NATIONAL JUNIOR COLLEGE
SH2 TIMED PRACTICE
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **9729/A1**
Paper A1 Multiple Choice **30 May 2025**
30 min

Additional Materials: Optical Answer Sheet
Data Booklet

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 **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the 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.
A Data Booklet is provided.

Instructions on how to fill in the Optical Mark Sheet
Shade the index number in a 5 digit format on the optical mark sheet:
2nd digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2405648	**45648**

This document consists of **8** printed pages.

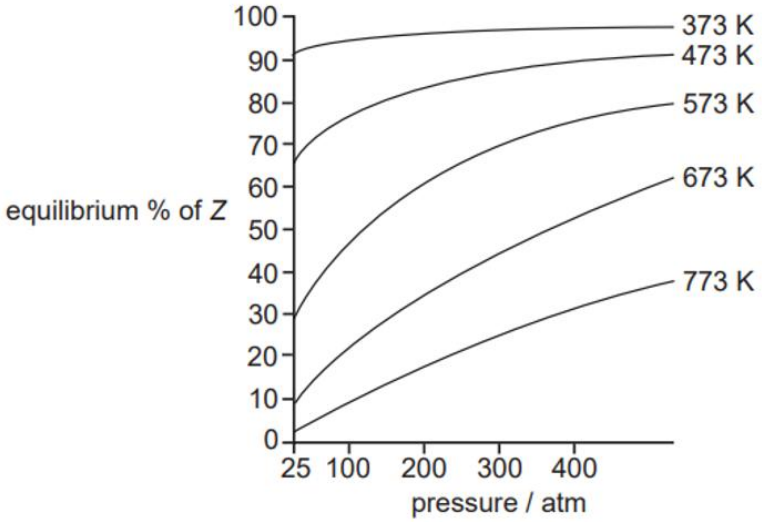
2025 SH2 H2 Chem Timed Practice Paper A1 Answer Key

1	**D**
2	**C**
3	**C**
4	**B**
5	**B**

6	**D**
7	**D**
8	**D**
9	**C**
10	**D**

11	**C**
12	**C**
13	**D**
14	**D**
15	**C**

1 The equilibrium percentage of **Z** varies according to varying pressures and temperatures as shown in the graph.



Which row in the table shows the correct information about the equilibrium?

	equilibrium reaction	sign of ΔH for the forward reaction
A	**Y**(g) + **X**(g) $\rightleftharpoons$ 3**Z**(g)	Positive
B	4**X**(g) + **Y**(g) $\rightleftharpoons$ 2**Z**(g)	Positive
C	**Y**(g) + **X**(g) $\rightleftharpoons$ 3**Z**(g)	Negative
D	4**X**(g) + **Y**(g) $\rightleftharpoons$ 2**Z**(g)	Negative

Ans: D

Graph shows decreasing % of product Z with increasing temperature. As increasing temperature favours endothermic reaction, since less Z is formed, the backward reaction is endothermic, and the forward reaction is exothermic (C or D)
Graph also shows increasing % of Z when pressure increases. As increasing pressure favours the side of the equation with fewer moles of gaseous particles, the RHS of the equation must have fewer gaseous moles than the LHS, so answer is D.

2 **X** decomposes on heating according to the following equation

$$2X(g) \rightleftharpoons 2Y(g) + B(g)$$

When 4 mol of **X** were put into a 2 dm^3 container and heated, the equilibrium mixture contained 0.8 mol of **B**.

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

A $\dfrac{0.8 \times 0.8}{3.2}$

B $\dfrac{1.6 \times 1.6 \times 0.8}{2.4 \times 2.4}$

C $\dfrac{1.6 \times 1.6 \times 0.8}{2.4 \times 2.4 \times 2}$

D $\dfrac{0.4 \times 0.4 \times 0.8}{0.4 \times 0.4}$

Ans: C

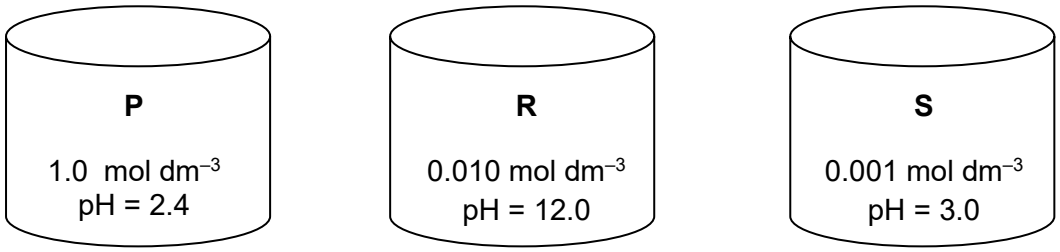
	2X	⇌	2Y	+	B
Initial / mol	4		0		0
Change / mol	−2×0.8		+2×0.8		+0.8
Equilibrium / mol	2.4		1.6		0.8

$$K_c = \frac{[Y]^2[B]}{[X]^2}$$

$$= \frac{\frac{1.6}{2} \times \frac{1.6}{2} \times \frac{0.8}{2}}{\frac{2.4}{2} \times \frac{2.4}{2}}$$

$$= \frac{1.6 \times 1.6 \times 0.8}{2.4 \times 2.4 \times 2}$$

3 The concentration and pH of each solution, **P**, **R** and **S** are shown below. Solutions **P**, **R** and **S** could be either a monobasic acid or a monoacidic base.



Which statements are correct?

1 **R** is a weak base.

2 **P** is a weak acid while **S** is a strong acid.

3 Mixing 100 cm^3 of **R** and 100 cm^3 of **S** produces a buffer solution.

4 Mixing 500 cm^3 of **P** and 500 cm^3 of **R** produces a buffer solution.

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

Ans: C

pH = 2.4 means [H$^+$] = $10^{-2.4}$ = 0.00398 mol dm^{-3} < 1.0 mol dm^{-3}
This means that P is a monobasic weak acid.

pH = 12.0 means pOH = 2 and [OH$^-$] = 10^{-2} = 0.01 mol dm^{-3} = [R] so R is a monoacidic strong base.
Statement 1 is wrong.

pH = 3.0 means [H$^+$] = 10^{-3} = 0.001 mol dm^{-3} = [S]
This means that S is a monobasic strong acid. Statement 2 is correct.

Mixing 100 cm^3 of 0.01 mol dm^{-3} **R** (0.001 mol of strong base) and 100 cm^3 of 0.001 mol dm^{-3} **S** (0.0001 mol of strong acid) produces 0.009 mol of excess strong base and 0.001 mol of neutral salt which is not a buffer solution). Statement 3 is wrong.

Mixing 500 cm^3 of 1.0 mol dm^{-3} **P** (0.5 mol of weak acid) and 500 cm^3 of 0.001 mol dm^{-3} **R** (0.0005 mol of strong base) produces 0.4995 mol of excess weak acid and 0.0005 mol of conjugate base of weak acid which is a buffer solution. Statement 4 is correct.

4 Equal volumes of 1.0×10^{-2} mol dm^{-3} aqueous $BaSiF_6$ and 2.5×10^{-1} mol dm^{-3} aqueous $CsBrO_3$ are mixed in a test-tube.

The numerical values of the solubility products are:
K_{sp} of $Ba(BrO_3)_2 = 2.43 \times 10^{-4}$
K_{sp} of $Cs_2SiF_6 = 1.3 \times 10^{-5}$

Which statement best describes what will be observed in the test tube?

A No precipitation is observed.
B Precipitation of Cs_2SiF_6 only.
C Precipitation of $Ba(BrO_3)_2$ only.
D Precipitation of both Cs_2SiF_6 and $Ba(BrO_3)_2$.

Ans: B

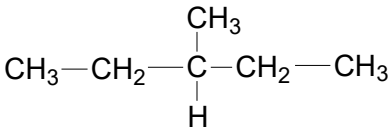
IP of $Ba(BrO_3)_2 = [Ba^{2+}][BrO_3^-]^2 = (½ \times 1.0 \times 10^{-2})(½ \times 2.5 \times 10^{-1})^2 = 7.81 \times 10^{-5} < K_{sp}$ (no ppt formed)
IP of $Cs_2SiF_6 = [Cs^+]^2[SiF_6^{2-}] = (½ \times 2.5 \times 10^{-1})^2(½ \times 1.0 \times 10^{-2}) = 7.81 \times 10^{-5} > K_{sp}$ (ppt formed)

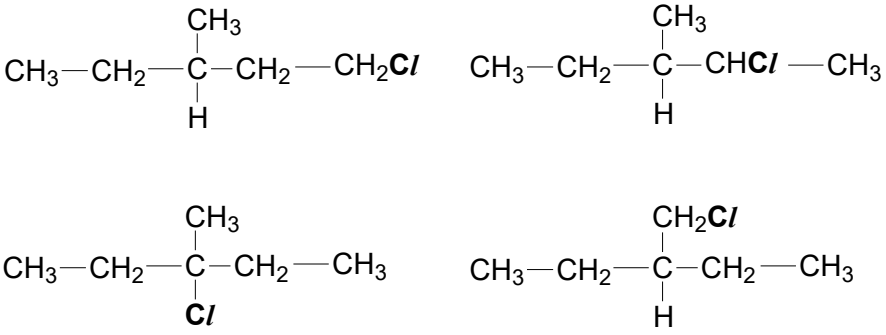
5 In the free radical substitution of 3-methylpentane with chlorine, a mixture of products was obtained.

How many constitutional isomers of mono-chlorinated products are theoretically possible?

A 3 **B** 4 **C** 5 **D** 6

Ans: B





6 Nitrobenzene is a precursor to many reagents. It can be prepared by reacting benzene with concentrated HNO_3 and concentrated H_2SO_4. What is the role of concentrated H_2SO_4?

A To generate NO_2^- for the reaction

B To act as a dehydrating agent

C To direct the electrophile to a specific position on the benzene ring

D To act as a catalyst

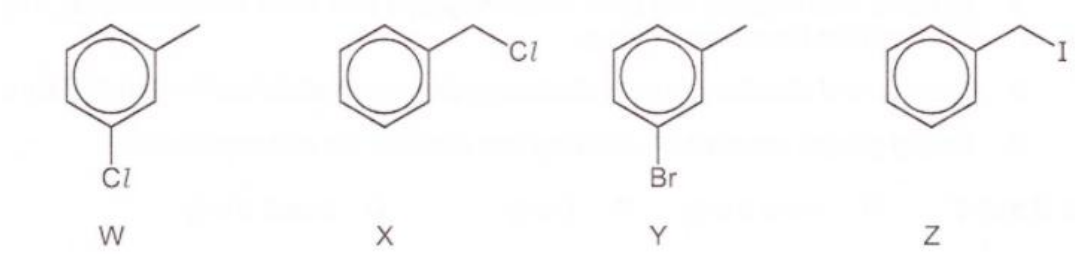
Ans: D

Concentrated H_2SO_4 reacts with HNO_3 to generate $^+NO_2$ (A is wrong)

H_2SO_4 is not a substituent on the benzene ring, so it does not have any directing effect (C is wrong)

As H_2SO_4 is regenerated and $^+NO_2$ is a strong electrophile to react with benzene with a lower E_a, Concentrated H_2SO_4 is a catalyst. (D is correct and B is wrong)

7 Equal amounts of compounds **W**, **X**, **Y** and **Z** are added separately to four test tubes containing equal concentrations of ethanolic silver nitrate solution in a heated water bath. No precipitate forms in two of the tubes. In the two other tubes, precipitates form at different rates.



Which row is correct?

	Compounds which do **not** form a precipitate	Colour of the precipitate which forms the fastest
A	W	cream
B	W and X	yellow
C	X and Z	white
D	W and Y	yellow

Ans: D

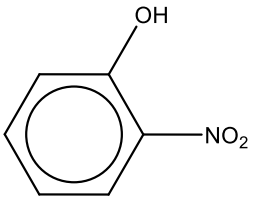
Compound W and Y do not form a precipitate when heated with ethanolic silver nitrate. C-C*l* and C-Br bonds have partial double bond character due to the lone pair electrons on C*l* and Br atom being delocalised into the π electron cloud of benzene.

C-X bond is strengthened hence resistant to substitution.

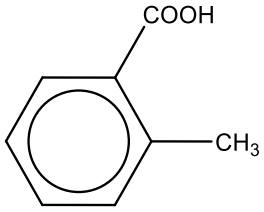
Comparing compounds X and Z, compound Z will give a yellow ppt of AgI more readily due to the weaker C-I bond as compared to C-C*l* bond in X.

8 Which compound is less acidic than phenol?

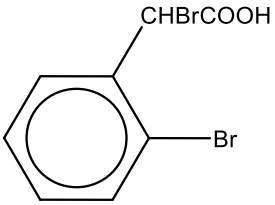
A



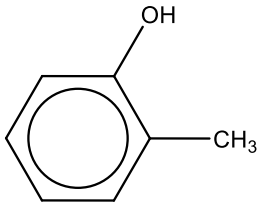
B



C



D



Ans: D

Acid strength increases with stability of the conjugate base and stability of conjugate base increases with the increasing dispersion of negative charge of conjugate base.

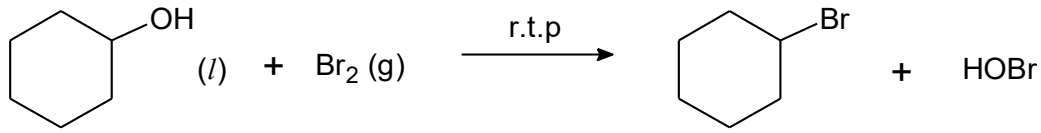
The electron-donating $-CH_3$ group in the conjugate base of D intensifies the negative charge on O of the conjugate base of D.

The conjugate base of D is less stable than phenoxide, hence compound D is less acidic than phenol.

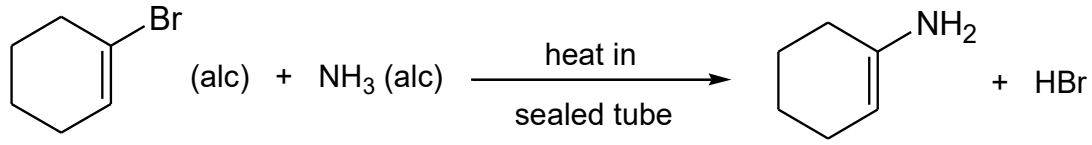
9 Which reaction gives the best yield of the organic products?

[(*alc*) indicates an alcoholic solution.]

