melting. Fullerene has a simple covalent structure with weaker td-id interactions between fullerene molecules to be overcome during melting. Hence, more energy is required to melt graphite and a higher temperature is required.
<b>(b)</b>	<b>Suggested solution</b>  Step 1: reaction 1 ;(-COCHO) Step 2: K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> /KMnO <sub>4</sub> with H <sub>2</sub> SO <sub>4</sub> (aq) and heat; (-COCOOH) Step 3: NaBH <sub>4</sub> in ethanol or H <sub>2</sub> with Nickel/Pt ; (compound B)
<b>c(i)</b>	<b>Suggested solution</b>  $P_{CO_2} = \frac{0.035}{100} \times 101.3\text{kPa}$ $= 0.03546\text{kPa}$  $K_H = \frac{[CO_2(aq)]}{P_{CO_2}}$ $[CO_2(aq)] = 1.17 \times 10^{-5} \text{ mol dm}^{-3}$
<b>c(ii)</b>	<b>Suggested solution</b>  $K_c = \frac{[H_2CO_2(aq)]}{[CO_2]}$ $[H_2CO_3] = 1.52 \times 10^{-8} \text{ mol dm}^{-3}$
<b>(iii)</b>	<b>Suggested solution</b>  It is more difficult to remove a proton from a negatively charged ion as attractive forces have to be overcome.
<b>c(iv)</b>	<b>Suggested solution</b>  $K_{a1} = \frac{[HCO_3^-][H^+]}{[H_2CO_3]}$  $[H^+] = 1.915 \times 10^{-6} \text{ mol dm}^{-3}$ $\text{pH} = 5.71$
<b>d</b>	<b>Suggested solution</b>



## Question 2

(a)

**Suggested solution:**

At anode: Co has  $E_{ox}^{\circ}(\text{Co}/\text{Co}^{2+}) = +0.28\text{V}$  more positive than  $E_{ox}^{\circ}(\text{Cu}/\text{Cu}^{2+}) = -0.34\text{V}$ , hence Co will be oxidised together with Cu and dissolve as  $\text{Co}^{2+}$ , becoming part of the electrolyte. Ag on the other hand has more negative  $E_{ox}^{\circ}(\text{Ag}/\text{Ag}^{+})$  of  $-0.80\text{V}$ , hence will not be oxidised. It will fall below anode as sludge.

At cathode:  $\text{Co}^{2+}$  has a more negative  $E_{red}^{\circ}(\text{Co}^{2+}/\text{Co}) = -0.28\text{V}$  than  $E_{red}^{\circ}(\text{Cu}^{2+}/\text{Cu}) = 0.34\text{V}$ , hence  $\text{Co}^{2+}$  is not reduced at the cathode, remain dissolved as electrolyte.

(b)

**Suggested solution**

(i)

- mass of Ag = 0.07 g
- No of moles of Co oxidised at anode = no of moles of  $\text{Co}(\text{C}_4\text{H}_7\text{N}_2\text{O}_2)_2$

$$= \frac{0.55}{58.9 + 2(4 \times 12 + 7 \times 2 \times 14 + 2 \times 16)}$$

$$= 0.0019038 \text{ mol}$$

$$\text{Mass of Co in alloy (anode)} = 0.0019038 \times 58.7 = 0.112 \text{ g}$$

$$\text{Mass of Cu} = 1.25 - 0.07 - 0.112 = 1.068 \text{ g}$$

b(ii)

$$\% \text{ purity} = 1.068 / 1.25 \times 100 = 85.4\%$$

b(iii)

**Suggested solution:**

**Any one of the suggestion below is acceptable:**

- Mass of Ag and  $\text{Co}(\text{C}_4\text{H}_7\text{N}_2\text{O}_2)_2$  should be heated to consistent mass to ensure all water is driven off, so that mass measured is that of dry mass of Ag and  $\text{Co}(\text{C}_4\text{H}_7\text{N}_2\text{O}_2)_2$ .
- As mass of Ag (sludge) is rather small, use electronic balance of higher precision in order to reduce % uncertainty in mass measurement.
- Repeat the experiment using fresh samples so that an average of the mass measurements can be taken to reduce random error.

b(iv)

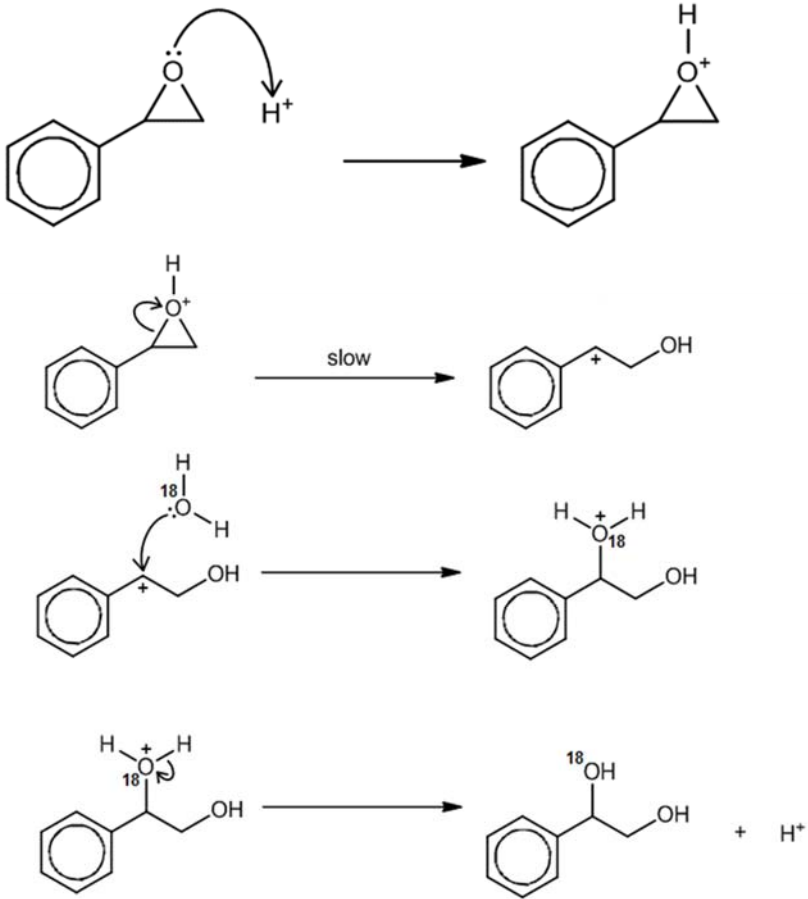
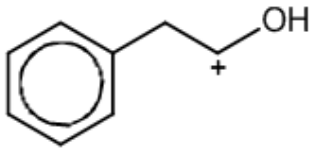
**Suggested solution:**

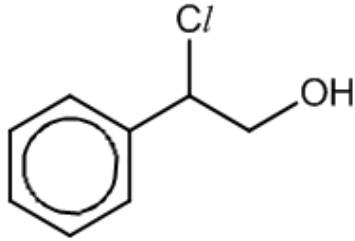
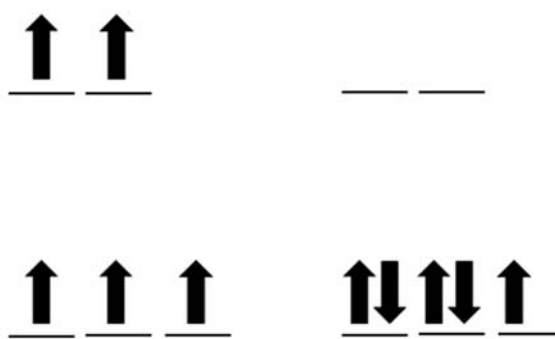
	<p>Total no of moles of e used for electrolysis = <math>2.15 \times 28.0 \times 60 \div 96500</math> = 0.03743</p> <p>No of moles of Cu expected to be discharged = <math>0.043523 \div 2</math> = 0.018715</p> <p>Mass expected = <math>0.018715 \times 63.5</math> = 1.19 g (3sf)</p>
(c)	<p><b>Suggested solution:</b></p> $\text{Co}(\text{C}_4\text{H}_7\text{N}_2\text{O}_2)_2 + \text{aq} \rightleftharpoons \text{Co}^{2+} + 2 \text{C}_4\text{H}_7\text{N}_2\text{O}_2^-$ $-1.23 \times 10^{-4} \quad +1.23 \times 10^{-4} \quad + 2 \times 1.23 \times 10^{-4}$ <p><math>K_{sp} = [\text{Co}^{2+}][\text{C}_4\text{H}_7\text{N}_2\text{O}_2^-]^2</math></p> $= (1.23 \times 10^{-4})(1.23 \times 10^{-4} \times 2)^2$ $= 7.44 \times 10^{-12} \text{ mol}^3\text{dm}^{-9}$
(d)(i)	<p><b>Suggested solution</b></p> <p>By Hess' law: L.E. = <math>73.0 - 519 - (\frac{1}{2} \times 436) - 159.5 - 90.5 = \underline{\underline{-914 \text{ kJ mol}^{-1}}}</math></p>
d(ii)	<p><b>Suggested solution:</b></p> $ LE  = \left  \frac{q^+ q^-}{r^+ + r^-} \right $ <p>Ionic radii of <math>\text{Cl}^- = 0.181</math>, ionic radii of <math>\text{H}^- = 0.208\text{nm}</math> They have the same product but LiH has a larger interionic distance than LiCl, therefore LE magnitude of LiH is smaller.</p>
(e)	<p><b>Suggested solution:</b></p> $\text{Amt of AlCl}_3 = \frac{5}{27 + 35.5 \times 3} = 0.037453 \text{ mol}$

	<p>Amt of LiH = <math>\frac{5}{7.9} = 0.6329 \text{ mol}</math></p> <p><math>\text{AlCl}_3</math> is limiting since <math>0.037453 \text{ mol}</math> of <math>\text{AlCl}_3</math> requires <math>0.037453 \times 4 \text{ mol}</math> of <math>\text{LiH}_4</math>  <math>= 0.14981 \text{ mol} &lt; 0.6329 \text{ mol}</math>.</p> <p>No of moles of <math>\text{LiAlH}_4</math> formed = <math>0.037453 \text{ mol}</math>  <math>0.037453 \times \Delta H_{\text{reaction}} = -1.24 \times 8.4</math></p> <p><math>\Delta H_{\text{reaction}} = -1.24 \times 8.4 \div 0.037453</math>  <math>= -278 \text{ kJmol}^{-1}</math></p>
(f)(i)	<p><b>suggested solution</b></p> <p><math>\Sigma n\Delta H_f(\text{products}) - \Sigma n\Delta H_f(\text{reactants}) = -454 - 3(-152.5)</math>  <math>= +3.5 \text{ kJmol}^{-1}</math></p>
f(ii)	<p><b>Suggested solution</b></p> <p><math>\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ</math>  <math>-27.7 = +3.5 - 298 \times \Delta S^\circ</math>  <math>\Delta S^\circ = +0.105 \text{ kJmol}^{-1}\text{K}^{-1}</math>  <math>\Delta S</math> is positive as there is an increase of 3 moles of gas molecules after the reaction;  there are more ways to distribute the molecules and their energies, increasing  entropy level of the system at the end of reaction.</p>
f(iii)	<p><b>Suggested solution</b></p> <p>Temp at which decomposition becomes spontaneous is the cross over temperature.</p> <p><math>\Delta G = 0</math>  <math>+3.5 = 0.105 \times T</math>  <math>T = 33.3 \text{ K}</math></p>

### Question 3

(a)(i)	<b>Suggested solution:</b>
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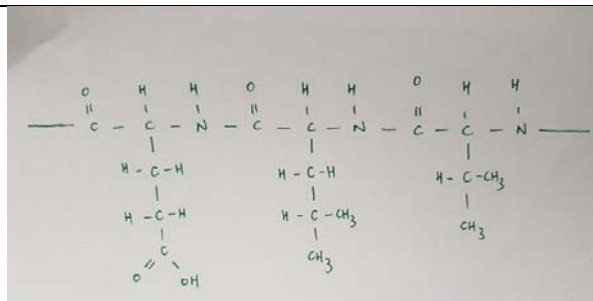
	 <p>The reaction mechanism is as follows:</p> <ol style="list-style-type: none"> <li>Styrene oxide reacts with <math>\text{H}^+</math> to form a protonated epoxide intermediate.</li> <li>The protonated epoxide undergoes a slow ring-opening step to form a primary carbocation intermediate (A), which is 1-phenylethanol-1-yl cation.</li> <li>The carbocation intermediate (A) is attacked by a water molecule (<math>\text{H}_2^{18}\text{O}</math>) to form a protonated diol intermediate.</li> <li>The protonated diol intermediate is deprotonated to form the final product, 1-phenylethane-1,2-diol, and regenerate the <math>\text{H}^+</math> catalyst.</li> </ol>
(ii)	<p><b>Suggested solution:</b></p> <p>A is formed from the primary carbocation as shown.</p>  <p>This primary carbocation is less stable due to the positive charge not being resonance stabilised by the aromatic ring. Hence, the carbocation is formed in trace amounts, leading to trace amounts of A being formed.</p>
(iii)	<p><b>Suggested solution:</b></p>

	
(b)(i)	<p><b>Suggested solution:</b></p> <p>In the presence of ligands, d-orbitals of <math>\text{Fe}^{3+}</math> are split into two different energy levels with small energy gap. d-d transition, where the electron is promoted from a lower energy d orbital to a higher energy d orbital, is possible.</p> <p>Energy that corresponds to the wavelength of light in the visible region of the electromagnetic spectrum is absorbed. Colour observed is complementary to the wavelength of visible light absorbed.</p>
(ii)	<p><b>Suggested solution:</b></p> <div style="text-align: center;">  </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <span>'High spin' state</span> <span>'Low spin' state</span> </div>
(iii)	<p><b>Suggested solution:</b></p> <p>G has a larger energy gap. Since the electronic configuration of <math>\text{Fe}^{3+}</math> in G is in a 'low spin' state, energy required to overcome the energy gap in adding subsequent electrons to higher energy d-orbitals is more than that required to overcome inter-electronic repulsion when electrons paired up in the lower energy d-orbitals.</p>
(c)(i)	<p><b>Suggested solution:</b></p> <p>Oxidation number of C in carbon dioxide: +4</p> <p>Oxidation number of C in methanol: -2</p>

(ii)	<p><b>Suggested solution:</b></p> <p>Electrode 1 : <math>\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-</math></p> <p>Electrode 2 : <math>\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}</math></p> <p>Overall: <math>2\text{CH}_3\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 4\text{H}_2\text{O}</math></p>
(iii)	<p><b>Suggested solution:</b></p> <p>When <math>[\text{CH}_3\text{OH}]</math> is decreased, oxidation of methanol becomes less favoured OR by LCP, the position of equilibrium for <math>\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-</math> shifts to the left to partially increase <math>[\text{CH}_3\text{OH}]</math>. Thus, <math>E_{\text{ox}(\text{CH}_3\text{OH}/\text{CO}_2)}</math> becomes less positive.</p> <p>A less positive <math>E_{\text{ox}(\text{CH}_3\text{OH}/\text{CO}_2)}</math> will cause <math>E_{\text{cell}}</math> to be less positive since <math>E_{\text{cell}} = E + E_{\text{ox}}</math>.</p>
(iv)	<p><b>Suggested solution:</b></p> <p><math>\text{CH}_3\text{OH}</math> is a liquid at room temperature and thus can be easily transported and stored than hydrogen gas</p> <p>OR</p> <p><math>\text{CH}_3\text{OH}</math> is less explosive than <math>\text{H}_2</math> gas</p> <p>OR</p> <p><math>\text{CH}_3\text{OH}</math> is less expensive to maintain than <math>\text{H}_2</math> gas</p>

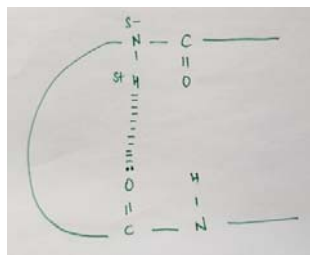
#### Question 4

(a)(i)



(ii)

**Suggested solution:**

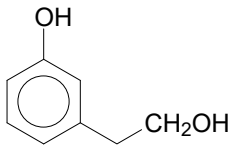
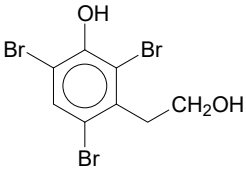
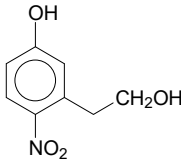
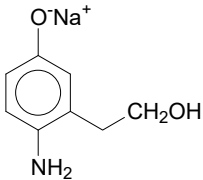
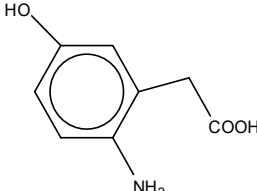
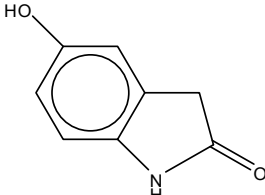


Hydrogen bonding

- lone pair

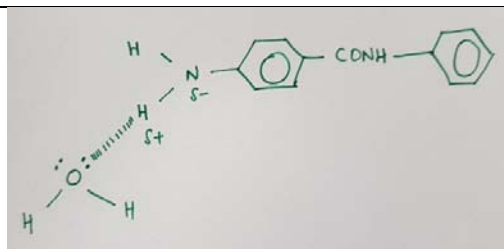


	- $\delta^+$ / $\delta^-$ - dotted lined to show bond	
(iii)	<b>Suggested solution:</b>  Leucine and Valine.  Their side chains consist of hydrocarbon chains which are able to form temporary dipole-induced dipole interactions with hydrophobic groups to transport them in the blood stream.	
(b)(i)	<b>Suggested solution:</b>  $\begin{array}{c} \text{H} \\   \\ ^-\text{OOC}-\text{C}-\text{N}^+\text{H}_3 \\   \\ \text{CH}_2\text{CH}(\text{CH}_3)_2 \end{array}$	
(ii)	<b>Suggested solution:</b>  <u>Melting point</u>  Unionised form: Hydrogen bonding Zwitterionic form: Ionic bonding More energy is required to overcome the stronger ionic bonding compared to the hydrogen bonds. Hence the zwitterionic form will have a higher melting point.  <u>Solubility:</u>  Unionised form: Hydrogen bonds with water Zwitterionic form: ion-dipole interactions with water Stronger ion-dipole interactions produce more energy to overcome the hydrogen bonds between water molecules and the interactions between the solute. Hence the zwitterionic form will be more soluble in water.	
(c)	<b>Suggested solution:</b>	
	Observation	Deductions
	Compound <b>A</b> , $\text{C}_8\text{H}_{10}\text{O}_2$ , reacts with $\text{Br}_2(\text{aq})$ to form a white precipitate compound <b>B</b> with molecular formula, $\text{C}_8\text{H}_7\text{O}_2\text{Br}_3$	<b>A</b> contains phenol (reacts without halogen carrier)  <b>B</b> is 2,4,6- trisubstituted
	Compound <b>A</b> also reacts with dilute nitric acid to give compound <b>C</b> , $\text{C}_8\text{H}_9\text{NO}_4$	Mononitration of <b>A</b> to give <b>C</b>  Confirm presence of phenol
	Compound <b>C</b> with tin in concentrated hydrochloric acid, followed by hot aqueous sodium hydroxide gives compound <b>D</b> , $\text{C}_8\text{H}_{10}\text{NO}_2\text{Na}$ .	$\text{NO}_2$ group in <b>C</b> is reduced to $-\text{NH}_2$  phenol in <b>C</b> is converted to sodium phenoxide in <b>D</b>