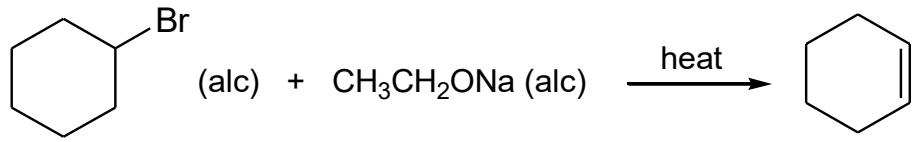
A



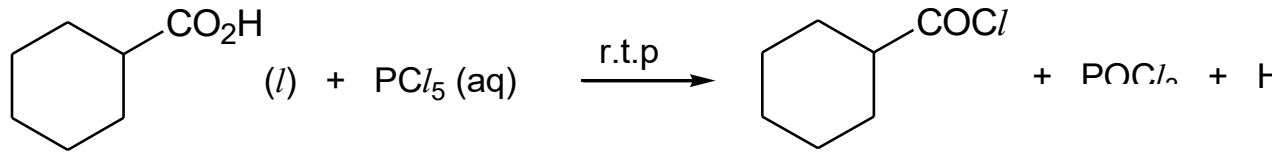
B



C



D



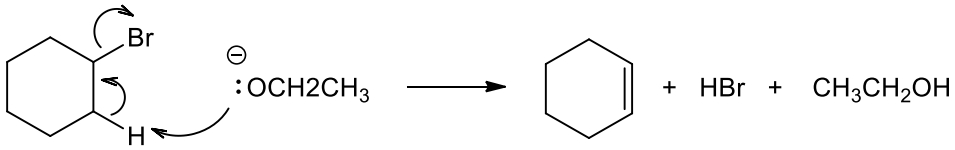
Answer: C

A Substitution of OH with Br requires HBr or PBr_3, as the C-O bond is strong and difficult to break.

B Br attached to C=C is unreactive towards nucleophilic substitution as the p orbital on Br overlaps with the π orbital of C=C, resulting in partial double bond character for the carbon-bromine bond making it resistant towards substitution.

C Elimination of HBr can take place in presence of a strong base in alcoholic medium. $CH_3CH_2O^-$ is a stronger base than OH^- since the electron donating ethyl group intensifies the negative charge on oxygen. Thus, $CH_3CH_2O^-$ is able to abstract the H atom on the adjacent carbon of a C-Br.

Mechanism FYI:



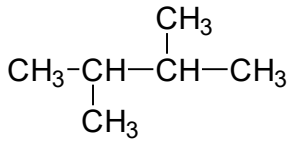
Na^+ is a spectator ion.

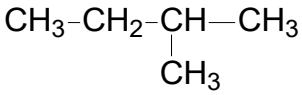
D PCl_5 will hydrolyse in aqueous medium and hence anhydrous PCl_5 should be used instead.
$PCl_5 + H_2O \rightarrow 5HCl + H_3PO_4$

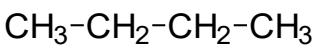
10 An iodoalkane and sodium, immersed in ether, react when heated under reflux to form an alkane according to the equation:

$$2RI + 2Na \rightarrow R-R + 2NaI$$

When iodoethane, CH_3CH_2I and 2-iodopropane, CH_3CHICH_3, are subjected to the reaction above, which alkane(s) will be formed?

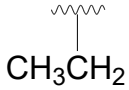
1 

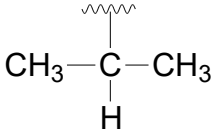
2 

3 

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

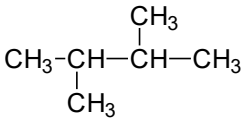
Ans: D

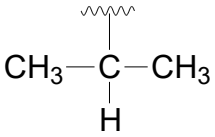
When CH_3CH_2I is used,  is the R group.

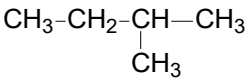


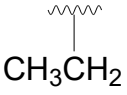
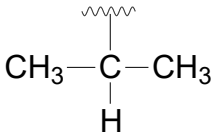
When CH_3CHICH_3 is used, is the R' group.

The product is formed after a new C-C bond is formed between R and R' groups.

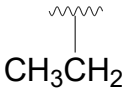
1 

2 moles of 

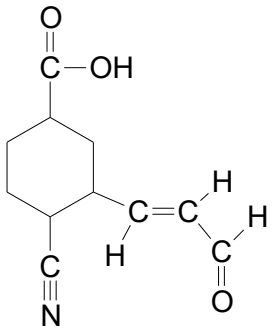
2 

1 mole of  and 1 mole of 

3 $CH_3-CH_2-CH_2-CH_3$

2 moles of 

11 How many moles of H_2 would react with one mole of the molecule below in the presence of Pt(s)?



A 2 **B** 3 **C** 4 **D** 6

Ans: C

H_2/ Pt only used to reduce C=C bond, C=O bond in carbonyl and −C≡N bond. It is not able to reduce carboxylic acid group.

2 moles of H_2 required to reduce −C≡N bond, 1 mole of H_2 to reduce each C=C bond and C=O bond.

12 A compound **Q** was heated with aqueous sulfuric acid and potassium manganate(VII), and the resulting mixture was cooled. One of the final products gave a yellow precipitate with alkaline aqueous iodine.

Which formula could **Q** represent?

A $CH_3CO_2CH_3$

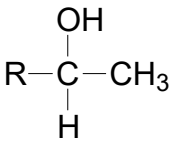
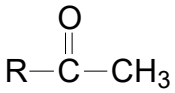
B $CH_3CO_2CH_2CH_3$

C $CH_3CO_2CH(CH_3)_2$

D $CH_3CO_2C(CH_3)_2CH_3$

Ans: C

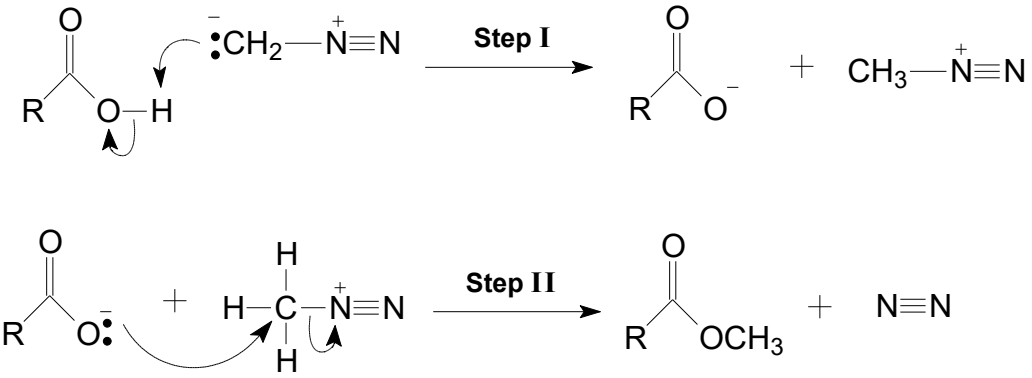
All options have COO ester bonds, so hydrolysis of ester occurs first, followed by any oxidation of primary or secondary alcohols to carboxylic acids or ketones respectively.

Check which final product has  or  structure.

$$CH_3CO_2CH(CH_3)_2 \xrightarrow[\text{heat}]{KMnO_4(aq),\ H_2SO_4(aq)} CH_3CO_2H + HOCH(CH_3)_2$$

$HOCH(CH_3)_2$ is further oxidized to CH_3COCH_3, which contains a methyl carbonyl structure, hence gives a positive test with alkaline aqueous iodine.

13 Diazomethane (CH_2N_2) is a highly explosive yellow gas which is known to explode upon gentle impact or exposure to light. It is an efficient agent used in the preparation of methyl esters and the mechanism is shown below.



What types of reaction took place in Steps **I** and **II**?

	Step **I**	Step **II**
A	nucleophilic substitution	elimination
B	acid-base reaction	elimination
C	nucleophilic substitution	electrophilic addition
D	acid-base reaction	nucleophilic substitution

Ans: D

Step 1: $^-CH_2N_2^+$ base uses a lone pair of electrons on C to abstract a H from alcohol (acid-base reaction)
Step 2: RCO_2^- nucleophile uses a lone pair of electrons on O to attack an electron-deficient C and 2 products are formed (nucleophilic substitution)

14 Methylamine was heated in a sealed tube with excess 1-bromoethane for a prolonged period.

Which is the major product?

A CH_5N
B C_3H_9N
C $C_5H_{13}N$
D $C_7H_{18}NBr$

Ans: D

When excess halogenoalkane is present, multiple nucleophilic substitutions occur until a quaternary ammonium salt is formed.

$CH_3NH_2 + CH_3CH_2Br \rightarrow CH_3NHCH_2CH_3$
1 carbon 2 carbons 3 carbons

$CH_3NHCH_2CH_3 + CH_3CH_2Br \rightarrow CH_3N(CH_2CH_3)_2$
3 carbons 2 carbons 5 carbons

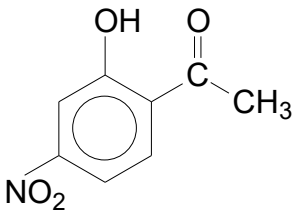
$CH_3N(CH_2CH_3)_2 + CH_3CH_2Br \rightarrow [CH_3N(CH_2CH_3)_3]^+ Br^-$
5 carbons 2 carbons 7 carbons

15 Compound **R** undergoes the following reactions.

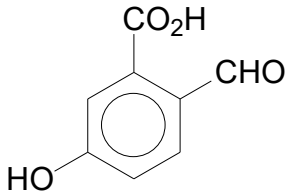
- It gives decolorises bromine water and gives white precipitate.
- It does not give any visible reaction with Fehling's solution.
- It gives a silver mirror with Tollen's reagent.
- It does not give any visible reaction with sodium carbonate.

What could compound **R** be?

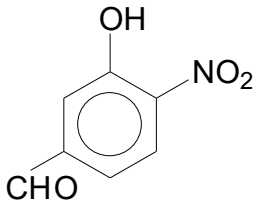
A



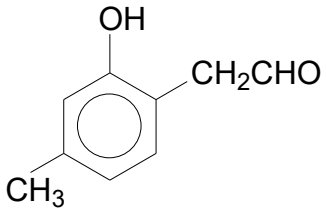
B



C



D



Ans: C
It gives decolorises bromine water and gives white precipitate (Phenol is present)
It does not give any visible reaction with Fehling's solution
It gives a silver mirror with Tollen's reagent (negative test with Fehling's but positive test with Tollen's means that benzaldehyde is present)
It does not give any visible reaction with sodium carbonate (no carboxylic acid, cannot be B)

NATIONAL JUNIOR COLLEGE
SH2 MID YEAR TIMED PRACTICE
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY

9729/A

Paper A Structured Questions

30 May 2025
1 hour 30 min

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE 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 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.

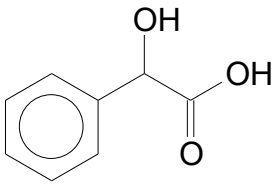
A Data Booklet is provided.

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

For Examiner's Use	
1	**/17**
2	**/14**
3	**/7**
4	**/14**
5	**/8**
Paper 2 Total	**/60**

This document consists of **20** printed pages.

1 Mandelic acid is widely used in chemical peels, serums, and creams due to its gentle exfoliating and antibacterial properties. It is a weak acid with K_a value of 3.89×10^{-4}.



mandelic acid

(a) **(i)** Calculate the pH of 0.050 mol dm^{-3} mandelic acid.

Mandelic acid is a weak acid that dissociates partially,

$RCOOH \rightleftharpoons H^+ + RCOO^-$

To calculate pH of weak acid, $[H^+]_{eqm} = \sqrt{K_a \times [\text{weak acid}]}$

$$[H^+]_{eqm} = \sqrt{(3.89 \times 10^{-4}) \times 0.05}$$
$$= 0.004410 \text{ mol dm}^{-3} \text{ [1m]}$$

$pH = -\lg [H^+] = \underline{\mathbf{2.36}}$ (2d.p.) [1m]

[2]

(ii) Calculate the pH of 0.050 mol dm^{-3} NaOH.

NaOH is a strong base that dissociates completely,

$NaOH \rightarrow Na^+ + OH^-$

$[OH^-] = 0.050$

$pOH = -\lg [OH^-] = 1.301$

$pH = 14 - pOH = \underline{\mathbf{12.70}}$ (2d.p.) [1m]

[1]

A student adds small portions of 0.050 mol dm^{-3} NaOH (aq) to 25.0 cm^3 of 0.050 mol dm^{-3} mandelic acid. The student uses a pH meter to measure the pH of the mixture and the data are shown in Table 1.1.

Table 1.1

volume of 0.050 mol dm^{-3} NaOH(aq) added / cm^3	pH of mixture
25.0	7.5
50.0	12.4

(iii) Explain why the pH of the mixture is slightly greater than 7 when the student adds a total of 25.0 cm^3 of 0.050 mol dm^{-3} NaOH(aq) to the mandelic acid. Include relevant equations in your answer.

Let mandelic acid be RCOOH,

$RCOOH + NaOH \rightarrow RCOONa + H_2O$ [1/2m]

25.0 cm^3 of NaOH reacts completely with RCOOH and the resulting solution **only contains the salt RCOONa** [1/2m] and H_2O.

$RCOO^-$ is the conjugate base of the weak acid RCOOH. $RCOO^-$ has a K_b value and **ionises partially** in water to **produce some OH^-**, [1/2m] hence the resulting mixture has a **pH of slightly greater than 7**.

$RCOO^- + H_2O \rightleftharpoons RCOOH + OH^-$ [1/2m]

[2]

(iv) State the volume of NaOH added to reach maximum buffer capacity and calculate the pH at that point.

Maximum buffer capacity is when [weak acid] = [conjugate base]
This occurs when **12.50 cm^3** of NaOH is added. [1/2m]

At maximum buffer capacity,
$pH = pK_a$
$= -\lg(3.89 \times 10^{-4})$
$=$ **3.41** (2d.p.) [1/2m]

[1]

(v) Sketch the shape of the pH curve on Fig 1.1 using all relevant information given or calculated.

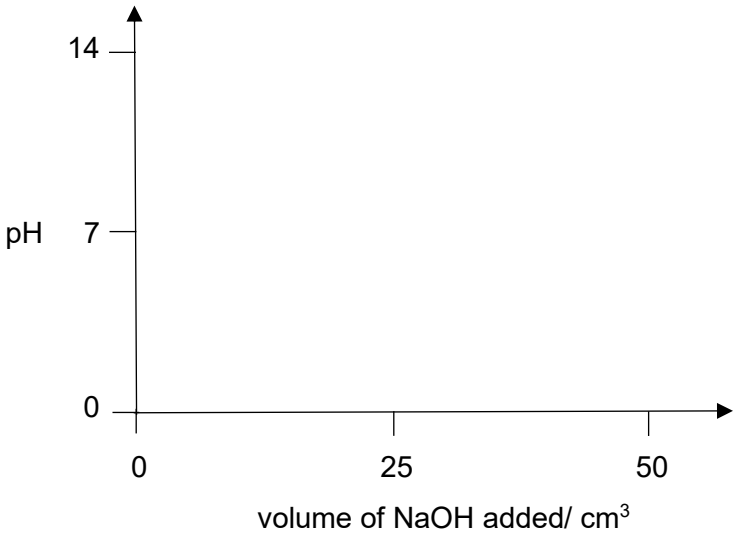
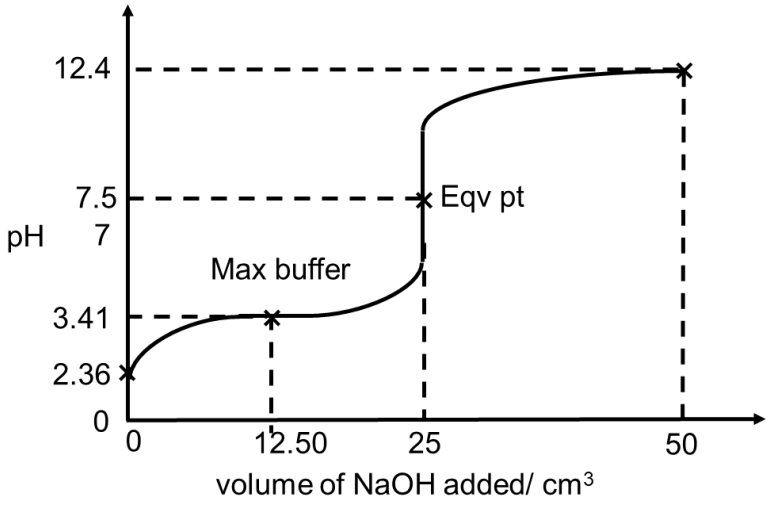


Fig 1.1



Shape [1/2 m]
all points correctly indicated [1/2m]

[1]

(b) The pH of the skin is usually 4.5 to 6.5. When aqueous mandelic acid is applied directly to skin, it may cause irritation and redness because the skin is sensitive to pH. To reduce skin sensitivity, skin creams often contain a pH buffer consisting of sodium mandelate and mandelic acid.

Calculate the volume of 0.050 mol dm^{-3} NaOH(aq) that needs to be added to 25.0 cm^3 of 0.050 mol dm^{-3} of mandelic acid so as to produce a buffer with pH 4.5. [K_a of mandelic acid = 3.89×10^{-4}]

Let the amount of NaOH added be x mol

Initial amount of mandelic acid RCOOH = $\frac{25}{1000} \times 0.050 = 0.00125$ mol

	RCOOH	+ NaOH	→	RCOONa	+ H_2O
I / mol	0.00125	x		0	-
C / mol	–x	–x		+x	-
F / mol	0.00125– x	0		x	-

The resultant mixture is a buffer solution containing RCOOH and $RCOO^-$.

For buffer,

$pH = pK_a + \lg \frac{[RCOO^-]}{[RCOOH]}$

$4.5 = -\lg (3.89 \times 10^{-4}) + \lg \frac{[x]}{[0.00125 - x]}$

$4.5 - 3.41 = \lg \frac{[x]}{[0.00125 - x]}$

$\frac{[x]}{[0.00125 - x]} = 10^{1.09}$

$\frac{[x]}{[0.00125 - x]} = 12.30$ [1m]

$x = 0.015375 - 12.3x$

$13.3\ x = 0.015375$

$x = 0.001156$

Volume of NaOH required = $\frac{0.001156}{0.05}$ = **0.0231 dm^3** [1m]

[2]

(c) Mandelic acid is made in a two-step process shown in Fig 1.2.

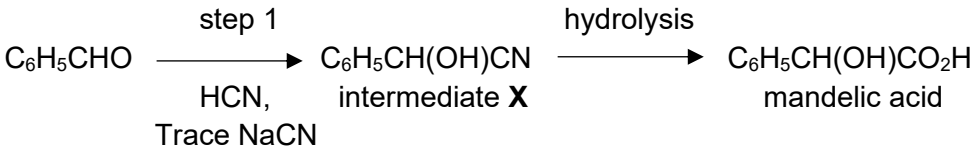
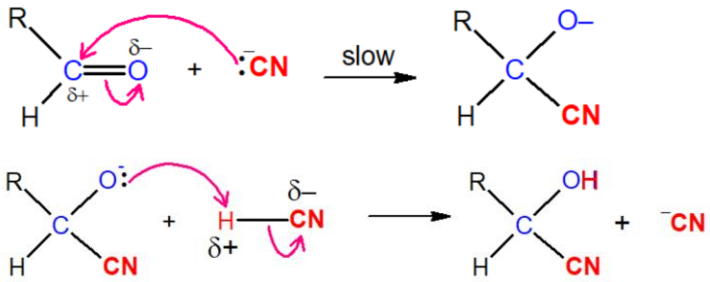


Fig 1.2

(i) Draw a reaction mechanism for step 1. Show relevant lone pairs of electrons, dipoles and curly arrows.
Let C_6H_5CHO be RCHO

Nucleophilic addition



Minus ½ for each mistake
Name of mechanism
Indicate slow step
Correct anion intermediate
Draw arrows correctly for bond forming and bond breaking
Show partial charges on polar bonds
Show lone pair electrons for CN^- and O^- during bond forming

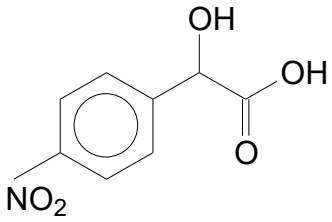
[3]

(ii) Deduce whether intermediate **X** formed from this reaction would be optically active.

In step 1, the **nucleophile CN^- can attack** the **trigonal planar C** of C=O from **either side of the plane with equal probability [1]**, giving rise to a racemic mixture. **The equal but opposite rotation of plane-polarised light by each enantiomer results in net zero optical activity. [1]**

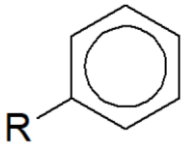
[2]

(d) Mandelic acid can be converted to other useful pharmaceutical intermediates such as 4-nitromandelic acid.



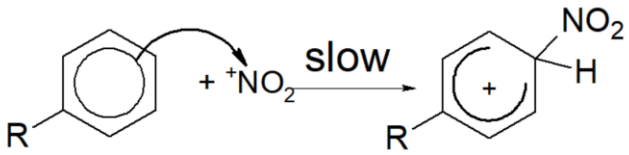
4-nitromandelic acid

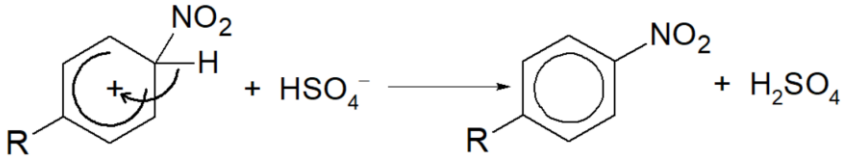
Draw a reaction mechanism for the conversion of mandelic acid to 4-nitromandelic acid using concentrated H_2SO_4 and concentrated HNO_3. Show relevant lone pairs of electrons, dipoles and curly arrows.

Let mandelic acid be 

Electrophilic substitution

$HNO_3 + H_2SO_4 \rightarrow {}^{+}NO_2 + HSO_4^{-} + H_2O$





Minus ½ for each mistake
Name of mechanism
Show generation of electrophile
Indicate slow step
Correct arenium intermediate
Draw arrows correctly for bond forming and bond breaking
Show regeneration of catalyst

[3]

[Total: 17]

2 Compounds **A** and **B** have the same molecular formula $C_5H_8O_3$.

(a) Compound **A** contains three functional groups. It is a straight chain compound that exhibits stereoisomerism.

Data about the reactions of **A** are given in Table 2.1.

Table 2.1

reaction	reagent	result
1	$K_2Cr_2O_7$ / H_2SO_4(aq), heat	solution turns from orange to green
2	2,4-dinitrophenylhydrazine	orange solution remains
3	I_2 / NaOH(aq), warm	yellow precipitate **D** produced
4	Br_2(aq)	orange solution decolourised. organic product formed with M_r = 212.9
5	Na_2CO_3 (aq)	effervescence observed

(i) Based on reactions **1** and **2**, name the functional group that could be present in **A**.

1° Alcohol and 2° Alcohol

Do not accept "alcohol" as 3° alcohol cannot be oxidized.

……..

[1]

(ii) State the name of the precipitate **D** formed in reaction **3**.

Triiodomethane

Do not accept CHI_3 as the question ask for the "name"

……..

[1]

(iii) What type of reaction takes place in reaction **4**?

Deduce the molecular formula of the organic product formed in reaction 4.

Type of reaction: …….. Electrophilic addition

Molecular formula: …….. $C_5H_9O_4Br$ (Addition of Br and OH)

[2]

(iv) Name the functional group present in **A** that is confirmed by reactions **4** and **5**.

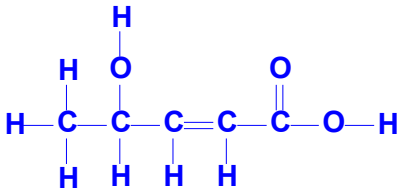
Reaction **4**: ..... Alkene

Reaction **5**: ..... Carboxylic acid

[2]

(v) You now have enough information to determine the structural formula of **A**.

Draw the displayed formula of compound **A**.



Need to show all bonds between the atoms.

Thinking process:

Compound **A**, $C_5H_8O_3$, is a straight chain compound that exhibit stereoisomerism (in this case, cis-trans and enantiomerism).

A contains methyl carbinol (2° alcohol), alkene and carboxylic acid functional groups.

Correct structure [1]

Showing all bonds between atoms for displayed formula [1]

[2]

(vi) Using your structure of compound **A**, deduce the total number of stereoisomers that **A** can exhibit.

A contains 1 cis-trans C=C and 1 chiral C, ...

Total number of stereoisomers = 2^2 = **4** .....

[1]

(b) Compound **B,** $C_5H_8O_3$, is an isomer of compound **A.** It can undergo several reactions as shown in Fig 2.1.

Draw the structures of organic compound **E**, **F** and **G** in the boxes in Fig 2.1.

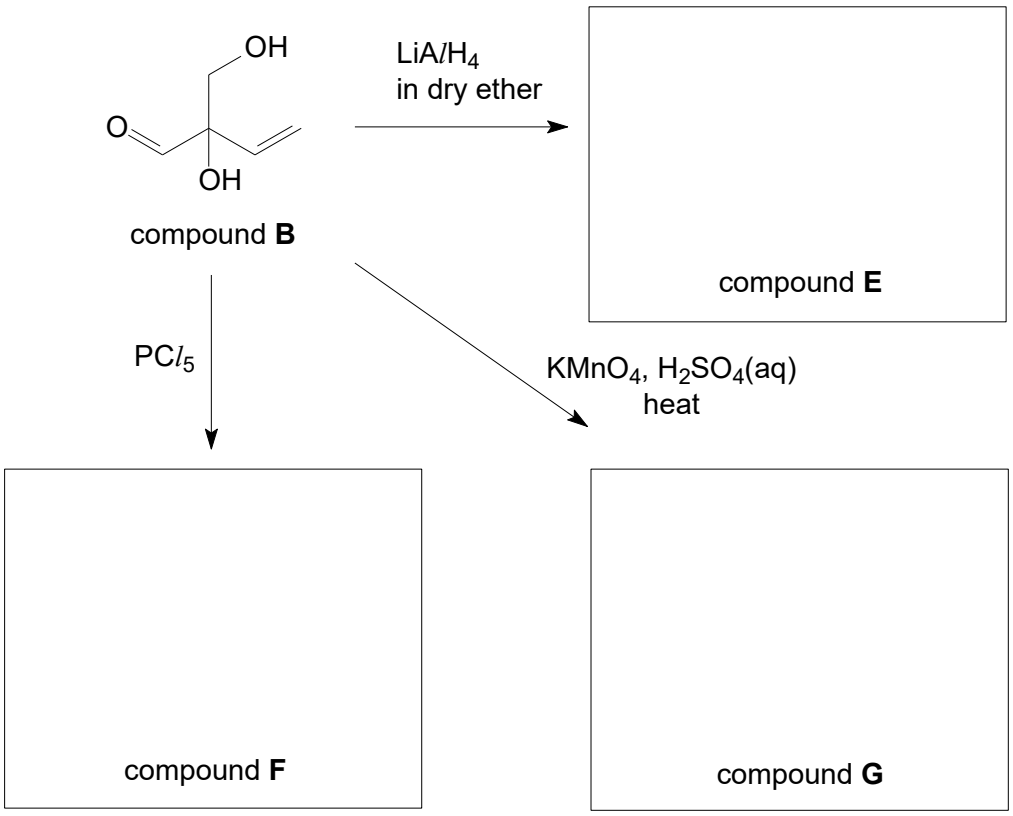
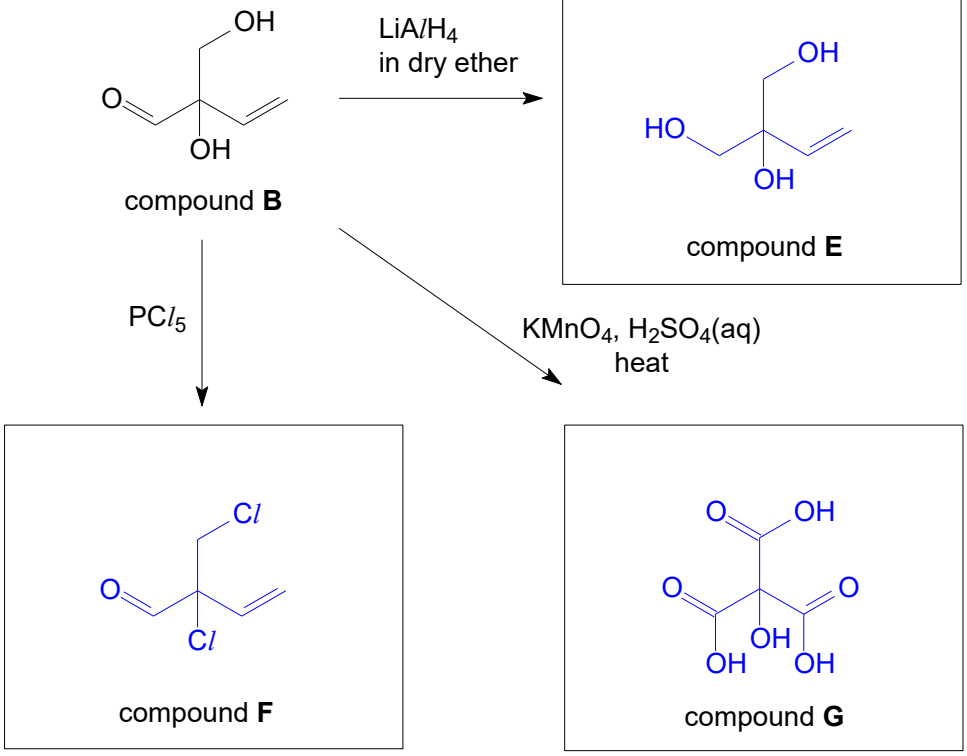


Fig 2.1

[3]

H⁻ cannot reduce C=C



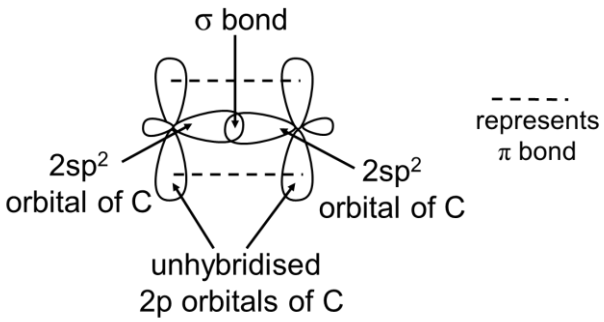
OH substituted by Cl

Oxidation of C=C, aldehyde and 1° alcohol
Tertiary alcohol CANNOT be oxidised

(c) Use a labelled diagram to show the orbitals that form the C=C bond in $CH_2=CH_2$.