<p>Compound <b>D</b> turns hot acidified potassium dichromate solution green and forms compound <b>E</b>, <math>C_8H_9NO_3</math>.</p>	<p><b>D</b> undergoes oxidation to form carboxylic acid</p> <p>primary alcohol present in <b>D</b>,</p> <p>phenoxide in <b>D</b> is acidified to phenol in <b>E</b></p>
<p>1 mole of compound <b>E</b> reacts with 2 moles of aqueous sodium hydroxide.</p>	<p>2 acidic groups present</p> <p>Carboxylic acid and phenol confirmation</p>
<p>Compound <b>E</b> reacts with phosphorus pentachloride to give compound <b>F</b>, <math>C_8H_7NO_2</math>.</p>	<p><math>-CO_2H</math>, in <b>E</b> is converted into an acyl chloride, <math>-COCl</math>, by <math>PCl_5</math>.</p> <p>Amine undergoes internal nucleophilic substitution, with loss of <math>Cl^-</math>, to yield the cyclic amide <b>F</b></p> <p>Carboxymethyl group, <math>-CH_2CO_2H</math>, must be adjacent to amine <math>-NH_2</math> group in <b>A</b> to enable ring formation</p>
<div style="display: flex; flex-wrap: wrap; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center; margin: 10px;">  <p>A:</p> </div> <div style="text-align: center; margin: 10px;">  <p>B:</p> </div> <div style="text-align: center; margin: 10px;">  <p>C:</p> </div> <div style="text-align: center; margin: 10px;">  <p>D:</p> </div> <div style="text-align: center; margin: 10px;">  <p>E:</p> </div> <div style="text-align: center; margin: 10px;">  <p>F:</p> </div> </div>	

**Question 5**

**(a)(i) Suggested solution:**



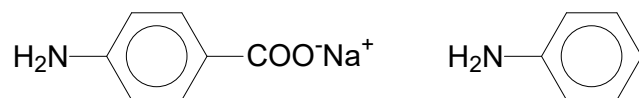
Hydrogen bond

- lone pair
- $\delta^+$  /  $\delta^-$
- dotted lined to show bond

(ii) **Suggested solution:**

Energy given out when hydrogen bonds are formed between water molecules and 4-amino-N-phenylbenzamide is insufficient to overcome the extensive temporary dipole-induced dipole interactions between 4-amino-N-phenylbenzamide molecules. Hence solubility is low.

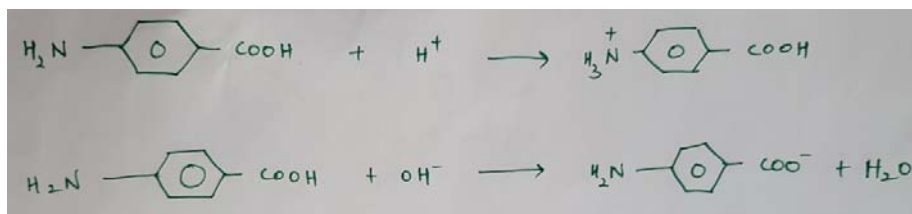
(b)(i) **Suggested solution:**



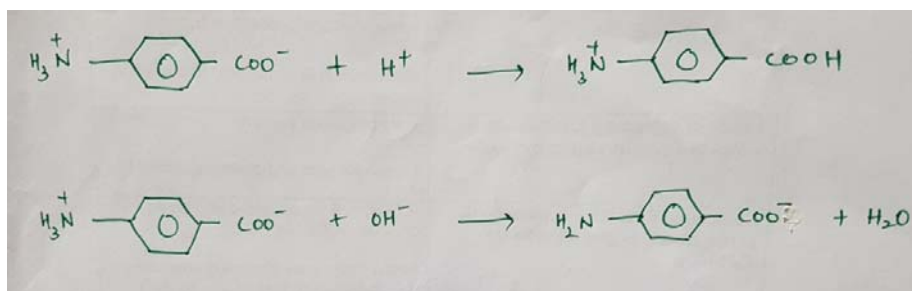
(ii) **Suggested solution:**

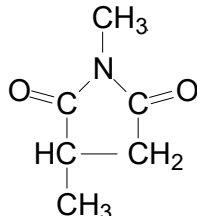
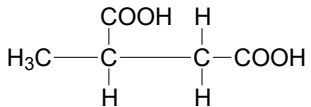
Phenylamine is a simple covalent molecule with weak intermolecular attractions between them whereas the other product is an ionic compound with strong electrostatic forces of attraction between ions. Phenylamine thus has a lower boiling point of the 2 and will distil out first to be the distillate.

(iii) **Suggested solution:**

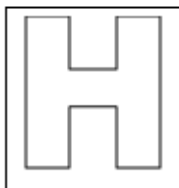


OR



(c)	<b>Suggested solution:</b>																
	<table><tr><th>Information / Type of reaction</th><th>Deductions</th></tr><tr><td>Compound <b>G</b>, <math>C_6H_9O_2N</math>, is a neutral compound with the ability to rotate plane polarised light.</td><td>As <b>G</b> contains N and is neutral, <b>G</b> is likely to be an amide.  <b>G</b> contains <u>at least 1 chiral carbon</u>.</td></tr><tr><td><b>G</b> reacts with aqueous sodium hydroxide to form pungent gas <b>H</b> that turned moist red litmus blue.  Upon acidification with aqueous hydrochloric acid, <b>J</b> <math>C_5H_8O_4</math>.</td><td>Alkaline hydrolysis Alkaline gas <b>H</b>: <math>CH_3NH_2(g)</math>. (<b>J</b> has 1 less carbon than <b>G</b>)  <b>J</b> has 2 <u>carboxylic acid</u> groups. <b>G</b> is cyclic <u>amide</u>.</td></tr><tr><td><b>J</b> <u>reacts with</u> <math>LiAlH_4</math> to form <b>K</b>, <math>C_5H_{12}O_2</math>.</td><td><b>K</b> has 2 is primary <u>alcohol</u> groups.</td></tr><tr><td>On heating with excess concentrated <math>H_2SO_4</math>, <b>K</b> forms <b>L</b>, <math>C_5H_8</math>. <b>L</b> does not exhibit cis-trans isomerism.</td><td><b>K</b> undergoes <u>elimination</u> of <math>H_2O</math> to form <b>L</b>, <math>C_5H_8</math>, with 2 alkene groups.  Most likely terminal alkenes as no cis-trans isomerism.</td></tr><tr><td>When <b>L</b> is heated with acidified <math>KMnO_4</math> solution, <b>M</b>, <math>C_3H_4O_3</math> is formed.</td><td><b>L</b> undergoes <u>oxidative cleavage</u> to form <b>M</b>, <math>C_3H_4O_3</math></td></tr><tr><td><b>M</b> reacts with aqueous <math>Na_2CO_3</math> to produce effervescence that forms a white precipitate in limewater.</td><td><u>acid-base reaction</u> <b>M</b> contains a <u>carboxylic acid</u>.</td></tr><tr><td><b>M</b> also forms a yellow precipitate when warmed with alkaline aqueous <math>I_2</math>.</td><td><b>M</b> contains <u><math>CH_3CO-</math> group</u>.  (must be ketone as it is a product of oxidative cleavage of a <math>C=C</math>)</td></tr></table>	Information / Type of reaction	Deductions	Compound <b>G</b> , $C_6H_9O_2N$ , is a neutral compound with the ability to rotate plane polarised light.	As <b>G</b> contains N and is neutral, <b>G</b> is likely to be an amide.  <b>G</b> contains <u>at least 1 chiral carbon</u> .	<b>G</b> reacts with aqueous sodium hydroxide to form pungent gas <b>H</b> that turned moist red litmus blue.  Upon acidification with aqueous hydrochloric acid, <b>J</b> $C_5H_8O_4$ .	Alkaline hydrolysis Alkaline gas <b>H</b> : $CH_3NH_2(g)$ . ( <b>J</b> has 1 less carbon than <b>G</b> )  <b>J</b> has 2 <u>carboxylic acid</u> groups. <b>G</b> is cyclic <u>amide</u> .	<b>J</b> <u>reacts with</u> $LiAlH_4$ to form <b>K</b> , $C_5H_{12}O_2$ .	<b>K</b> has 2 is primary <u>alcohol</u> groups.	On heating with excess concentrated $H_2SO_4$ , <b>K</b> forms <b>L</b> , $C_5H_8$ . <b>L</b> does not exhibit cis-trans isomerism.	<b>K</b> undergoes <u>elimination</u> of $H_2O$ to form <b>L</b> , $C_5H_8$ , with 2 alkene groups.  Most likely terminal alkenes as no cis-trans isomerism.	When <b>L</b> is heated with acidified $KMnO_4$ solution, <b>M</b> , $C_3H_4O_3$ is formed.	<b>L</b> undergoes <u>oxidative cleavage</u> to form <b>M</b> , $C_3H_4O_3$	<b>M</b> reacts with aqueous $Na_2CO_3$ to produce effervescence that forms a white precipitate in limewater.	<u>acid-base reaction</u> <b>M</b> contains a <u>carboxylic acid</u> .	<b>M</b> also forms a yellow precipitate when warmed with alkaline aqueous $I_2$ .	<b>M</b> contains <u><math>CH_3CO-</math> group</u> .  (must be ketone as it is a product of oxidative cleavage of a $C=C$ )
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	<div data-bbox="349 180 683 394"> <p>K</p> <math display="block">  \begin{array}{c}  \text{CH}_2\text{OH} \quad \text{H} \\    \quad   \\  \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_2\text{OH} \\    \quad   \\  \text{H} \quad \text{H}  \end{array}  </math> </div>	<div data-bbox="683 180 1018 394"> <p>L</p> <math display="block">  \begin{array}{c}  \text{CH}_2 \\     \\  \text{H}_3\text{C}-\text{C}-\text{C}=\text{CH}_2 \\    \\  \text{H}  \end{array}  </math> </div>	<div data-bbox="1018 180 1352 394"> <p>M</p> <math display="block">  \begin{array}{c}  \text{O} \\     \\  \text{H}_3\text{C}-\text{C}-\text{COOH}  \end{array}  </math> </div>
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**NATIONAL JUNIOR COLLEGE**  
**SH2 Year-End Practical Examination**  
 Higher 2

CANDIDATE  
NAME

SUBJECT  
CLASS

REGISTRATION  
NUMBER

**CHEMISTRY**

**9729/04**

Paper 4 Practical

**14 August 2018**

Candidates answer on the Question paper

**2 hours 30 minutes**

Additional Materials: As listed in the Confidential Instructions

**READ THESE INSTRUCTIONS FIRST**

Write your identification number and name.

Give details of the practical shift and laboratory where appropriate, in the boxes provided.

Write in blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.  
 Qualitative Analysis Notes are printed on pages 18 and 19.

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

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

<b>Shift</b>
<b>Laboratory</b>

For Examiner's use	
<b>1</b>	/ 14
<b>2</b>	/ 6
<b>3</b>	/ 13
<b>4</b>	/ 9
<b>5</b>	/ 10
<b>Presentation</b>	/ 3
<b>Total</b>	/ 55

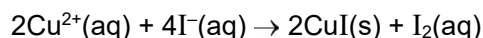
This document consists of **19** printed pages including this cover page.

Answer **all** the questions in the spaces provided.

**1 Determination of the average relative formula mass of a mixture of two copper salts**

In this experiment, you will determine the average relative formula mass of a mixture of two copper salts by titration.

A solution of the copper salts mixture reacts with excess acidified potassium iodide, producing iodine.



This iodine is then titrated with aqueous sodium thiosulfate, using starch indicator.

**FA 1** is an aqueous solution of the copper salt prepared by dissolving 26.0 g of the salt mixture to make 1.00 dm<sup>3</sup> of solution.

**FA 2** is dilute sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

**FA 3** is aqueous potassium iodide, KI.

**FA 4** is 1.50 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.  
starch indicator

**(a) Preparation of diluted FA 4**

1. Pipette 25.0 cm<sup>3</sup> of **FA 4** into the 250 cm<sup>3</sup> graduated flask.
2. Make up the contents of the flask to the 250 cm<sup>3</sup> mark with deionised water.
3. Stopper the flask and mix the contents thoroughly to ensure a homogeneous solution.  
This prepared solution is **diluted FA 4**.

**Titration**

1. Fill the burette with **diluted FA 4**.
2. Pipette 25.0 cm<sup>3</sup> of **FA 1** into a conical flask.
3. Use the measuring cylinder to add approximately 10.0 cm<sup>3</sup> of **FA 2** to the same conical flask.
4. Use the measuring cylinder to add approximately 20.0 cm<sup>3</sup> of **FA 3** to the mixture in the conical flask. The mixture will appear brown, due to iodine produced in the reaction.
5. Begin your rough titration by adding **diluted FA 4** from the burette until the intensity of the brown colour decreases.
6. Add 10 drops of starch indicator. The mixture will become darker.
7. Continue titrating until the dark colour is discharged. The mixture should appear off-white. This is the end-point.
8. Add **one** drop of starch indicator to check that no traces of dark colour are produced.
9. If the mixture stays off-white, the titration is completed. If some dark colour is produced, because iodine is still present, continue the titration until mixture appears off-white.
10. Record your burette readings and the rough titre in the space below.
11. Carry out as many accurate titrations as you think necessary to obtain consistent results.

12. Make sure any recorded results show the precision of your practical work.  
 13. Record in a suitable form below all of your burette readings and the volume of **diluted FA 4** added in each accurate titration.

[7]

I	
II	
III	
IV	
V	
VI	
VII	

From your accurate titration results, obtain a suitable value for the volume of **diluted FA 4** to be used in your calculations.

Show clearly how you obtained this value.

The iodine produced required ..... cm<sup>3</sup> of **diluted FA 4**.  
 [1]

**(b) Calculations**

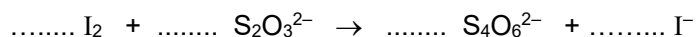
Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- (i) Calculate the number of moles of sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>, in the volume of **diluted FA 4** obtained in (a).

moles of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> = ..... mol  
 [1]



- (ii) Balance the ionic equation for the reaction of iodine with sodium thiosulfate. State symbols are not required.



Hence calculate the number of moles of iodine that reacted with the number of moles of  $\text{Na}_2\text{S}_2\text{O}_3$  calculated in (i).

moles of  $\text{I}_2$  = ..... mol  
[1]

- (iii) Using your answer to (ii), calculate the number of moles of copper(II) ions in  $25.0 \text{ cm}^3$  of **FA 1**.

moles of  $\text{Cu}^{2+}$  ions = ..... mol  
[1]

- (iv) Using your answer to (iii) and the information on page 2, calculate the average relative formula mass of the copper salts in **FA 1**.

Average  $M_r$  of copper salts = .....  
[1]

- (v) Write the full electronic configuration of  $_{29}\text{Cu}$  in  $\text{CuI}$ .

.....[1]

(vi) Hence, explain why solid CuI appears white in colour.

.....

.....

.....

[1]

**[Total: 14]**

## 2 Qualitative analysis

In this question, you will deduce the two anions present in **FA 1**. Perform the tests described in **Table 2** and record your observations in the table. Test and identify any gases evolved.

**If any solution is warmed, a boiling tube MUST be used.**

**Table 2**

	Test	Observations
(a)	To a 1 cm depth of <b>FA 1</b> in a test-tube, add aqueous silver nitrate.	
(b)	To a 0.5 cm depth of <b>FA 1</b> in a boiling tube, add aqueous sodium hydroxide and add one piece of aluminium foil and warm.	
(c)	To a 1 cm depth of <b>FA 1</b> in a test-tube, add aqueous barium chloride followed by nitric acid.	
(d)	To a 1 cm depth of <b>FA 1</b> in a test-tube, add an equal volume of sulfuric acid followed by $\text{KMnO}_4$ .	

[3]

(e) From your observations, state the anions present in **FA 1**. Explain your answers.

First anion: .....

Second anion:.....

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

[3]

**[Total: 6]**

### 3 Investigation of thermal decomposition of sodium hydrogencarbonate

Sodium hydrogencarbonate,  $\text{NaHCO}_3$ , is used as baking soda in cooking. Baking soda may also contain small amounts of other chemicals.

When baking soda is heated, carbon dioxide is produced. In this experiment, you will investigate the reaction taking place when the sodium hydrogencarbonate in baking soda is thermally decomposed.

**FA 5** is baking soda (impure  $\text{NaHCO}_3$ ).

#### (a) Method

Record all your readings in the space below.

1. Weigh the crucible with its lid.
2. Transfer all the **FA 5** from the container into the crucible.
3. Weigh the crucible, lid and **FA 5**.
4. Calculate and record the mass of **FA 5** used.
5. Place the crucible and contents on a pipe-clay triangle.
6. Heat gently, **with the lid off**, for approximately one minute.
7. Heat strongly, **with the lid off**, for a further three minutes.
8. Replace the lid and leave the crucible to cool for about ten minutes.

**While the crucible is cooling, you should work on other questions.**

9. When it has cooled down, weigh the crucible with its lid and contents.
10. Heat strongly, **with the lid off**, for a further two minutes.
11. Replace the lid and leave the crucible to cool for ten minutes.
12. When it has cooled down, weigh the crucible with its lid and contents.
13. Calculate and record the mass of residue obtained.
14. This residue is **FA 6**. Keep this for use in **3(d)**.

#### Results

I	
II	
III	
IV	

[4]

**(b) Calculations**

- (i) Given that the percentage purity by mass of **FA 5** is 95.8%, calculate the mass of sodium hydrogencarbonate in the sample of **FA 5** that you weighed out.

mass of  $\text{NaHCO}_3$  in **FA 5** weighed out = ..... g

- (ii) Calculate the mass of impurity present in your sample of **FA 5**.

mass of impurity = ..... g  
[1]

- (iii) The impurity in **FA 5** does not decompose when it is heated.

This means that the residue, **FA 6**, contains the mass of impurity calculated in (ii) together with the solid decomposition product of sodium hydrogencarbonate.

Calculate the mass of the solid decomposition product.

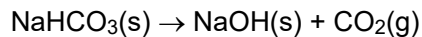
mass of solid decomposition product = ..... g  
[1]

- (c) Why was the lid put on while the crucible and its contents were cooled?

.....  
.....  
[1]

- (d) (i) Ah Beng carried out the experiment by heating 84.0 g of pure  $\text{NaHCO}_3$  to constant mass, he obtained 53.0 g of the solid decomposition product.

Ah Hock then suggested the following equation for the thermal decomposition of sodium hydrogencarbonate.



Explain why Ah Hock's suggestion is **incorrect**. Show working in order to explain your answer.

[Ar: C; 12.0; Na; 23.0; H, 1.0; O: 16.0]

.....  
 .....  
 [1]

- (ii) Add 1 cm depth of sulfuric acid into a test-tube.  
 Add some **FA 6** from the crucible to the acid in the test-tube.  
 Record all your observations.  
 Use your observations to identify the anion present in **FA 6**.

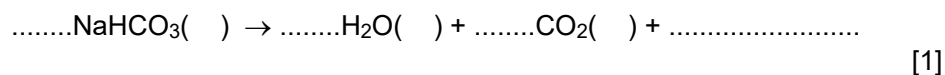
.....  
 .....  
 .....  
 [2]

- (iii) State the assumption you have made in (ii).

.....  
 .....  
 [1]

- (iv) Steam is one of **three** products obtained when sodium hydrogencarbonate is thermally decomposed.

Use your answer in (ii) to complete and balance the equation for the thermal decomposition of sodium hydrogencarbonate. Include state symbols.



- (v) State whether the balanced equation in (iv) agrees with Ah Beng's results.

Show working in order to explain your answer.