Show **head-on** overlap between **sp^2** hybrid orbital of C_1 with **sp^2** hybrid orbital of C_2. to form sigma (σ) bond **1m**

Show **sideway** overlap between unhybridised **2p** orbital of C_1 with unhybridised **2p** orbital of C_2 to form pi (π) bond **1m**



[2]

[Total: 14 marks]

3 **(a)** In the presence of a base such as aqueous sodium carbonate, compound **X** can react with iodine to form compound **P** as shown in Fig 3.1.

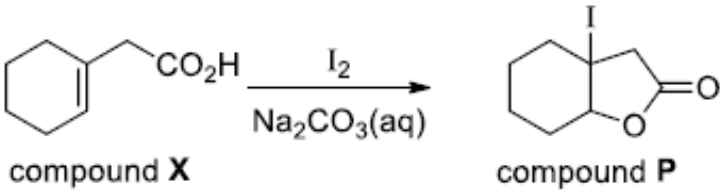
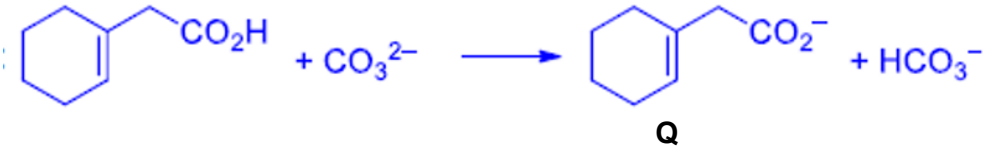


Fig 3.1

(i) This reaction follows a three-step mechanism.

The first step of the mechanism involves the acid-base reaction of **X** by Na_2CO_3 as shown below.

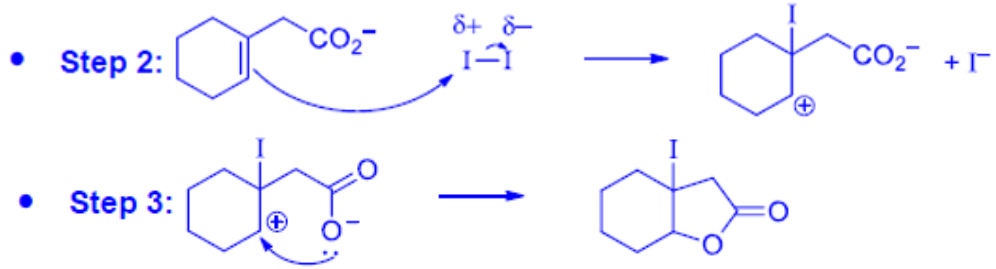


In the second step, **Q** reacts with I_2 to form a secondary carbocation **R**.

In the third step, the carbocation is attacked by O^- to form the product **P**.

Describe the mechanism for step 2 and 3. Show clearly any intermediates that may be formed, all charges and use curly arrows to indicate the movement of electron pairs and state the role of iodine in the reaction.

Electrophilic addition [1/2]

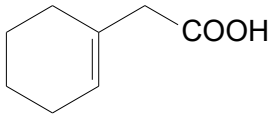


1 mark for each step 2 and 3 mechanism
Minus ½ for missing within each step
- curly arrows,
- partial charges, lone pair
- charged intermediate
- balanced equation

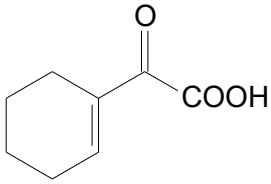
Iodine acts as the **electrophile** **[1/2]**

[3]

(ii) Describe a simple chemical test to distinguish between compounds **X** and **Y**. State the observations clearly.



compound **X**



compound **Y**

Add compounds **X** and **Y** to two separate test-tubes and then add

2,4-nitrophenylhydrazine (2,4-DNPH). [1]

For Y, orange ppt with 2,4-DNPH. [1/2]

For X, no ppt. [1/2]

[2]

(b) When the compounds shown below were reacted with aqueous sodium hydroxide at 55 °C, the rate of reaction decreases in the following order.

$$CH_3COBr > C_6H_5CH_2Br > C_6H_5Br$$

(i) Explain why C_6H_5Br has the slowest rate with aqueous sodium hydroxide at 55 °C.

In C_6H_5Br, **the p orbital of the Br overlaps with the π electron cloud of the benzene ring**, leading to a **partial double bond character**. Thus, the **C-Br bond is stronger** and more difficult to be broken.

[1]

(ii) Explain why $C_6H_5CH_2Br$, a 1° halogenoalkane, undergoes S_N1 rather than S_N2 mechanism.

$C_6H_5CH_2Br$ can undergo S_N1 with aqueous NaOH as **$C_6H_5CH_2Br$ gives a stable carbocation**, $C_6H_5CH_2^+$ because the **positive charge is dispersed via resonance into the benzene ring**. Thus, the **formation of $C_6H_5CH_2^+$ is favoured.**

[1]

[Total: 7]

4 **(a)** Depending on the conditions of the reaction, 4–ethylphenol can react with chlorine in two different ways, giving the two isomers **J** and **K** as shown in Fig. 4.1.

When ethanolic silver nitrate is added to both **J** and **K** and the resultant solutions are warmed, white precipitate is observed for **K** but no white precipitate is observed for **J.**

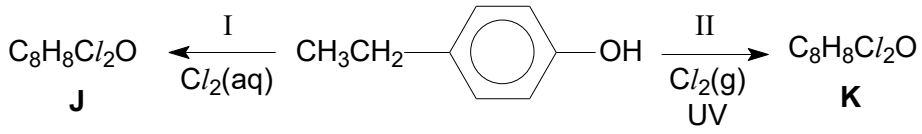
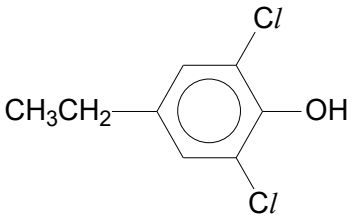


Fig. 4.1

(i) Deduce the structure of compound **J**.



[1]

(ii) Explain whether you would expect **J** to be more or less acidic than 4–ethylphenol.

The **electron–withdrawing C*l* groups increases the dispersion of the negative charge of the conjugate base of J and making it more stable than conjugate base of 4-ethylphenol** [1]. Hence, **J undergoes greater acid dissociation** [1] than 4-ethylphenol.

[2]

(iii) Suggest the type of reaction to convert 4–ethylphenol to **K.**

Free Radical Substitution

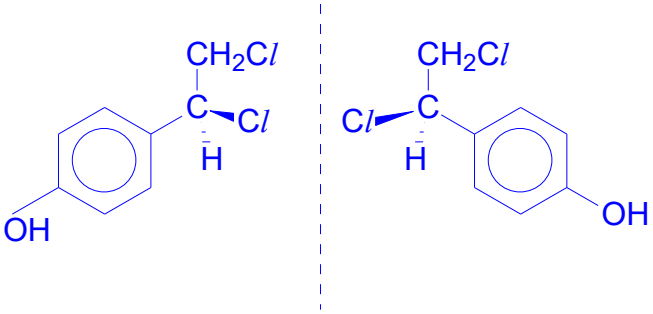
……..

[1]

(iv) **K** is observed to exhibit stereoisomerism.

State the type of stereoisomerism that **K** exhibits and draw the pair of stereoisomers.

Optical Isomerism / enantiomerism [1]



Correct structure of K and mirror images [1/2]

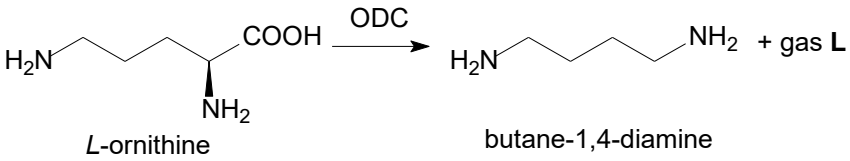
Show the 3D tetrahedral arrangement around chiral C [1/2]

[2]

(b) Ornithine, an amino acid, has 2 stereoisomers, *L*-ornithine and *D*-ornithine.

When enzyme ODC is added to *L*-ornithine, reaction 4.1 occurs.

reaction 4.1



L-ornithine butane-1,4-diamine

When enzyme ODC is added to *D*-ornithine, no reaction occurs.

(i) Deduce the identity of the gaseous by-product of reaction 4.1.

CO_2 (by balancing the equation)

……..

[1]

(ii) Explain why enzyme ODC reacts with *L*-ornithine but does not react with *D*-ornithine.

Enzyme is a biological catalyst with **specific activity**. *D*-ornithine has a ……..

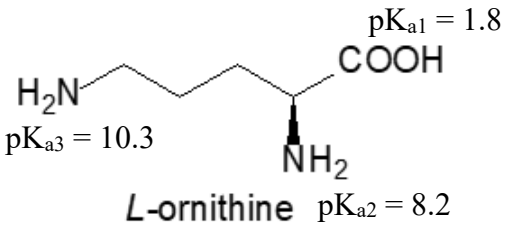
different spatial arrangement of atoms from *L*-ornithine and **could not** ……..

interact with enzyme ODC. ……..

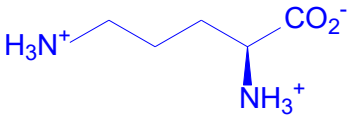
……..

[1]

(iii) There are three pK_a values associated with *L*-ornithine: 1.8, 8.2, 10.3.

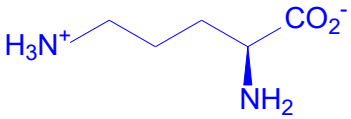


Make use of these pK_a values to suggest the major species present in solutions of L-ornithine with the following pH values.



α–COO$^-$ pH > pK_a 1.8
α–NH$_3^+$ pH < pK_a 8.2
R group –NH$_3^+$ pH < pK_a 10.3

pH 3



α–COO$^-$ pH > pK_a 1.8
α–NH$_2$ pH > pK_a 8.2
R group –NH$_3^+$ pH < pK_a 10.3

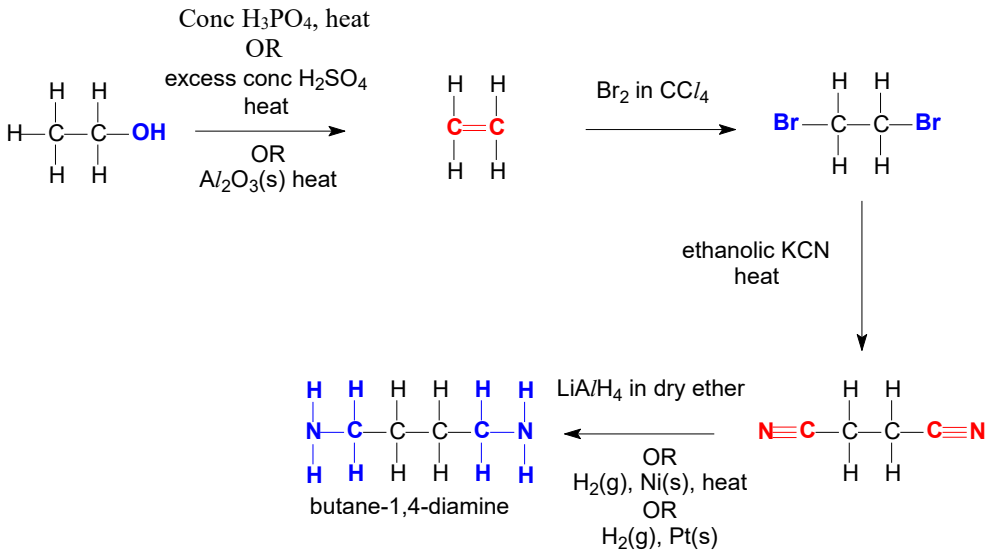
Note: α–NH$_3^+$ is more acidic than R group –NH$_3^+$

pH 9

[2]

(iv) In no more than 4 steps, suggest a reaction scheme to synthesise butane-1,4-diamine from ethanol.

State the reagents and conditions required and draw the structures of the intermediates formed for each step.



1m for each step (correct reagent and intermediate formed)

[4]

[Total : 14]

5 Fig. 5.1 shows the solubility of silver(I) chloride, AgC*l* in varying concentrations of C*l*$^-$ ions.

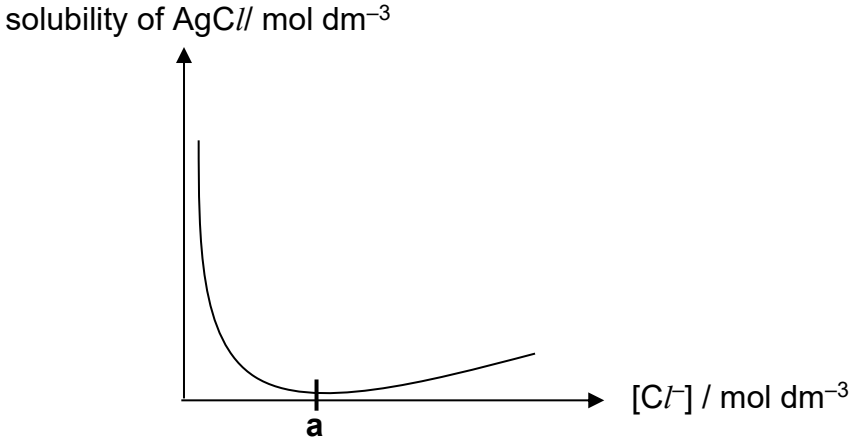


Fig. 5.1

The difference in solubility of AgC*l*, can be explained by the following two equilibria.

equation 5.1 $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ $K_1 = 1.8 \times 10^{-10}$ mol^2 dm^{-6}

equation 5.2 $Ag^+(aq) + 2Cl^-(aq) \rightleftharpoons [AgCl_2]^-(aq)$ $K_2 = 1.8 \times 10^5$ mol^{-2} dm^6

(a) Use the information provided to explain the shape of the graph in Fig. 5.1.