.....  
 ..... [1]

**[Total: 13]**

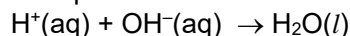
#### 4 Determination of the enthalpy change of a reaction, $\Delta H_r$

**FA 7** is 1.00 mol dm<sup>-3</sup> sodium hydrogen carbonate, NaHCO<sub>3</sub>

**FA 8** is 2.00 mol dm<sup>-3</sup> sodium hydroxide, NaOH

**FA 9** is 2.00 mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>

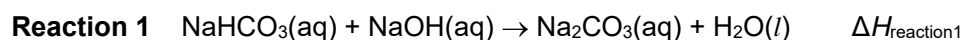
An acid-base neutralisation reaction involves reacting the two solutions, to produce water molecules. The equation for this neutralisation reaction is given below.



You will follow the instructions to perform two experiments, **Experiment A** and **Experiment B**. Record your results in Tables 4.1 and 4.2.

##### Experiment A

Reaction between **FA 7**, NaHCO<sub>3</sub>, and **FA 8**, NaOH.



The molar enthalpy change for **reaction 1**,  $\Delta H_{\text{reaction1}}$ , is the enthalpy change when 1.00 mol of NaHCO<sub>3</sub> reacts completely with NaOH.

- Using a measuring cylinder, transfer 30.0 cm<sup>3</sup> of **FA 7** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm<sup>3</sup> glass beaker. Place the lid on the cup.
- Stir and measure the temperature of this **FA 7**,  $T_{\text{FA7}}$ .
- Using another measuring cylinder, measure 20.0 cm<sup>3</sup> of **FA 8**.
- Stir and measure the temperature of this **FA 8**,  $T_{\text{FA8}}$ .
- Add **FA 8** from the measuring cylinder to the **FA 7** in the Styrofoam cup. Immediately replace the lid.
- Using the thermometer, stir the mixture continuously until a maximum temperature is reached. Read and record this temperature  $T_{\text{max}}$ .
- Calculate the weighted average initial temperature,  $T_{\text{average}}$ , of **FA 7** and **FA 8** using the formula given below:

$$T_{\text{average}} = \frac{(V_{\text{FA7}} \times T_{\text{FA7}}) + (V_{\text{FA8}} \times T_{\text{FA8}})}{(V_{\text{FA7}} + V_{\text{FA8}})}$$

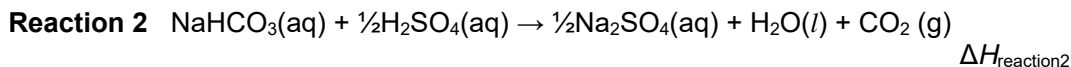
	Experiment A
$T_{\text{FA7}} / ^\circ\text{C}$	
$T_{\text{FA8}} / ^\circ\text{C}$	
$T_{\text{average}} / ^\circ\text{C}$	
$T_{\text{max}} / ^\circ\text{C}$	
$\Delta T_{\text{max}} / ^\circ\text{C}$	

**Table 4.1**



**Experiment B**

Reaction between **FA 7**,  $\text{NaHCO}_3$ , and **FA 9**,  $\text{H}_2\text{SO}_4$ .



The molar enthalpy change for **reaction 2**,  $\Delta H_{\text{reaction 2}}$ , is the enthalpy change when 1.00 mol of  $\text{NaHCO}_3$  reacts completely with  $\text{H}_2\text{SO}_4$ .

- 1 Using a measuring cylinder, transfer 30.0 cm<sup>3</sup> of **FA 7** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm<sup>3</sup> glass beaker. Place the lid on the cup.
- 2 Stir and measure the temperature of this **FA 7**,  $T_{\text{FA7}}$ .
- 3 Using another measuring cylinder, measure 20.0 cm<sup>3</sup> of **FA 9**.
- 4 Stir and measure the temperature of this **FA 9**,  $T_{\text{FA9}}$ .
- 5 Add **slowly**, the **FA 9** from the measuring cylinder to the **FA 7** in the Styrofoam cup. Immediately replace the lid.
- 6 Using the thermometer, stir the mixture continuously until a maximum/minimum temperature is reached. Read and record this temperature  $T_{\text{max}}$ .
- 7 Calculate the weighted average initial temperature,  $T_{\text{average}}$ , of **FA 7** and **FA 9** using the formula given below:

$$T_{\text{average}} = \frac{(V_{\text{FA7}} \times T_{\text{FA7}}) + (V_{\text{FA9}} \times T_{\text{FA9}})}{(V_{\text{FA7}} + V_{\text{FA9}})}$$

	Experiment B
$T_{\text{FA7}} / ^\circ\text{C}$	
$T_{\text{FA9}} / ^\circ\text{C}$	
$T_{\text{average}} / ^\circ\text{C}$	
$T_{\text{max}} / ^\circ\text{C}$	
$\Delta T_{\text{max}} / ^\circ\text{C}$	

**Table 4.2**

[2]

- (a) For the purpose of calculations, you should assume that the mixture has a density of  $1.00 \text{ g cm}^{-3}$  and specific heat capacity,  $c$ , of  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ .
- (i) Use your results from **Table 4.1** to calculate a value for the molar enthalpy change for **reaction 1**,  $\Delta H_{\text{reaction1}}$ .

$$\Delta H_{\text{reaction1}} = \dots\dots\dots [2]$$

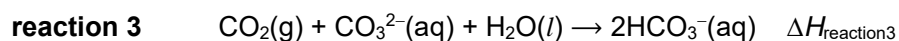
- (ii) Use your results from **Table 4.2** to calculate a value for the molar enthalpy change for **reaction 2**,  $\Delta H_{\text{reaction2}}$ .

$$\Delta H_{\text{reaction2}} = \dots\dots\dots [2]$$

(b) Ionic equations for neutralisation, **reaction 1**, and **reaction 2** are shown below.

$\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$	$\Delta H_{\text{neu}} = -57.1 \text{ kJ mol}^{-1}$
$\text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	$\Delta H_{\text{reaction1}}$
$\text{HCO}_3^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$	$\Delta H_{\text{reaction2}}$

Carbon dioxide reacts with solutions of carbonate ions according to the following equation.



Using your calculated answers in (a), together with the given value of enthalpy change of neutralisation,  $\Delta H_{\text{neu}}$ , construct an energy cycle to determine a value for the enthalpy change for this reaction,  $\Delta H_{\text{reaction3}}$ .

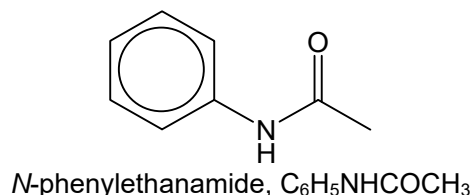
$\Delta H_{\text{reaction3}} = \dots\dots\dots$

[3]

[Total: 9]

**5 Planning**

The structure of *N*-phenylethanamide is shown below:



The preparation of *N*-phenylethanamide from phenylamine is termed acylation. Ethanoic anhydride,  $(\text{CH}_3\text{CO})_2\text{O}$  is commonly used as an acylating agent as its low reactivity relative to ethanoyl chloride allows the reaction rate to be more easily controlled.

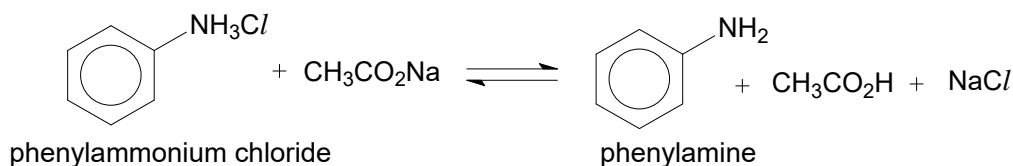
Phenylamine is most conveniently used in the form of the salt phenylammonium chloride,  $\text{C}_6\text{H}_5\text{NH}_3\text{Cl}$ .

The reaction is performed in **two** stages:

**Stage 1:**

Phenylamine can be prepared from phenylammonium chloride and sodium ethanoate in an aqueous medium under room temperature.

The reaction is as shown below:



The reaction mixture needs to be continuously stirred for 3 minutes.

**Stage 2:**

Phenylamine then reacts with ethanoic anhydride to form solid *N*-phenylethanamide together with ethanoic acid. The addition of ethanoic anhydride to the reaction mixture may be violent.

This mixture is heated under reflux for about 15 minutes, before the crude solid product is removed by filtration and purified by recrystallisation from hot water. The melting point of *N*-phenylethanamide is  $114^\circ\text{C}$ .

- (a) (i) State the type of reaction taking place in stage 1.

..... [1]

- (ii) Write an equation for the reaction of phenylamine with ethanoic anhydride in stage 2.

..... [1]

- (b) The above reaction between phenylamine and ethanoic anhydride in stage **2** gives an 80% yield.

Assuming phenylammonium chloride is completely converted to phenylamine in stage **1**, determine the mass of phenylammonium chloride required to prepare 2 g of *N*-phenylethanamide.

(A<sub>r</sub>: C: 12.0, H: 1.0, N: 14.0, O: 16.0, Cl: 35.5)

[2]

- (c) Write a full description of the procedure to carry out stages **1** and **2**.  
*You do not need to describe the recrystallization process to obtain a pure sample of N-phenylethanamide in stage 2.*

You may assume that you are provided with :

- 30 cm<sup>3</sup> of water for use as solvent
- 6.0 g of hydrated sodium ethanoate
- 2.0 cm<sup>3</sup> of ethanoic anhydride
- Apparatus normally found in a school or college laboratory

Your plan should include details of:

- (i) appropriate quantities of reactants
- (ii) appropriate choice of apparatus
- (iii) drawing of reflux set-up

[1]

[1]

**[Turn over**

**Qualitative Analysis Notes**

[ppt. = precipitate]

**(a) Reactions of aqueous cations**

<b>cation</b>	<b>reaction with</b>	
	<b>NaOH(aq)</b>	<b>NH<sub>3</sub>(aq)</b>
aluminium, $Al^{3+}(aq)$	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, $NH_4^+(aq)$	ammonia produced on heating	–
barium, $Ba^{2+}(aq)$	no ppt. (if reagents are pure)	no ppt.
calcium, $Ca^{2+}(aq)$	white ppt. with high [ $Ca^{2+}(aq)$ ]	no ppt.
chromium(III), $Cr^{3+}(aq)$	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), $Cu^{2+}(aq)$	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), $Fe^{2+}(aq)$	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), $Fe^{3+}(aq)$	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, $Mg^{2+}(aq)$	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), $Mn^{2+}(aq)$	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, $Zn^{2+}(aq)$	white ppt. soluble in excess	white ppt. soluble in excess

**(b) Reactions of anions**

<b><i>anions</i></b>	<b><i>reaction</i></b>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ )
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )
nitrate, $\text{NO}_3^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; $\text{NO}$ liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	$\text{SO}_2$ liberated by dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

**(c) Tests for gases**

<b><i>gas</i></b>	<b><i>test and test result</i></b>
ammonia, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint
sulfur dioxide, $\text{SO}_2$	turns aqueous potassium manganate(VII) from purple to colourless

**(d) Colour of halogens**

<b><i>halogen</i></b>	<b><i>colour of element</i></b>	<b><i>colour in aqueous solution</i></b>	<b><i>colour in hexane</i></b>
chlorine, $\text{Cl}_2$	greenish yellow gas	pale yellow	pale yellow
bromine, $\text{Br}_2$	reddish brown gas / liquid	orange	orange-red
iodine, $\text{I}_2$	black solid / purple gas	brown	purple



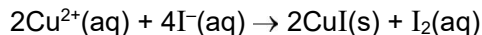
## 2018 SH2 H2 Chemistry P4 Solutions

Answer **all** the questions in the spaces provided.

### 1 Determination of the average relative formula mass of a mixture of two copper salts

In this experiment, you will determine the average relative formula mass of a mixture of two copper salts by titration.

A solution of the copper salts mixture reacts with excess acidified potassium iodide, producing iodine.



This iodine is then titrated with aqueous sodium thiosulfate, using starch indicator.

**FA 1** is an aqueous solution of the copper salt prepared by dissolving 26.0 g of the salt mixture to make 1.00 dm<sup>3</sup> of solution.

**FA 2** is dilute sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

**FA 3** is aqueous potassium iodide, KI.

**FA 4** is 1.50 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.  
starch indicator

#### (a) Preparation of diluted FA 4

1. Pipette 25.0 cm<sup>3</sup> of **FA 4** into the 250 cm<sup>3</sup> graduated flask.
  2. Make up the contents of the flask to the 250 cm<sup>3</sup> mark with deionised water.
  3. Stopper the flask and mix the contents thoroughly to ensure a homogeneous solution.
- This prepared solution is **diluted FA 4**.

#### Titration

1. Fill the burette with **diluted FA 4**.
2. Pipette 25.0 cm<sup>3</sup> of **FA 1** into a conical flask.
3. Use the measuring cylinder to add approximately 10.0 cm<sup>3</sup> of **FA 2** to the same conical flask.
4. Use the measuring cylinder to add approximately 20.0 cm<sup>3</sup> of **FA 3** to the mixture in the conical flask. The mixture will appear brown, due to iodine produced in the reaction.
5. Begin your rough titration by adding **diluted FA 4** from the burette until the intensity of the brown colour decreases.
6. Add 10 drops of starch indicator. The mixture will become darker.
7. Continue titrating until the dark colour is discharged. The mixture should appear off-white. This is the end-point.
8. Add **one** drop of starch indicator to check that no traces of dark colour are produced.
9. If the mixture stays off-white, the titration is completed. If some dark colour is produced, because iodine is still present, continue the titration until mixture appears off-white.
10. Record your burette readings and the rough titre in the space below.

11. Carry out as many accurate titrations as you think necessary to obtain consistent results.
12. Make sure any recorded results show the precision of your practical work.
13. Record in a suitable form below all of your burette readings and of **diluted FA 4** added in each accurate titration.

**I** All the following data is recorded  
initial and final burette readings for **two** (or more) titrations

I	
II	
III	
IV	
V	
VI	
VII	

**II** **Titre values** recorded for accurate titrations, **and**  
**Appropriate headings** and units

- initial / start (burette) reading
  - final / end (burette) reading
  - titre **or** volume used / added (*not "difference"*)
- unit: /  $\text{cm}^3$  (for each heading) **or**  $\text{cm}^3$  unit given for each volume recorded.

**III:** All burette readings are recorded to the nearest  $0.05 \text{ cm}^3$ . (2 d.p)  
(Rough reading do not need 2 d.p)

*including  $0.00 \text{ cm}^3$  (if this was the initial reading).*

Do **not** award if: (reverse burette readings)

- $50.00$  is used as an initial burette reading
  - more than one final burette reading is  $50.00$
- any burette reading is greater than  $50.00$*

**IV:** at least two titres within  $0.10 \text{ cm}^3$

[7]

From your accurate titration results, obtain a suitable value for the volume of **diluted FA 4** to be used in your calculations.

Show clearly how you obtained this value.

**Candidate calculates the mean correctly.**

- Candidate must take the average of two (or more) titres within  $0.10 \text{ cm}^3$ .
- Working / explanation **or** ticks must be shown
- The mean should be quoted to **2 d.p.**, and be rounded to nearest  $0.01 \text{ cm}^3$ .  
(*e.g.  $26.667 \text{ cm}^3$  must be rounded to  $26.67 \text{ cm}^3$* )

The iodine produced required .....  $\text{cm}^3$  of **diluted FA 4**.

[1]

**(b) Calculations**

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- (i) Calculate the number of moles of sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$ , in the volume of **diluted FA 4** obtained in (a).

$$\text{No of moles of thiosulfate used} = 1.50 \times \frac{25.0}{250} \times \text{mean titre} / 1000$$

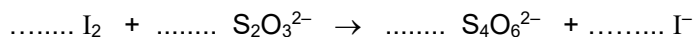
$$\text{Or No of moles of thiosulfate used} = 0.150 \times \text{mean titre} / 1000$$

(expressed to 3 or 4 sig fig)

$$\text{moles of Na}_2\text{S}_2\text{O}_3 = \dots\dots\dots \text{ mol}$$

[1]

- (ii) Balance the ionic equation for the reaction of iodine with sodium thiosulfate. State symbols are not required.



Hence calculate the number of moles of iodine that reacted with the number of moles of  $\text{Na}_2\text{S}_2\text{O}_3$  calculated in (i).

$$\text{Equation balanced } \text{I}_2 + 2 \text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2\text{I}^-$$

$$\text{no of moles of I}_2 = 0.5 \times \text{ans. in (i)}$$

$$\text{moles of I}_2 = \dots\dots\dots \text{ mol}$$

[1]

- (iii) Using your answer to (ii), calculate the number of moles of copper(II) ions in  $25.0 \text{ cm}^3$  of **FA 1**.

$$\text{No of moles of copper(II) ions} = 2 \times \text{answer (ii)}$$

(expressed to 3 or 4 sig fig)

$$\text{moles of Cu}^{2+} \text{ ions} = \dots\dots\dots \text{ mol}$$

[1]

- (iv) Using your answer to (iii) and the information on page 2, calculate the average relative formula mass of the copper salts in **FA 1**.

$$\text{Average Mr} = [26.0 / \text{ans (iii)}] \times 25 / 1000$$

Average Mr of copper salts = .....  
[1]

(v) Write the full electronic configuration of  $_{29}\text{Cu}$  in  $\text{CuI}$ .



(vi) Hence, explain why solid  $\text{CuI}$  appears white in colour.

- d subshell is fully filled, no vacant / half-filled d orbitals
- electrons cannot be promoted from lower energy d orbitals to higher energy d orbitals / d-d transition not possible
- No wavelength of visible spectrum is absorbed, hence solid appears white

[1]

**[Total: 14]**

## 2 Qualitative analysis

In this question, you will deduce the two anions present in **FA 1**. Perform the tests described in **Table 2** and record your observations in the table. Test and identify any gases evolved.

**If any solution is warmed, a boiling tube MUST be used.**

**Table 2**

	Test	Observations
(a)	To a 1 cm depth of <b>FA 1</b> in a test-tube, add aqueous silver nitrate.	Solution remained blue / no ppt
(b)	To a 0.5 cm depth of <b>FA 1</b> in a boiling tube, add aqueous sodium hydroxide and add one piece of aluminium foil and warm.	Blue ppt formed, insoluble in excess sodium hydroxide Black ppt formed upon heating Colourless, pungent gas / gas evolved turns (damp red) litmus blue
(c)	To a 1 cm depth of <b>FA 1</b> in a test-tube, add aqueous barium chloride followed by nitric acid.	White ppt formed and insoluble in excess nitric acid
(d)	To a 1 cm depth of <b>FA 1</b> in a test-tube, add an equal volume of sulfuric acid followed by $\text{KMnO}_4$ .	<b>FA 1</b> remained blue. Purple $\text{KMnO}_4$ remained/ not decolourised

[3]

- (e) From your observations, state the anions present in **FA 1**. Explain your answers.

Nitrate  $\text{NO}_3^-$  + Sulfate  $\text{SO}_4^{2-}$

Explanation for  $\text{NO}_3^-$

Both Nitrate or Nitrite is reduced by Al foil in  $\text{NaOH(aq)}$  to give  $\text{NH}_3$  gas +  
Since  $\text{KMnO}_4$  remained purple, **FA 1** does not contain reducing agent  $\text{NO}_2^-$ .

Or

Since no brown  $\text{NO}_2$  gas is evolved with nitric acid, **FA 1** contains Nitrate  $\text{NO}_3^-$

Explanation for  $\text{SO}_4^{2-}$

Since a white ppt is formed with  $\text{BaCl}_2$ , and remained in nitric acid, anion in **FA1** cannot be  $\text{SO}_3^{2-}$ .

Since  $\text{KMnO}_4$  remained purple, **FA 1** does not contain reducing agent  $\text{SO}_3^{2-}$ .

[3]

[Total: 6]

### 3 Investigation of thermal decomposition of sodium hydrogencarbonate

Sodium hydrogencarbonate,  $\text{NaHCO}_3$ , is used as baking soda in cooking. Baking soda may also contain small amounts of other chemicals.