(i) Before point **a**

Before point a (At low concentrations of C*l*$^-$), as **concentration C*l*$^-$, increases**, **equilibrium position of equation 1 will shift left** to partially offset the increased in the concentration of C*l*$^-$, and **solubility decreases.**

[1]

[1]

(ii) After point **a**

After point a (At higher concentration of C*l*$^-$), **Ag$^+$ reacts with C*l*$^-$ to form [AgC*l*$_2$]$^-$(aq) complex ions (equation 2)**, causing **[Ag$^+$(aq)] in solution to drop**. **[1]** In order to partially offset the decrease in [Ag$^+$(aq)], **position of equilibrium for reaction 1 shifts right** to produce more Ag$^+$(aq). Hence, **increasing the solubility of AgC*l* (s)**. **[1]**

[2]

(b) **(i)** Write an expression for the equilibrium constant, K_2.

$$K_2 = \frac{[AgCl_2^-]}{[Ag^+][Cl^-]^2}$$

[1]

(ii) Hence, use equations 1 and 2 to show that the concentration of [AgC*l*$_2$]$^-$ is expressed as [AgC*l*$_2$]$^-$ = 3.24 × 10^{-5} × [C*l*$^-$].

[AgC*l*$_2^-$] = K_2 [Ag$^+$] [C*l*$^-$]^2
= K_2 K_1 [C*l*$^-$]
= (1.8 × 10^5) (1.8 × 10^{-10}) [C*l*$^-$]
= 3.24 × 10^{-5} × [C*l*$^-$] (shown)

[1]

(c) The solubility of AgC*l* is expressed as the sum of the concentrations of Ag^+ and $[AgCl_2]^-$.

Solubility of AgC*l* is lowest when $[Ag^+] = [AgCl_2]^-$.

(i) Use your answer in **(b)(i)** to calculate the concentration of Cl^- when $[Ag^+] = [AgCl_2]^-$.

$$K_2 = \frac{[AgCl_2^-]}{[Ag^+][Cl^-]^2}$$

When $[Ag^+] = [AgCl_2]^-$, $K_2 = \frac{1}{[Cl^-]^2}$

$$[Cl^-] = \sqrt{\frac{1}{K_2}}$$

$$[Cl^-] = \sqrt{\frac{1}{1.8\times10^5}}$$

$[Cl^-] = 0.00236$ mol dm^{-3} **[1]**

[1]

(ii) Hence, calculate the lowest solubility of AgC*l*.

$[Ag^+][Cl^-] = 1.8 \times 10^{-10}$

$[Ag^+] = 1.8 \times 10^{-10} \div 0.00236$

$[Ag^+] = 7.63 \times 10^{-8}$

$[Ag^+] = [AgCl_2]^- = 7.63 \times 10^{-8}$ **[1]**

Lowest solubility of AgC*l* = sum of the concentrations of Ag^+ and $[AgCl_2]^-$

$= 7.63 \times 10^{-8} + 7.63 \times 10^{-8}$

$= 1.53 \times 10^{-7}$ mol dm^{-3} **[1]**

[2]

[Total: 8]

NATIONAL JUNIOR COLLEGE
SH2 TIMED PRACTICE
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **9729/B1**
Paper B1 Multiple Choice **3 July 2025**
30 min

Additional Materials: Optical Answer Sheet
Data Booklet

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 **fifteen** 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.
A Data Booklet is provided.

Instructions on how to fill in the Optical Mark Sheet
Shade the index number in a 5 digit format on the optical mark sheet:
2nd digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2405648	**45648**

This document consists of **7** printed pages.

2025 SH2 H2 Chem Timed Practice Paper B1 Answer Key

1	A
2	C
3	A
4	C
5	C

6	B
7	A
8	D
9	B
10	A

11	D
12	C
13	D
14	A
15	C

1 Which statement about one mole of a metal is always correct?

A It contains the same number of atoms as 0.5 mol of hydrogen gas.

B It contains the same number of atoms as $\frac{1}{12}$ mol of ^{12}C.

C It has the same mass as 1 mol of hydrogen atoms.

D It produces one mole of hydrogen gas when reacted with excess acid.

Ans: (A)

One mole of a metal = 6.02×10^{23} metal atoms

Option A is correct: 0.5 mol of H_2 gas = 1 mol of H atom = 6.02×10^{23} H atoms

Option B is incorrect: $\frac{1}{12}$ mol of ^{12}C = $\frac{1}{12} \times 6.02 \times 10^{23}$ of ^{12}C atoms

Option C is incorrect: Mass of 1 mol of H atom = 1 g
Mass of 1 mol of metal = $(1 \times A_r)$ g of metal

Option D is incorrect: Not all metals can be oxidised by an acid (H^+) e.g. copper

$Cu^{2+} + 2e \rightarrow Cu$ $E^\ominus = +0.34$ V
$2H^+ + 2e \rightarrow H_2$ $E^\ominus = 0.00$ V

$E^\ominus_{cell} = E^\ominus[R] - E^\ominus[O]$
$= E^\ominus(H^+/H_2) - E^\ominus(Cu^{2+}/Cu)$
$= 0.00 - (+0.34)$
$= -0.34$ V

Hence, reaction between H^+ and Cu is not feasible, no hydrogen gas is produced.

2 10 cm^3 of a gaseous hydrocarbon was reacted with an excess of oxygen. A contraction of 30 cm^3 occurred. On treating the cooled resulting mixture with excess barium hydroxide, a further contraction of 40 cm^3 occurred. All volumes were measured at room temperature and pressure.

What is the formula of the hydrocarbon?

A C_2H_4 **B** C_2H_6 **C** C_4H_8 **D** C_4H_{10}

Ans: (C)

$Ba(OH)_2$ reacts with acidic gas CO_2.
Vol of CO_2 = 40 cm^3 (from 2nd contraction)

Initial vol – Final vol = 30 cm^3 (1st contraction)
(Vol of hydrocarbon + Total Vol of O_2) – (Vol of unreacted O_2 + Vol of CO_2) = 30 cm^3
(10 + Total vol of O_2) – (Vol of unreacted O_2 + 40) = 30 cm^3
Total vol of O_2 − Vol of unreacted O_2 = 60 cm^3
Vol of O_2 reacted = 60 cm^3

	$C_xH_y(g)$	+ $(x + \frac{y}{4})O_2(g)$	$\longrightarrow$ $x\,CO_2(g)$	+ $\frac{y}{2}H_2O(l)$
Reacting vol / cm^3	10	60	40	
Mole ratio	$\frac{10}{10} = 1$	$\frac{60}{10} = 6$	$\frac{40}{10} = 4$	

Hence x = 4

$(x + \frac{y}{4}) = 6$
$(4 + \frac{y}{4}) = 6$
$\therefore$ y = 8

The molecular formula of the hydrocarbon is C_4H_8.

3 In an experiment, 40 cm^3 of 0.020 mol dm^{-3} acidified iron(II) sulfate was used to react with 20 cm^3 of 0.010 mol dm^{-3} of XO_3^-.

What is the final oxidation state of X?

A +1 **B** +2 **C** −1 **D** −2

Ans: (A)

Amt of $Fe^{2+} = \frac{40}{1000} \times 0.020 = 8.0 \times 10^{-4}$ mol

Amt of $XO_3^- = \frac{20}{1000} \times 0.010 = 2.0 \times 10^{-4}$ mol

[O] $Fe^{2+} \rightarrow Fe^{3+} + e$
8×10^{-4} mol of Fe^{2+} releases 8×10^{-4} mol of e^-

[R] $XO_3^- + ne^-$
2×10^{-4} mol of XO_3^- gains 8×10^{-4} mol of e^-
Mol ratio XO_3^- : e^- = 1 : 4
1 mol of XO_3^- gains 4 mol of e^- during reduction.
Oxidation state of X decreases by 4 units from +5 (in XO_3^-) to +1 (in the product)

4 The information on two particles, $\mathbf{Q}^+$ and $\mathbf{R}^+$, are given in the table below.

particles	number of electrons	number of neutrons	angle of deflection in an electric field
$\mathbf{Q}^+$	20	25	2.0°
$\mathbf{R}^+$		20	2.3°

Which of the following pairs of particles are isoelectronic?

A **Q** and **R**

B **Q** and $\mathbf{R}^+$

C $\mathbf{Q}^+$ and **R**

D $\mathbf{Q}^+$ and $\mathbf{R}^+$

Ans: (C)

Angle of deflection = k $\times \frac{charge}{mass}$
In particle $\mathbf{Q}^+$,
No. of protons = 21, mass number = 25 + 21 = 46
For $^{46}\mathbf{Q}^+$, +2 = k $\times \frac{+1}{46}$
k = 92

For $^{m}\mathbf{R}^+$, +2.3 = 92 $\times \frac{+1}{\text{mass}}$
m = 40

In particle $\mathbf{R}^+$, since mass number = 40, hence no of protons = 40 – 20 = 20,
For element, no. of protons = no. of electrons, hence no. of electrons in **R** = 20

$\mathbf{Q}^+$ and **R** are isoelectronic.

5 The successive ionisation energies (in kJ mol^{-1}) of an element are shown below:

1762, 2540, 4320, 5590, 9100, 10800

Which group does this element belong to?

A 2 **B** 13 **C** 14 **D** 15

Ans: (C)

Greatest jump in I.E. is from 4th to 5th I.E., hence 5th electron is removed from an inner principal quantum shell, there are 4 valence electrons, hence element belongs to Group 14.

6 For which pairs does the first species have a smaller bond angle?

1 NCl_3, CO_2

2 BF_4^-, SCl_2

3 PCl_6^-, ClO_2^-

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

Ans: (B)

Option 1: There is 3 bond pairs + 1 lone pair in NCl_3 => trigonal pyramidal, 107°
There are 2 bond pairs + 0 lone pair in CO_2 => linear, 180°

Option 2: There are 4 bond pairs + 0 lone pair in BF_4^- => tetrahedral, 109.5°
There are 2 bond pairs + 2 lone pairs in SCl_2 => bent, 105°

Option 3: There are 6 bond pairs + 0 lone pair in PCl_6^- => octahedral, 90°
There are 2 bond pairs + 2 lone pairs in ClO_2^- => bent, 105°

7 Which statements about the properties associated with ionic and covalent bonds are **incorrect**?

1 A covalent compound cannot be an electrolyte.

2 Any covalent compound that contains both oxygen and hydrogen forms hydrogen bonds.

3 Ionic bonds and covalent bonds can both occur in the same compound.

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

Ans: (A)

Option 1 is an incorrect statement: There are covalent compounds that can be electrolytes, e.g. HCl in aq state dissociates to give mobile ions.

Option 2 is an incorrect statement: Hydrogen bonds can only be formed between lone pair electrons on F, O and N and the protonic H (i.e. H bonded directly to F, O and N).
E.g. Aldehyde, HCHO, does not have protonic H and cannot form hydrogen bond with another aldehyde.

Option 3 is a correct statement: Compounds such as NH_4Cl contains ionic bonds between NH_4^+ and Cl^-, and covalent bonds between N–H within NH_4^+.

8 In which of the following pairs of compounds would the first compound have a higher melting point than the second compound?

	first compound	second compound
1	$SiCl_4$	SiO_2
2	$NaCl$	KCl
3	AlF_3	$AlBr_3$

A 1, 2 and 3 **B** 2 only

C 3 only **D** 2 and 3 only

Ans: (D)

Option 1 is incorrect: SiO_2 has a much higher melting point than $SiCl_4$. SiO_2 is a giant covalent molecule with strong electrostatic forces of attraction between its nuclei and shared pair of electrons while $SiCl_4$ is a simple molecule with weak intermolecular forces of attraction. Hence, more energy is required to overcome the stronger electrostatic forces of attraction in SiO_2 as compared to the weaker intermolecular forces of attraction in $SiCl_4$.

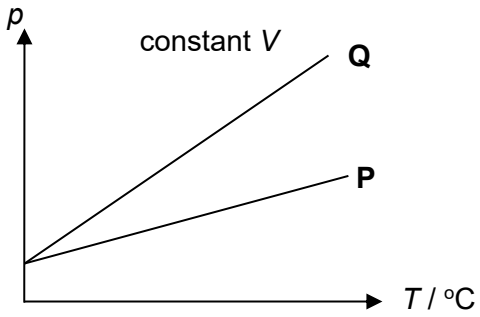
Option 2 is correct: $NaCl$ has a higher melting point than KCl since the ionic radius of Na^+ is smaller than K^+ and therefore, the magnitude of the lattice energy of $NaCl$ is larger than that of KCl.

Since magnitude of Lattice Energy $\propto \left|\frac{q_+ q_-}{r_+ + r_-}\right|$

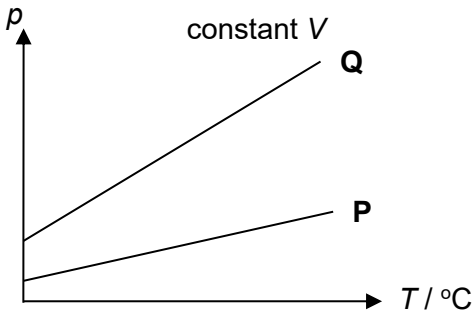
Option 3 is correct: AlF_3 has a much higher melting point than $AlBr_3$ as AlF_3 has a giant ionic lattice structure with strong electrostatic forces of attraction between oppositely charged ions while $AlBr_3$ is a simple molecule (recall: $AlCl_3$ is a simple covalent molecule, Br atom being bigger in size than Cl, its electron cloud will be even more polarisable than that of Cl hence $AlBr_3$ is also a simple molecule) with weak intermolecular forces of attraction. Hence, more energy is required to overcome the stronger electrostatic forces of attraction in AlF_3 as compared to the weaker intermolecular forces of attraction in $AlBr_3$.