When baking soda is heated, carbon dioxide is produced. In this experiment, you will investigate the reaction taking place when the sodium hydrogencarbonate in baking soda is thermally decomposed.

**FA 5** is baking soda (impure  $\text{NaHCO}_3$ ).

#### (a) Method

Record all your readings in the space below.

1. Weigh the crucible with its lid.
2. Transfer all the **FA 5** from the container into the crucible.
3. Weigh the crucible, lid and **FA 5**.
4. Calculate and record the mass of **FA 5** used.
5. Place the crucible and contents on a pipe-clay triangle.
6. Heat gently, **with the lid off**, for approximately one minute.
7. Heat strongly, **with the lid off**, for a further three minutes.
8. Replace the lid and leave the crucible to cool for about ten minutes.

**While the crucible is cooling, you should work on other questions.**

9. When it has cooled down, weigh the crucible with its lid and contents.
10. Heat strongly, **with the lid off**, for a further two minutes.
11. Replace the lid and leave the crucible to cool for ten minutes.
12. When it has cooled down, weigh the crucible with its lid and contents.
13. Calculate and record the mass of residue obtained.
14. This residue is **FA 6**. Keep this for use in **3(d)**.

#### Results

**Four weighings recorded and correct headings given and mass of FA 5 used and mass of residue recorded**

Mass	/g
Crucible + lid	a
Crucible + lid + <b>FA 5</b> before heating	b
Crucible + lid + content after 1 <sup>st</sup> heating	c
Crucible + lid + content after 2 <sup>nd</sup> heating	d
<b>FA 5</b> used	b-a = e
Residue OR <b>FA 6</b>	d-a = f

I	
II	
III	
IV	

*If 'mass' not written then 'g' must be with each entry.*

*Use of lid must be consistent*

## II

- All weighings recorded to 3 decimal places
- Mass of **FA 5** and **FA 6** / residue must be correctly subtracted

[4]

## (b) Calculations

- (i) Given that the percentage purity by mass of **FA 5** is 95.8%, calculate the mass of sodium hydrogencarbonate in the sample of **FA 5** that you weighed out.

$$\text{Mass NaHCO}_3 = (95.8 / 100) \times \text{mass of FA 5 used}$$

mass of NaHCO<sub>3</sub> in **FA 5** weighed out = ..... g

- (ii) Calculate the mass of impurity present in your sample of **FA 5**.

$$\begin{aligned} \text{Mass impurity} &= \text{mass of FA 5} - \text{answer (i)} \\ \text{or mass impurity} &= 4.2 / 100 \times \text{mass FA 5} \end{aligned}$$

mass of impurity = ..... g  
[1]

- (iii) The impurity in **FA 5** does not decompose when it is heated.

This means that the residue, **FA 6**, contains the mass of impurity calculated in (ii) together with the solid decomposition product of sodium hydrogencarbonate.

Calculate the mass of the solid decomposition product.

$$\begin{aligned} \text{Mass of decomposition solid} \\ &= \text{mass of residue (FA 6) from table} - \text{mass of impurity (ii) and} \\ &\text{expressed to 3 d.p / 3 s.f} \end{aligned}$$

$$\text{or mass of decomposition solid} = \text{mass of NaHCO}_3 - \text{mass lost on heating [(i) - (mass FA 5 - mass FA 6)]}$$

mass of solid decomposition product = ..... g  
[1]

- (c) Why was the lid put on while the crucible and its contents were cooled?

Lid reduces / stops absorption of water (vapour) by solid / residue / **FA 5** while cooling/ prevents reaction with carbon dioxide.

Do not accept: falling impurities/ loss of solid due to wind/oxidation in the air. [1]

- (d) (i) Ah Beng carried out the experiment by heating 84.0 g of pure  $\text{NaHCO}_3$  to constant mass, he obtained 53.0 g of the solid decomposition product.

Ah Hock then suggested the following equation for the thermal decomposition of sodium hydrogencarbonate.



Explain why Ah Hock's suggestion is **incorrect**. Show working in order to explain your answer.

[Ar: C; 12.0; Na; 23.0; H, 1.0; O: 16.0]

If Ah Hock is **correct**., (84 g)  $\text{NaHCO}_3$  would give **40 g** residue /  $\text{NaOH}$   
**or**  
 mole ratio of  $\text{NaHCO}_3$ :  $\text{NaOH}$  is **1:1.3** (so not 1:1)  
**or**  
 Answers could refer to mass lost / moles of  $\text{CO}_2$

- (ii) Add 1 cm depth of sulfuric acid into a test-tube.  
 Add some **FA 6** from the crucible to the acid in the test-tube.  
 Record all your observations.  
 Use your observations to identify the anion present in **FA 6**.

**Any observation below + gas forms white ppt in limewater**

Do NOT accept milky / chalky / cloudy

- fizzing / effervescence / bubbling
- solid dissolves / colourless solution **formed**

**FA 6** contains carbonate ion /  $\text{CO}_3^{2-}$

[2]

- (iii) State the assumption you have made in (ii).

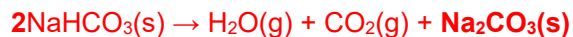
**Complete decomposition** of  $\text{NaHCO}_3$ .  
**OR**  
 There is no leftover  $\text{NaHCO}_3$ .

[1]



- (iv) Steam is one of **three** products obtained when sodium hydrogencarbonate is thermally decomposed.

Use your answer in (ii) to complete and balance the equation for the thermal decomposition of sodium hydrogencarbonate. Include state symbols.



[1]

- (v) State whether the balanced equation in (iv) agrees with Ah Beng's results.

Show working in order to explain your answer.

(From equation) 84.0 g  $\text{NaHCO}_3$  should give  $0.5 \times 106$  g residue (= 53.0 g)  
**And this agrees with Ah Beng's 53.0 g**

[1]

**[Total: 13]**

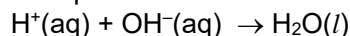
#### 4 Determination of the enthalpy change of a reaction, $\Delta H_r$

**FA 7** is 1.00 mol dm<sup>-3</sup> sodium hydrogen carbonate, NaHCO<sub>3</sub>

**FA 8** is 2.00 mol dm<sup>-3</sup> sodium hydroxide, NaOH

**FA 9** is 2.00 mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>

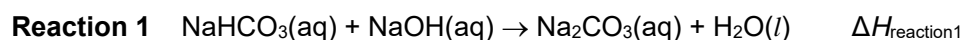
An acid-base neutralisation reaction involves reacting the two solutions, to produce water molecules. The equation for this neutralisation reaction is given below.



You will follow the instructions to perform two experiments, **Experiment A** and **Experiment B**. Record your results in Tables 4.1 and 4.2.

##### Experiment A

Reaction between **FA 7**, NaHCO<sub>3</sub>, and **FA 8**, NaOH.



The molar enthalpy change for **reaction 1**,  $\Delta H_{\text{reaction1}}$ , is the enthalpy change when 1.00 mol of NaHCO<sub>3</sub> reacts completely with NaOH.

- Using a measuring cylinder, transfer 30.0 cm<sup>3</sup> of **FA 7** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm<sup>3</sup> glass beaker. Place the lid on the cup.
- Stir and measure the temperature of this **FA 7**,  $T_{\text{FA7}}$ .
- Using another measuring cylinder, measure 20.0 cm<sup>3</sup> of **FA 8**.
- Stir and measure the temperature of this **FA 8**,  $T_{\text{FA8}}$ .
- Add **FA 8** from the measuring cylinder to the **FA 7** in the Styrofoam cup. Immediately replace the lid.
- Using the thermometer, stir the mixture continuously until a maximum temperature is reached. Read and record this temperature  $T_{\text{max}}$ .
- Calculate the weighted average initial temperature,  $T_{\text{average}}$ , of **FA 7** and **FA 8** using the formula given below:

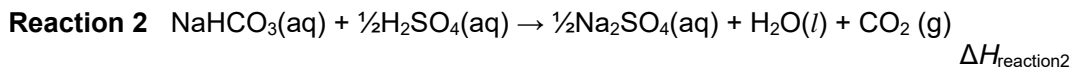
$$T_{\text{average}} = \frac{(V_{\text{FA7}} \times T_{\text{FA7}}) + (V_{\text{FA8}} \times T_{\text{FA8}})}{(V_{\text{FA7}} + V_{\text{FA8}})}$$

	Experiment A
$T_{\text{FA7}} / ^\circ\text{C}$	
$T_{\text{FA8}} / ^\circ\text{C}$	
$T_{\text{average}} / ^\circ\text{C}$	
$T_{\text{max}} / ^\circ\text{C}$	
$\Delta T_{\text{max}} / ^\circ\text{C}$	

**Table 4.1**

**Experiment B**

Reaction between **FA 7**,  $\text{NaHCO}_3$ , and **FA 9**,  $\text{H}_2\text{SO}_4$ .



The molar enthalpy change for **reaction 2**,  $\Delta H_{\text{reaction 2}}$ , is the enthalpy change when 1.00 mol of  $\text{NaHCO}_3$  reacts completely with  $\text{H}_2\text{SO}_4$ .

- Using a measuring cylinder, transfer 30.0 cm<sup>3</sup> of **FA 7** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm<sup>3</sup> glass beaker. Place the lid on the cup.
- Stir and measure the temperature of this **FA 7**,  $T_{\text{FA7}}$ .
- Using another measuring cylinder, measure 20.0 cm<sup>3</sup> of **FA 9**.
- Stir and measure the temperature of this **FA 9**,  $T_{\text{FA9}}$ .
- Add **slowly**, the **FA 9** from the measuring cylinder to the **FA 7** in the Styrofoam cup. Immediately replace the lid.
- Using the thermometer, stir the mixture continuously until a maximum/minimum temperature is reached. Read and record this temperature  $T_{\text{max}}$ .
- Calculate the weighted average initial temperature,  $T_{\text{average}}$ , of **FA 7** and **FA 9** using the formula given below:

$$T_{\text{average}} = \frac{(V_{\text{FA7}} \times T_{\text{FA7}}) + (V_{\text{FA9}} \times T_{\text{FA9}})}{(V_{\text{FA7}} + V_{\text{FA9}})}$$

	Experiment B
$T_{\text{FA7}} / ^\circ\text{C}$	
$T_{\text{FA9}} / ^\circ\text{C}$	
$T_{\text{average}} / ^\circ\text{C}$	
$T_{\text{max}} / ^\circ\text{C}$	
$\Delta T_{\text{max}} / ^\circ\text{C}$	

**Table 4.2**

[2]

All temperature readings are recorded to the nearest 0.1 °C.

(for both Tables 4.1 & 4.2)

$\Delta T_{\text{max/min}}$  must be correctly calculated i.e.  $T_{\text{max}}$  – average initial temperature.

(for both Tables 4.1 & 4.2)

- (a) For the purpose of calculations, you should assume that the mixture has a density of  $1.00 \text{ g cm}^{-3}$  and specific heat capacity,  $c$ , of  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ .

- (i) Use your results from **Table 4.1** to calculate a value for the molar enthalpy change for **reaction 1**,  $\Delta H_{\text{reaction1}}$ .

$$q = (20.0 + 30.0)(1.00) \times 4.18 \times \Delta T_{\text{max}}$$

$$n(\text{NaHCO}_3) = 1.00 \times 30.0/1000 = 0.03 \text{ mol}$$

$$\Delta H_{\text{reaction1}} = -q / n(\text{NaHCO}_3) \quad (\text{this reaction is exothermic})$$

$$\Delta H_{\text{reaction1}} = \dots\dots\dots [2]$$

- (ii) Use your results from **Table 4.2** to calculate a value for the molar enthalpy change for **reaction 2**,  $\Delta H_{\text{reaction2}}$ .

$$q = (20.0 + 30.0)(1.00) \times 4.18 \times \Delta T_{\text{min}}$$

$$n(\text{NaHCO}_3) = 1.00 \times 30.0/1000 = 0.03 \text{ mol}$$

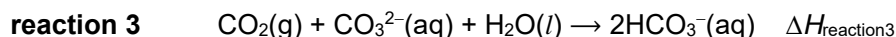
$$\Delta H_{\text{reaction1}} = +q / n(\text{NaHCO}_3) \quad (\text{this reaction is endothermic})$$

$$\Delta H_{\text{reaction2}} = \dots\dots\dots [2]$$

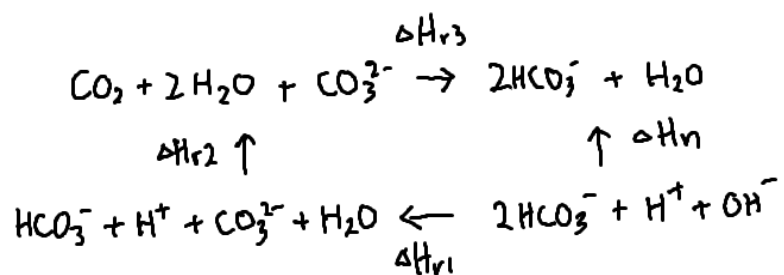
- (b) Ionic equations for neutralisation, **reaction 1**, and **reaction 2** are shown below.

$\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$	$\Delta H_{\text{neu}} = -57.1 \text{ kJ mol}^{-1}$
$\text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	$\Delta H_{\text{reaction1}}$
$\text{HCO}_3^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$	$\Delta H_{\text{reaction2}}$

Carbon dioxide reacts with solutions of carbonate ions according to the following equation.



Using your calculated answers in (a), together with the given value of enthalpy change of neutralisation,  $\Delta H_{\text{neu}}$ , construct an energy cycle to determine a value for the enthalpy change for this reaction,  $\Delta H_{\text{reaction3}}$ .



$$\Delta H_{\text{reaction3}} = (- (a)(ii)) + (- (a)(i)) + (-57.1)$$

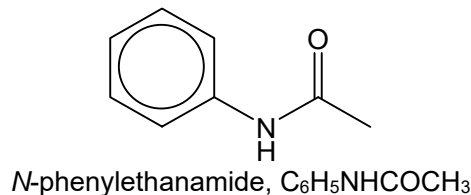
$$\Delta H_{\text{reaction3}} = \dots\dots\dots$$

[3]

**[Total: 9]**

## 5 Planning

The structure of *N*-phenylethanamide is shown below:



The preparation of *N*-phenylethanamide from phenylamine is termed acylation. Ethanoic anhydride,  $(\text{CH}_3\text{CO})_2\text{O}$  is commonly used as an acylating agent as its low reactivity relative to ethanoyl chloride allows the reaction rate to be more easily controlled.

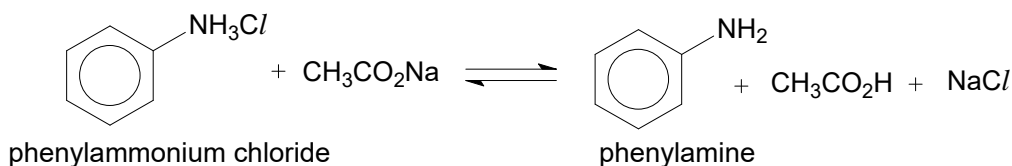
Phenylamine is most conveniently used in the form of the salt phenylammonium chloride,  $\text{C}_6\text{H}_5\text{NH}_3\text{Cl}$ .

The reaction is performed in **two** stages:

### Stage 1:

Phenylamine can be prepared from phenylammonium chloride and sodium ethanoate in an aqueous medium under room temperature.

The reaction is as shown below:



The reaction mixture needs to be continuously stirred for 3 minutes.

### Stage 2:

Phenylamine then reacts with ethanoic anhydride to form solid *N*-phenylethanamide together with ethanoic acid. The addition of ethanoic anhydride to the reaction mixture may be violent.

This mixture is heated under reflux for about 15 minutes, before the crude solid product is removed by filtration and purified by recrystallisation from hot water. The melting point of *N*-phenylethanamide is  $114^\circ\text{C}$ .

- (a) (i) State the type of reaction taking place in stage 1.

Acid base reaction/ neutralisation

[1]

- (ii) Write an equation for the reaction of phenylamine with ethanoic anhydride in stage 2.



- (b) The above reaction between phenylamine and ethanoic anhydride in stage 2 gives an 80% yield. [1]

Assuming phenylammonium chloride is completely converted to phenylamine in stage 1, determine the mass of phenylammonium chloride required to prepare 2 g of *N*-phenylethanamide.

( $A_r$ : C: 12.0, H: 1.0, N: 14.0, O: 16.0, Cl: 35.5)

$$\text{Amount of } N\text{-phenylethanamide} = 2 / 135 = 0.01481 \text{ mol}$$

$$\text{Amount of phenylamine} = 0.01481 \text{ mol}$$

$$\begin{aligned} \text{Mass of phenylammonium chloride} \\ &= 0.01481 \times (72 + 8 + 14 + 35.5) \times 100/80 \\ &= 2.398 \text{ g} \end{aligned}$$

[2]

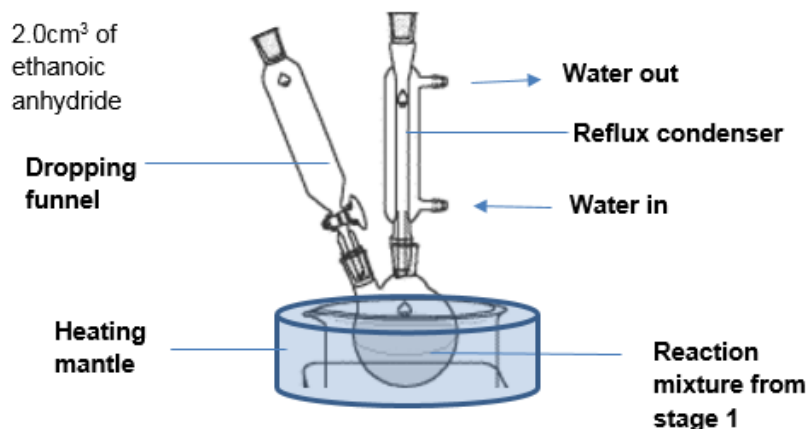
- (c) Write a full description of the procedure to carry out stages 1 and 2. *You do not need to describe the recrystallization process to obtain a pure sample of *N*-phenylethanamide in stage 2.*

You may assume that you are provided with :

- 30 cm<sup>3</sup> of water for use as solvent
- 6.0 g of hydrated sodium ethanoate
- 2.0 cm<sup>3</sup> of ethanoic anhydride
- Apparatus normally found in a school or college laboratory

Your plan should include details of:

- appropriate quantities of reactants
- appropriate choice of apparatus
- drawing of reflux set-up



1. **Weight out** accurately about **2.40 g** of phenylammonium chloride in a clean and dry weighing bottle.
2. **Measure** **30 cm<sup>3</sup>** of water using a 100 cm<sup>3</sup> measuring cylinder.
3. **Dissolve/Add** this completely in 30 cm<sup>3</sup> of water in a clean and dry 250 cm<sup>3</sup> round bottom flask.
4. Weigh out **6.0 g** of hydrated sodium ethanoate in a weighing bottle.
5. Add sodium ethanoate to the solution in (3) and **stir the mixture for three minutes** using a magnetic stirrer.
6. Measure **2.0 cm<sup>3</sup>** of ethanoic anhydride using a 10 cm<sup>3</sup> measuring cylinder.
7. Introduce **2.0 cm<sup>3</sup>** of ethanoic anhydride slowly using a **dropping funnel/dropwise using dropper** /(using ice bath for the reaction) and connect the reaction mixture to the reflux condenser as shown in the set up below inside a fumehood.
8. Carry out the **reflux for 15minutes**.
9. **Filter off** the crude product and wash it with a little cold water

(d) Suggest a method to check the purity of *N*-phenylethanamide obtained.

Determine the melting point and verify it against literature data/ value of 114 °C.  
If the melting point is within  $\pm 2$  °C of literature data/ 114 °C, it is pure

[Total: 10]