9 Which graph correctly describes the behaviour of two ideal gases **P** and **Q**, both having the same mass, where **P** has a larger M_r than **Q**?

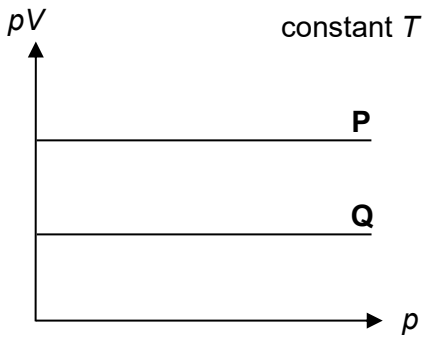
A



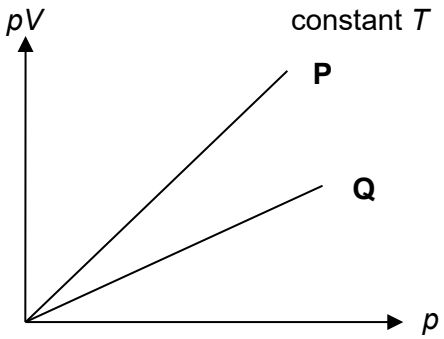
B



C



D

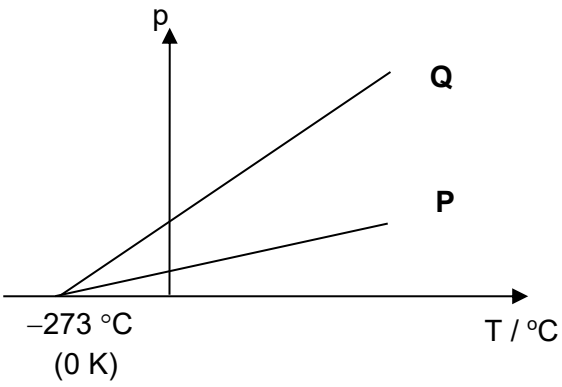


Ans: (B)

$pV = nRT \Rightarrow pV = \frac{mRT}{M} \Rightarrow p = (\frac{mR}{VM})T$

For graph of p against T, gradient = $\frac{mR}{VM}$

Since **P** has a larger M_r than **Q**, the graph for **P** has a less steep gradient.



For a fixed mass of gas at constant T, $pV = \frac{mRT}{M}$ = constant

Hence, the graph of pV against p is a horizontal straight line (option D is incorrect).
Since **P** has a larger M_r than **Q**, the pV value for **P** is smaller than that for **Q** (option C is incorrect).

10 During the operation of a refrigerator, the coolant is constantly being liquefied under pressure, and vaporised once the pressure is released. Under these conditions, the gas does not behave as an ideal gas.

Which statement best describes why the gas liquefies under pressure?

A Increasing the pressure pushes the molecules closer together, and so the short-range intermolecular forces of attraction are more effective.

B Increasing the pressure decreases the kinetic energy of the molecules, creating the ordered liquid state.

C Increasing the pressure decreases the size of the molecules, and so increases the intermolecular attraction.

D Increasing the pressure causes the temperature of the gas to decrease to below its boiling point.

Ans: (A)

Option A is correct: Increasing the pressure causes the gas molecules to be closer to one another and the intermolecular forces of attraction becomes significant enough to result in a change in state.

Option B is incorrect: Kinetic energy of the molecules is affected by change in temperature rather than pressure.

Option C is incorrect: Size of individual molecules does not change with the change in pressure.

Option D is incorrect: If gas assumes ideal gas behaviour (pV = nRT), pressure and temperature are directly proportional. That is, increasing pressure of gas causes temperature of gas to increase.

11 When bromine vapourises at 58.8 °C, 30.9 kJ mol^{-1} of heat was required.

What is the entropy change of vaporisation?

A − 525.5 J mol^{-1} K^{-1}

B + 525.5 J mol^{-1} K^{-1}

C − 93.1 J mol^{-1} K^{-1}

D + 93.1 J mol^{-1} K^{-1}

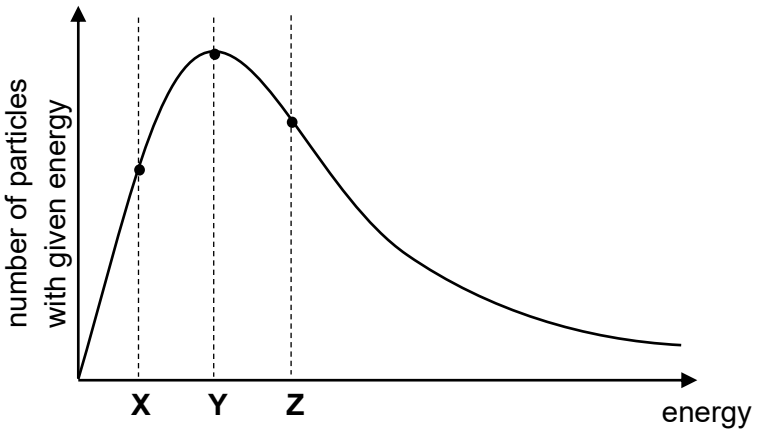
Ans: (D)

When bromine vapourises at 58.8°C, it is the boiling point.
ΔG = 0 since $Br_2(l)$ and $Br_2(g)$ are in equilibrium at the boiling point.
$Br_2(l) \rightleftharpoons Br_2(g)$ ΔH = +30.9 kJ mol^{-1}
$\Delta G = \Delta H - T\Delta S$
$\Delta H = T\Delta S$

$$\Delta S = \frac{\Delta H}{T} = \frac{30.9 \times 10^3}{(58.8 + 273)}$$

= + 93.1 J mol^{-1} K^{-1}

12 The Maxwell–Boltzmann distribution for a gas at constant temperature is shown below.

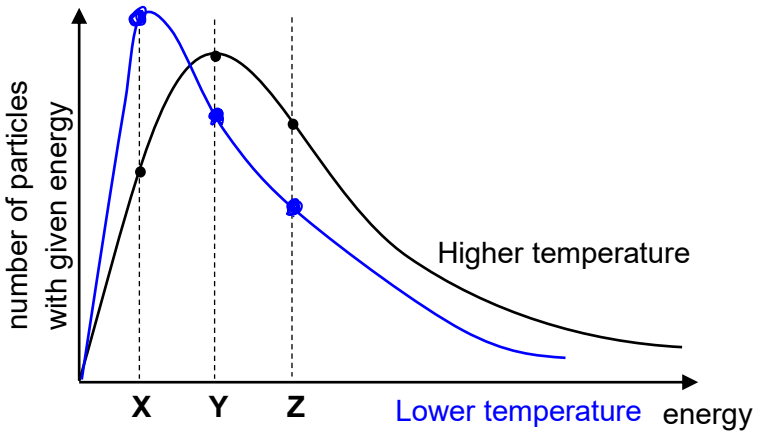


How would the number of particles change at the kinetic energies **X**, **Y** and **Z** when temperature is lowered by 5 °C?

	X	Y	Z
A	lower	lower	higher
B	lower	higher	higher
C	higher	lower	lower
D	higher	higher	lower

Ans: (C)

When temperature is lowered, the graph shifts towards the left, with a higher peak. There will be more particles with lower energy, lesser particles with higher energy.



13 The table below shows the results of three experiments conducted for the reaction

$$P + Q \rightarrow \text{products}$$

[P] / mol dm^{-3}	[Q] / mol dm^{-3}	rate / mol dm^{-3} s^{-1}
0.012	0.005	1.0×10^{-4}
0.024	0.010	2.0×10^{-4}
0.048	0.010	4.0×10^{-4}

If the rate constant doubles for each 10 °C rise in temperature, which pairs of experimental conditions will result in the same rate?

	[P] / mol dm^{-3}	[Q] / mol dm^{-3}	temperature / °C
condition 1	0.10	0.20	40
condition 2	0.20	0.20	30
condition 3	0.30	0.30	20

1 conditions 1 and 2

2 conditions 1 and 3

3 conditions 2 and 3

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

Ans: (D)

From data given, when [**P**] doubled while [**Q**] remained constant, rate doubled;
Hence, 1st order w.r.t. **P**

From data given, when [**P**] doubled while [**Q**] doubled, rate doubled;
Hence, zero order w.r.t. **Q**

Hence rate equation: rate = k[**P**]

Let rate equation for condition 3 be rate = k[0.30] = 0.30 k
At condition 2, a 10°C increase in temp, rate constant is now 2k, rate = 2k[0.20] = 0.40 k
At condition 1, a 20°C increase in temp, rate constant is now 2k, rate = 4k[0.10] = 0.40 k

Hence, condition 1 & 2 (statement 1) will result in the same rate.

14 Element **G** is found in Period 3 of the Periodic Table.

The oxide and chloride of element **G** are separately mixed with water. The two resulting solutions have the same effect on purple litmus solution.

What is the identity of element **G**?

A phosphorus **B** magnesium

C silicon **D** sodium

Ans: (A)

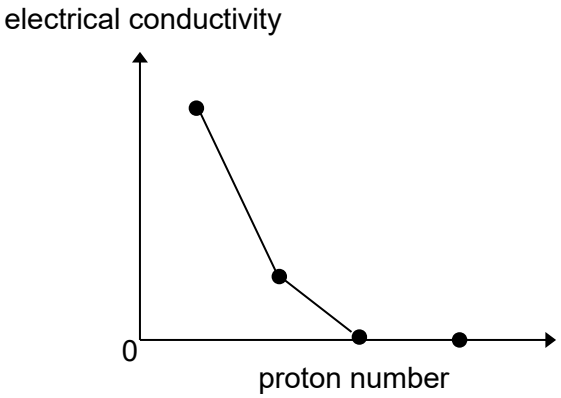
P_4O_{10} reacts with water to give an acidic solution of H_3PO_4 (pH = 2 – 3, litmus turns red) and PCl_5 reacts with water to give an acidic solution of H_3PO_4 and HCl (pH = 1, litmus turns red).

MgO is slightly soluble to give a weakly alkaline solution (pH 8 – 9, litmus turns blue), while $MgCl_2$ undergoes slight hydrolysis to give a weakly acidic solution (pH 6.5, litmus turns red).

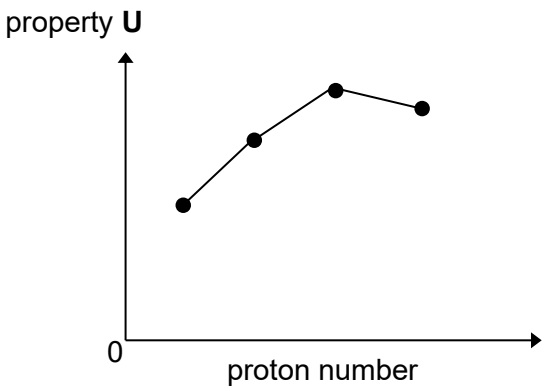
SiO_2 is insoluble in water (pH = 7, litmus remains purple) while $SiCl_4$ reacts with water to give SiO_2(s) and HCl (pH = 1, litmus turns red).

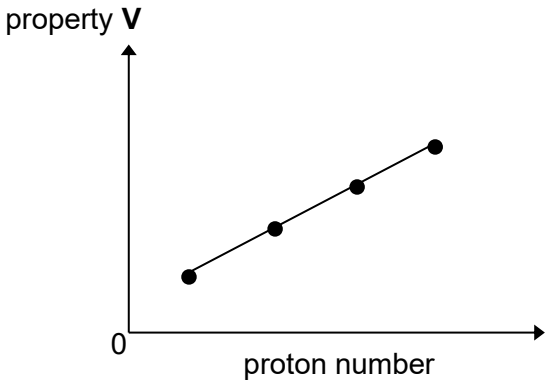
Na_2O reacts with water to give NaOH (pH 14, litmus turns blue) while NaCl is neutral (pH 7, litmus remains purple).

15 The diagram represents the electrical conductivity of four consecutive elements in Period 3 of the Periodic Table.



The sketches below represent another two properties of the four consecutive elements.





What are properties **U** and **V**?

	property **U**	property **V**
A	ionic radius	nuclear charge
B	boiling point	melting point
C	first ionisation energy	electronegativity
D	number of valence electrons	atomic radius

Ans: (C)

The four consecutive elements are aluminium (conductor), silicon (semi–conductor), phosphorus (non–conductor) and sulfur (non–conductor) respectively.

U can **only** represent the first ionisation energy as the first ionisation energy increases from Al to P due to increase in effective nuclear charge. The first ionisation energy decreases from P to S due to inter–electronic repulsion between the paired 3p electrons in sulfur.

V represents either electronegativity or nuclear charge as these two properties both increase across the Period as the proton number increases.

SH2 H2 Chemistry Timed Practice Paper B2 Suggested Answer

1 **(a)** The elements in Group 13 of the Periodic Table form compounds which display a range of chemical and physical properties.

The table below shows the properties of $AlCl_3$ and Al_2O_3.

compound	melting point/ °C	pH of aqueous solution
$AlCl_3$	192 (sublimes)	3
Al_2O_3	2072	–

(i) Explain the difference in melting points between $AlCl_3$ and Al_2O_3.

$AlCl_3$ has a **simple molecular structure with instantaneous dipole induced dipole (id−id) interactions [1/2]** between the molecules whereas Al_2O_3 has a **giant ionic lattice structure with ionic bonds [1/2]** between the oppositely charged ions. **Ionic bonds** between ions in Al_2O_3 is **stronger [1/2]** than id−id interactions between $AlCl_3$ molecules. **More energy is required [1/2]** to overcome the stronger ionic bonds and therefore, Al_2O_3 has a higher melting point.

[2]

(ii) $AlCl_3$ dissolves in water to form a solution with pH 3. Write balanced equations and account for the pH of $AlCl_3$ solution.

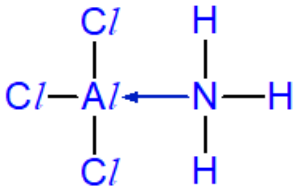
$AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$ **[1/2]**
$[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+$ **[1/2]**

Al^{3+} ion has **high (charge/size) ratio [1/2]** and hence, high polarising power. The Al^{3+} ion **polarises and weakens the O−H bonds in H_2O molecules to] a large extent**. **[1/2]** The H^+ ions released during this hydrolysis process gives an acidic solution of pH less than 7.

[2]

1 **(b)** **(i)** $AlCl_3$ can react with NH_3 to form an addition product $AlCl_3NH_3$.

Draw the structure of the addition product formed.



[1]

(b) **(ii)** Explain why aluminium can form four bonds even though it has only three valence electrons. Describe the type of bond formed during this reaction.

Aluminium has an **vacant** 3p **orbital in its valence shell (or empty low-lying** 3p **orbital) [1/2]** to **accept a lone pair of electron [1/2]** from the nitrogen atom of NH_3 to form a **dative bond [1]**.

[2]

(c) Explain why the first ionisation energy of the elements decreases down Group 13.

Down the Group 13, there is an **increase in the number of filled principal quantum shells (electronic shells) [1/2]**. The **most loosely held electron is further away from the nucleus [1/2]** and experiences **greater shielding effect [1/2]** due to increase in number of inner shell electrons. These factors **outweigh the increasing nuclear charge [1/2]** due to increase in number of protons down the group. The nuclear attraction for the most loosely held electrons is weaker for atoms down the group, and less energy is required to remove it, resulting in lower 1st I.E. down the Group 13.

[2]

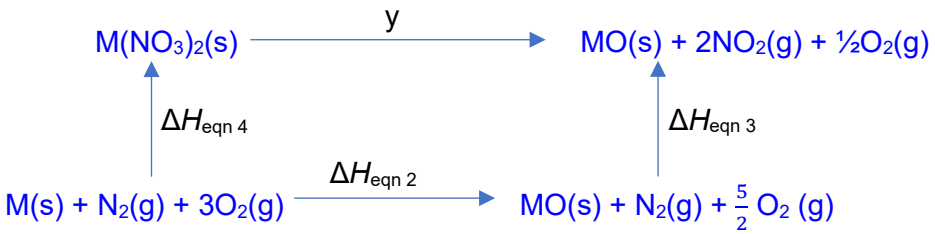
[Total: 9]

2 A metal nitrate, $M(NO_3)_2$, decomposes upon heating to form the metal oxide, MO, nitrogen dioxide gas (NO_2), and oxygen gas (O_2). The enthalpy change of decomposition, ΔH_{decomp}, can be determined using Hess' Law.

(a) (i) The following thermochemical equations are given

equation	reaction	ΔH / kJ mol^{-1}
1	$M(NO_3)_2(s) \rightarrow MO(s) + 2NO_2(g) + \frac{1}{2}O_2(g)$	$\Delta H_1 = y$
2	$M(s) + \frac{1}{2} O_2(g) \rightarrow MO(s)$	$\Delta H_2 = -400$
3	$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$	$\Delta H_3 = +66$
4	$M(s) + N_2(g) + 3O_2(g) \rightarrow M(NO_3)_2(s)$	$\Delta H_4 = -450$

Construct an energy cycle to determine the value of y, the enthalpy change of decomposition, ΔH_{decomp}, for $M(NO_3)_2$.



[1] for correct Energy cycle. Penalise ½ mark if state symbol not written or written wrongly.

By Hess Law,
$\Delta H_4 + y = \Delta H_2 + \Delta H_3$

$y = \Delta H_{eqn\ 2} + \Delta H_{eqn\ 3} - \Delta H_{eqn\ 4}$ [1]
$= -400 + 66 - (-450)$
$= +116$ kJ mol^{-1} [1] for correct calculation

[3]

(ii) Explain how entropy changes during the decomposition of $M(NO_3)_2$.

There is an **increase in number of gaseous particles** / **increase in number of moles of gas** [1/2], hence more ways to **arrange the particles and distribute their energy** [1/2].

Hence **entropy increases** OR **$\Delta S > 0$** [1]

[2]

2 (a) (iii) Hence, explain the effects of increasing temperature on the spontaneity of the decomposition of $M(NO_3)_2$.

At high temperatures **large positive ΔS makes ΔG more negative**, increasing spontaneity. [1]

OR

At high temperature, **Magnitude of TΔS > Magnitude of ΔH**, making ΔG negative, increasing spontaneity. [1]

Award marks for error from part **(ii)** when candidates wrote entropy is negative and 'decreasing spontaneity'.

[1]

(iv) Given that the minimum temperature for the decomposition of $M(NO_3)_2$ is 872 K, where $\Delta G = 0$. With reference to your answer in **(a)(i)**, calculate ΔS for the decomposition of $M(NO_3)_2$, stating its unit.

$\Delta G = \Delta H - T\Delta S$

For reaction to be feasible $\Delta G = 0$

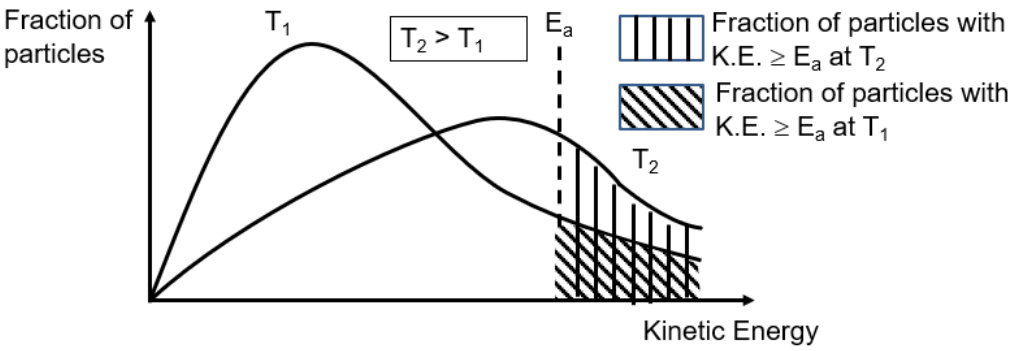
Hence,
$\Delta H - T\Delta S = 0$
$+116 - 872(\Delta S) = 0$
$\Delta S = +0.133$ kJ mol^{-1} K^{-1} or +133 J mol^{-1} K^{-1}

[1] for correct value of ΔS and [1] for correct unit.

ECF for using incorrect part **(i)** answer.

[2]

(b) Explain with the aid of the Boltzmann distribution curve, how an increase in temperature affects the rate of decomposition of $M(NO_3)_2$.



[2] for Boltzmann distribution curve. Minus [1/2] for every error.

When temperature of the reaction increases, **average kinetic energy** of the reacting particles **increases**. [1/2]
The **fraction of particles with K.E. ≥ E_a increases** [1/2] as shown in the Boltzmann distribution.
The **frequency of effective collisions increases** [1] hence rate of reaction increases.

[4]

2 **(c)** Nitrogen monoxide, NO, reacts with oxygen to form nitrogen dioxide, NO_2.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The rate equation for the reaction is rate = $k[NO]^2[O_2]$.

Two separate experiments are carried out at 30 °C to determine the rate of the reaction.

experiment	[NO] / mol dm^{-3}	[O_2] / mol dm^{-3}	rate / mol dm^{-3} s^{-1}
1	0.00300	0.00200	1.51×10^{-4}
2		0.00500	6.05×10^{-5}

(i) Use the data for experiment 1 to calculate the value of the rate constant, k. State the units of k.

From experiment 1,
rate = $k[NO]^2[O_2]$
$1.51 \times 10^{-4} = k(0.00300)^2(0.00200)$
$k = 8388.9$
$= 8390$ (3 s.f.) mol^{-2} dm^6 s^{-1}

[2]

(ii) Calculate the value of [NO] in experiment 2.

rate = $k[NO]^2[O_2]$
$6.05 \times 10^{-5} = 8388.9[NO]^2(0.00500)$
$[NO]^2 = 1.442 \times 10^{-6}$
$[NO] = 1.20 \times 10^{-3}$ mol dm^{-3}

[1]

2 (c) (iii) In another experiment, a large excess of NO is mixed with 0.00975 mol dm^{-3} O_2. Under the conditions used, the half-life of $[O_2]$ is 48 s.

Calculate $[O_2]$ at t = 192 s.

Since NO is present in large excess, [NO] remains relatively constant throughout the reaction,
rate = k'$[O_2]$ where k' = $k[NO]^2$

Number of $t_{1/2}$ passed = $\frac{192}{48}$ = 4

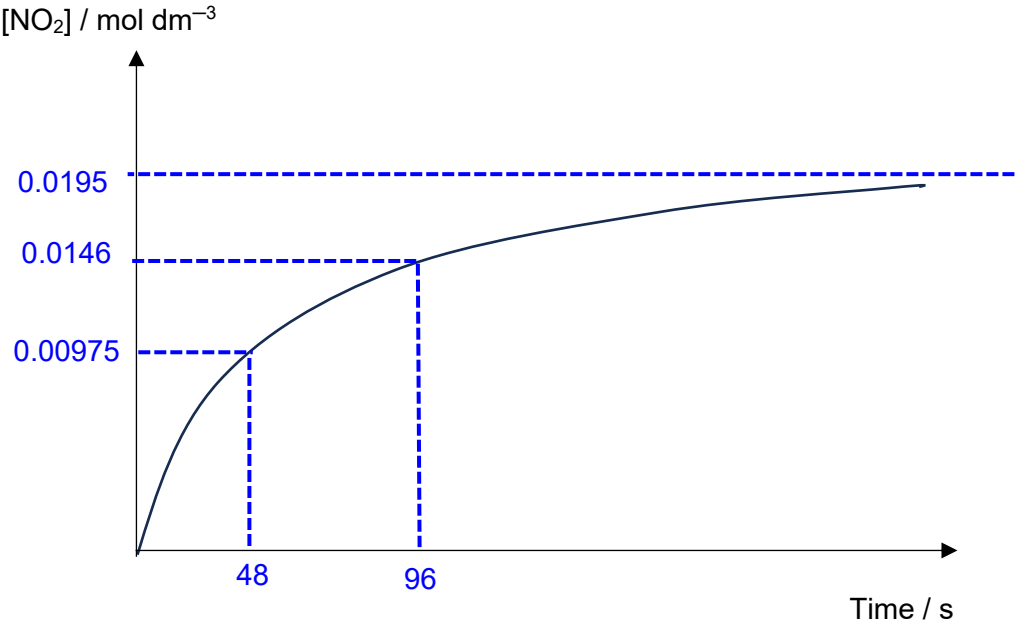
0.00975 → 0.004875 → 0.002438 → 0.001219 → 0.0006094

Hence $[O_2]$ = 0.000609 mol dm^{-3} (3 s.f.)

[2]

(iv) The graph below shows how $[NO_2]$ changes with time.

Using the information given in **(iii)** and the given equation for the reaction in **(a)**, complete the graph by labelling the appropriate concentration values and time values to show that the reaction is first order with respect to O_2.



[2]

(v) Another similar experiment is carried out at a higher temperature. State how the half-life of the reaction will be affected.
It will be shorter.
[Note: since k increases at higher temperature, $t_{1/2} = \frac{ln2}{k}$, half-life will be smaller.]

[1]

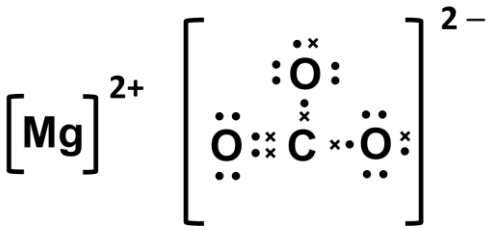
[Total: 20]

3 **(a)** An experiment was conducted to investigate the thermal decomposition of Group 2 carbonates.

$MgCO_3$ decomposes at 350 °C whereas $SrCO_3$ decomposes at 1200 °C.

A 20.0 g sample containing a mixture of magnesium carbonate and strontium carbonate was heated at 500 °C. The remaining white solid weighed 11.3 g.

(i) Draw the dot-and-cross diagram for magnesium carbonate.



[1]

(ii) Using relevant data from the *Data Booklet*, explain the difference in decomposition temperature of magnesium carbonate and strontium carbonate.

The ionic radius of Mg^{2+} and Sr^{2+} is 0.065 nm and 0.113 nm respectively.
The charges of the cations are the same, hence the $\frac{\text{charge}}{\text{size}}$ ratio of Mg^{2+} is larger than Sr^{2}.
Hence, Mg^{2+} has greater polarising power and can distort the electron cloud of CO_3^{2-} / polarise the C-O bond to a greater extent, thereby weakening the C–O bond to a greater extent.
Hence, $MgCO_3$ has lower thermal stability / greater ease of thermal decomposition and thermal decomposition temperature is lower.

[3]

(iii) Write an equation for the reaction that occurred when the sample is heated at 500 °C.

$MgCO_3\,(s) \rightarrow MgO\,(s) + CO_2\,(g)$
Do not accept $SrCO_3$ as $SrCO_3$ will not decompose at 500 °C.

[1]

3 (a) (iv) Calculate the percentage composition by mass of magnesium carbonate in the 20.0 g sample.

$MgCO_3$ (s) → MgO (s) + CO_2 (g)

Let mass of $SrCO_3$= x g
mass of $MgCO_3$= (20.0 – x) g
mass of MgO= (11.3 – x) g

amount of MgO = amount of $MgCO_3$

$$\frac{11.3-x}{24.3+16.0} = \frac{20.0-x}{24.3+12.0+3(16.0)}$$

$$\frac{11.3-x}{40.3} = \frac{20.0-x}{84.3}$$

84.3 (11.3 – x) = 40.3 (20.0 – x)
x = 3.3316

mass of $MgCO_3$ = (20.0 – 3.3316)
= 16.67 g

% by mass of $MgCO_3$ = $\frac{16.67}{20.0}$ x 100%
= 83.35 %
= 83.4 % (3 s.f.)

Alternative method:
Mass of CO_2 = 20.0 – 11.3 = 8.7 g
Amount of CO_2 = $\frac{8.7}{44.0}$ = 0.1977 mol = Amt of $MgCO_3$

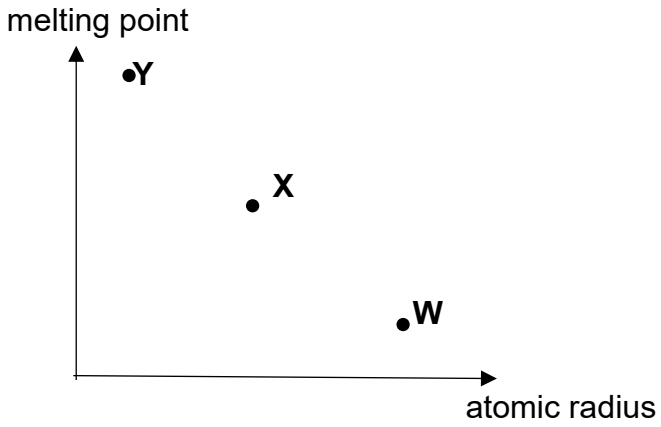
Mass of $MgCO_3$ = 0.1977 x 84.3 = 16.67 g

% by mass of $MgCO_3$ = $\frac{16.67}{20.0}$ x 100%

= 83.35 %
= 83.4 % (3 s.f.)

[2]

(b) **W**, **X** and **Y** represent consecutive elements in Period 3. The following shows a graph of their melting points plotted against the atomic radius (not drawn to scale).



The oxide of **Y** is insoluble in water but dissolves when the oxide of **W** is subsequently added.

(i) Suggest the identities of **Y** and **W**.

Y is aluminum and **W** is Sodium (**X**: Magnesium)

[1]

(ii) Explain the above observations and write equations for all the reactions that have occurred.

- Al_2O_3 is insoluble in water due to its high lattice energy.
  When Na_2O dissolves in water, it forms NaOH(aq).
- $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$
  Since Al_2O_3 is an amphoteric oxide, it can react with NaOH(aq) and hence dissolves.
- $Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$

Note: **Y** is not Si because SiO_2 does not dissolve in weakly alkaline solution.

[3]

3 **(c)** The lattice energies of three ionic compounds are given.

compound	lattice energy / kJ mol^{-1}
LiF(s)	−1022
CaO(s)	−3513
SrO(s)	−3310

(i) Define the term *lattice energy*.

Lattice energy of an ionic compound is the energy released when one mole of a solid ionic compound is formed from its constituent gaseous ions.

[1]

(ii) With the aid of the *Data Booklet*, explain why the lattice energy of CaO is more exothermic than the lattice energy of LiF.

The product of charges is higher in CaO than LiF. [1/2]

Ca^{2+} ionic radius is 0.099 nm; Li^{+} ionic radius is 0.060 nm
O^{2-} ionic radius is 0.140 nm; F^{-} ionic radius is 0.136 nm [1m for values]
Hence, interionic distance in CaO is larger than that in LiF. [1/2]

Since $|L.E| \propto |\frac{q_+ \times q_-}{r_+ + r_-}|$ **[1]**
CaO has a more exothermic lattice energy than LiF.

[3]

(iii) Use the data in the table to estimate approximate values for the lattice energies of magnesium oxide and barium oxide.

Lattice energy of MgO(s) = ... kJ mol^{-1}

Lattice energy of BaO(s) = ... kJ mol^{-1}

Since ionic radius is in the order: $Mg^{2+} < Ca^{2+} < Sr^{2+} < Ba^{2+}$,
Magnitude of lattice energy of MgO is expected to be larger than CaO, while magnitude of lattice energy of BaO is expected to be smaller than SrO.

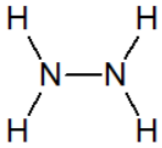
ΔH_{latt}MgO(s) = any value more exothermic than −3513 kJ mol^{-1} (e.g. −3600)

ΔH_{latt}BaO(s) = any value less exothermic than −3310 kJ mol^{-1} (e.g. −3200)

[1]

[Total : 16]

4 Hydrazine, N_2H_4, was used as a propellant for the rocket to fly a probe to explore Mars in 2012.



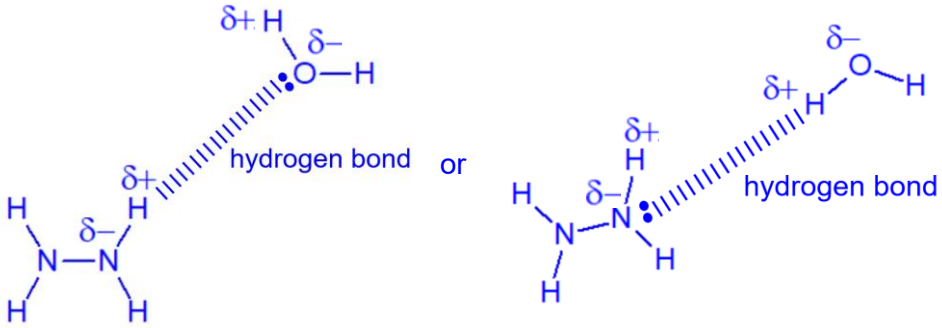
hydrazine

(a) (i) State and explain, with reference to the Valence Shell Electron Pair Repulsion Theory, the shape and bond angle about the N atom in N_2H_4.

For N_2H_4, there are four electron regions, with **3 bond pair of electrons and 1 lone pair of electrons [1/2]**, By VSEPR theory, in order to minimise the inter−electronic repulsion around the central N atom, which has the central N atom will adopt the **trigonal pyramidal shape [1/2]**. Since **lone pair−bond pair repulsion is greater than bond pair−bond pair repulsion [1/2]**, the bond angle is **107° [1/2]** (less than 109.5°).

[2]

(ii) Hydrazine is soluble in water. Use a suitable diagram to illustrate the interactions between a hydrazine molecule and a water molecule.



Marking points:
- lone pair electrons on N or O atom
- δ+ and δ− between H atom and N or O atom
- show hydrogen bond between lone pair and H atom
- label hydrogen bond or H bond

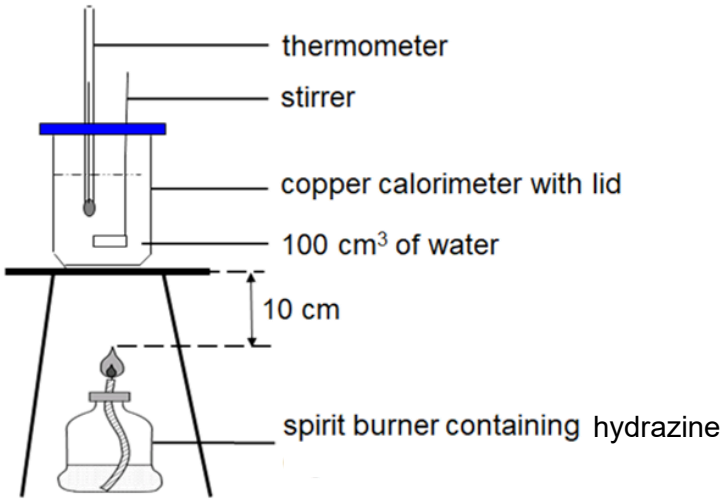
each mistake deduct **[1/2]**

[1]

4 **(b)** Liquid hydrazine undergoes combustion in oxygen to form nitrogen gas and water.

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

An experiment is carried out to determine the enthalpy change of combustion of liquid hydrazine. Some hydrazine was burnt in a spirit burner to heat 100 cm^3 of water in a copper calorimeter as shown in the diagram below. The experimental data collected are shown in the table below.



initial temperature of water/ °C	25.0
highest temperature of water/ °C	78.8
mass of spirit burner containing hydrazine before combustion/ g	85.8
mass of spirit burner containing hydrazine after combustion/ g	84.2

You may assume the following:

1. The heat released from the burning of the wick is negligible,

2. There is negligible loss of hydrazine through evaporation during the experiment.

(i) Using relevant data in **(b)** and from the *Data Booklet*, calculate the enthalpy change of combustion of liquid hydrazine.

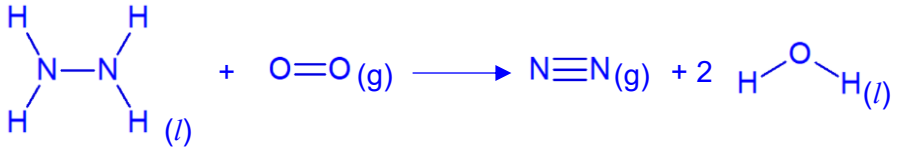
amount of hydrazine used = $\left(\frac{85.8-84.2}{2(14.0)+4(1.0)}\right)$ = 0.0500 mol

$$\Delta H_c \text{ (hydrazine}(l)) = -\frac{mc\Delta T}{n_{hydrazine}} = -\frac{(100)(4.18)(78.8-25.0)}{0.0500}$$

$$= -449768 \text{ J mol}^{-1} \approx -450 \text{ kJ mol}^{-1} \text{ (3.s.f)}$$

[2]

4 **(b)** **(ii)** Using the bond energies in the *Data Booklet*, calculate the enthalpy change of combustion of liquid hydrazine.



bonds broken	∑BE/ kJ mol^{-1}	bonds formed	∑BE/ kJ mol^{-1}
1 × N−N 4 × N−H 1 × O=O	1(+160) 4(+390) 1(+496)	1 × N≡N 4 × O−H	1(+944) 4(+460)

ΔH_c (hydrazine(l)) = ∑n(BE (reactants)) − ∑n(BE (products))
= [1(+160) + 4(+390) +1(+496)] – [1(+944) + 4(+460)]
= −568 kJ mol^{-1}

[2]

(iii) The actual enthalpy change of combustion of hydrazine of liquid hydrazine is −622 kJ mol^{-1}.

Suggest **two** reasons for the deviation of the enthalpy change of combustion of liquid hydrazine calculated in **(b)(ii)** from the actual value.

The **bond energy values in the *Data Booklet* are averages** and hence the actual bond energy of the covalent bonds in this reaction may differ. **[1]**

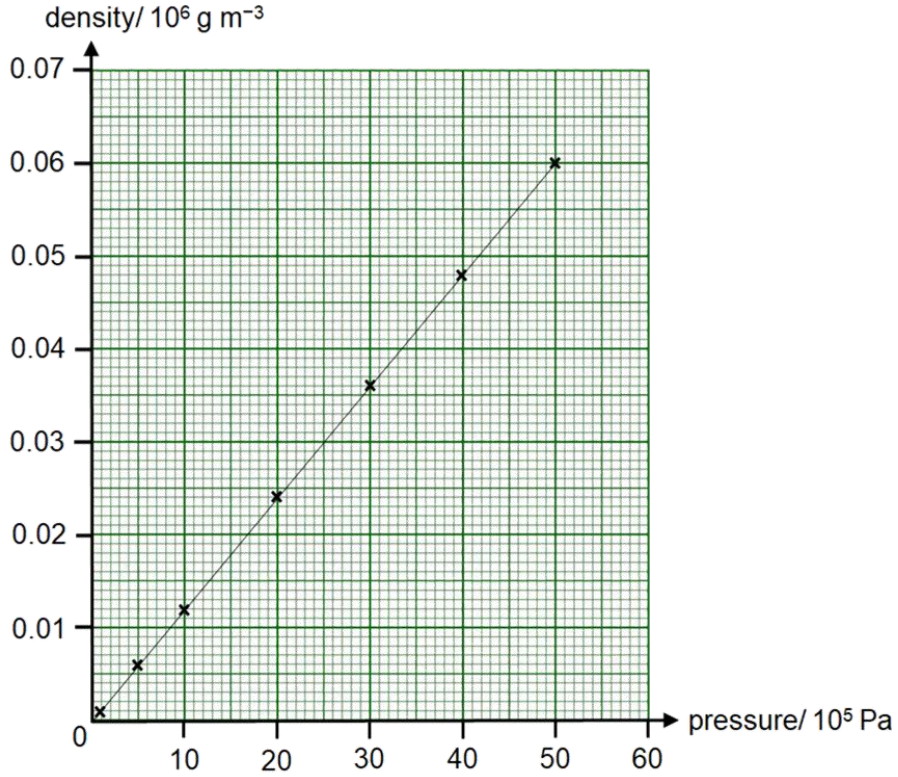
The **bond energy values** from the *Data Booklet* are **for gaseous molecules [1/2]**, but in (b)(ii), both the **hydrazine and water are in liquid state [1/2]**. Hence, enthalpy change of vaporisation of hydrazine and water are needed in **(b)(ii)** calculation to get more accurate results.

[2]

4 **(c)** A gas sample of Mars' atmosphere collected during an exploration was taken back to Earth and studied.

It was found that most of the gas mixture is made up of a single type of gas **X**, whose identity is either nitrogen, oxygen, carbon dioxide or argon gas.

The relationship between density and pressure for the gas sample from Mars is plotted in the graph below. The experiment was conducted at 180 ºC.



(i) Determine the value for the gradient of the graph.

$$\text{gradient} = \frac{(0.06-0.00)\times10^{6}}{(50-0)\times10^{5}} = 0.0120$$

[1]

4 **(c)** **(ii)** Using information in **(c)** and your answer in **(c)(i)**, calculate the average M_r of the gas sample from Mars and determine the identity of gas **X**.

$$PV = nRT$$

$$PV = \frac{mRT}{M_r}$$

$$\frac{m}{V} = \left(\frac{M_r}{RT}\right) \times P$$

$$\rho = \left(\frac{M_r}{RT}\right) \times P$$

Therefore, $\text{gradient of graph} = \frac{M_r}{RT}$.

$$0.0120 = \frac{M_r}{(8.31)(180 + 273)}$$

$$M_r = 45.2$$

[1/2] – correct substitution of values
[1] – correct final answer with no units

A possible identity of the gas **X** is **CO_2 [1/2]** (M_r = 44.0).

[2]

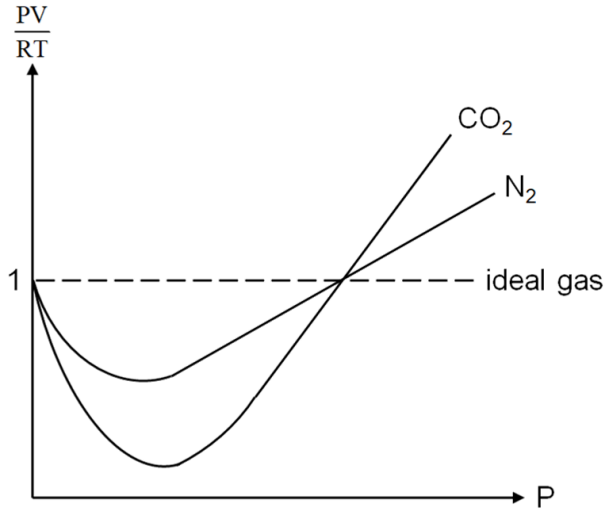
(d) On Mars, the average temperature is about −70 ºC.

Explain why a gas is more likely to show more deviation from the ideal gas behaviour on Mars than on Earth.

On Mars, the **temperature is lower** and the gas particles have a **lower average kinetic energy [1/2]** and are insufficient to overcome the intermolecular forces of attractions. The **intermolecular forces of attraction between them become more significant [1/2]**. Hence, a gas is more likely to show more deviation from the ideal gas equation on Mars.

[1]

4 **(e)** The graph below shows the behaviour of 1 mole each of N_2 and CO_2 gas at 293 K.



Give a reason to account for the difference in the graphs of CO_2 and N_2.

Both CO_2 and N_2 are simple molecular structure with intermolecular instantaneous dipole−induced dipole (id-id) interaction between the molecules. However, due to the **larger electron cloud size in CO_2 [1/2]**, it is more easily induced and the **id−id interaction in CO_2 molecules is stronger [1/2]** and more significant than that between N_2 molecules. Hence, there is a **greater deviation from ideal gas behaviour for CO_2. [1]**

[2]

[Total: 15]