ANDERSON SERANGOON JUNIOR COLLEGE

2025 JC 2 Preliminary Paper

NAME:____________________________ (   ) **CLASS:** 25 / ___

CHEMISTRY **8873/02**

Higher 1 **27 August 2025**

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces provided at the top of this page.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
The number of marks is given in brackets [ ] at the end of each question or part question.

Section A	**1**	**/12**	**Section B**	**7/8**	**/ 20**
	2	**/9**	**Paper 1**		**/ 30**
	3	**/13**	**Paper 2**		**/ 80**
	4	**/12**	**Percentage Overall**		
	5	**/10**			
	6	**/4**	**Grade**		

This document consists of __ printed pages and ___blank pages.

Section A

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

1 **(a)** Two Period 3 elements react with an excess of oxygen at room pressure.

(i) Complete Table 1.1.

Table 1.1

Period 3 element	Physical state of oxide at room temperature and pressure	Approximate pH of solution made when oxide is added to water
Na	solid	13-14
S	gas	1-2

[2]

any two correct [1]

(ii) The solutions made from oxides of sodium and sulfur of Table 1.1 are mixed together.
Name the type of reaction that occurs.

……………………………………………………………………………………[1]

Acid-base or neutralisation [1]

(b) Aluminium oxide, Al_2O_3 is amphoteric.

(i) Explain what is meant by amphoteric.

……………………………………………………………………………………...

……………………………………………………………………………………[1]

Reacts with both acid <u>and</u> bases / shows <u>both</u> acidic and basic behaviour. [1]

(ii) Aluminium oxide is added to separate samples of dilute sulfuric acid and aqueous sodium hydroxide.

Write two equations to describe the reactions that occur.

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……………………………………………………………………………………...

……………………………………………………………………………………[2]

$Al_2O_3(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2O(l)$ [1]

Al_2O_3(s) +2NaOH(aq) + $3H_2O$(*l*) → 2Na[A*l*$(OH)_4$] (aq) [1]

Ignored state symbols although we encouraged we written equations.
Maximum 1 credit for correct ionic equations.

(c) Chorine gas reacts with oxygen to form chlorine dioxide. When used in small quantities, chlorine dioxide can disinfect water.

(i) Complete the electronic configurations of C*l*.

C*l*: $1s^2$ …………………………………… [1]

C*l*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

(ii) State the total number of outer shell electrons in one molecule of ClO_2 and explain why this is an unusual number.

……………………………………………………………………………………...

……………………………………………………………………………………[2]

6+6+7 = 19 electrons. [1]

It has odd number of electrons. [1]

(iii) ClO_2 contains two double bonds in the molecule.

Draw a 'dot-and-cross' diagram for the molecule ClO_2.

[1]

(iv) Deduce whether ClO_2 is a polar molecule. Explain your answer.

……………………………………………………………………………………...

……………………………………………………………………………………...

……………………………………………………………………………………[2]

Polar [1]
It has polar C=O bonds and the shape of the molecule is bent. Dipole moments are not cancelled /accept similar idea. [1]

[Total:12]

2 Atmospheric carbon dioxide can dissolve in seawater.

The three inorganic carbon-containing species present in the seawater are:

- dissolved $CO_2(g)$
- $CO_3^{2-}(aq)$
- $HCO_3^-(aq)$.

Increasing levels of $CO_2(g)$ in the atmosphere can change the proportions of these inorganic carbon-containing species present in sea water. This can lead to a series of chemical reactions resulting in the increase of concentration of hydrogen ions. This is ocean acidification. This process also causes carbonate ions to be less abundant.

Equilibrium 1 $CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$ K_1

Equilibrium 2 $HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$ K_2

When changes to the amount of dissolved carbon dioxide in the ocean occur, the pH of seawater remains approximately constant between pH 7.5 and 8.5. This is due to $CO_3^{2-}(aq)$ and $HCO_3^-(aq)$ acting as a buffer.

(a) Write the expression for the equilibrium constant, K_c, for equilibrium 2.

[1]

$Kc = \frac{[CO_3^{2-}][H^+]}{[HCO_3^-]}$ [1]

(b) Approximately 200 years ago, the average pH of sea water taken from the ocean surface was 8.2. At present, this is 8.1.

Calculate the hydrogen ion concentrations of the sea water taken from the ocean surface at 8.2 and 8.1.

Hence, calculate the percentage increase in hydrogen ion concentration of the sea water taken from the ocean surface at present compared with 200 years ago.

[3]

pH = -log $[H^+]$

$[H^+] = 10^{-8.1}$ = **7.943 x10^{-9}** mol dm^{-3}

$[H^+] = 10^{-8.2}$ = **6.309 x10^{-9}** mol dm^{-3} both [1]

Amount increase =**7.943 x10^{-9} — 6.309 x10^{-9}** = 1.634 x10^{-9} [1]

Percentage increase = (1.634 x10^{-9} / 6.309 x10^{-9}) x 100 = **25.9 %** [1]

(c) Using equilibrium 1 and 2, explain how the increase in dissolved CO_2(g) leads to a lower abundance of CO_3^{2-}(aq).

………………………………………………………………………………………..…………

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

When CO_2(g) dissolved in sea water, **position of equilibrium in reaction 1 shifts right** increasing **concentration of H^+**. [1]

This leads to **increase in concentration of H^+** and **position of equilibrium in reaction 2 shifts left**. This causes concentration of CO_3^{2-} to decrease. [1]

(d) Suggest an impact on the ecology in the sea due to the decrease in concentration of carbonate ions.

……………………………………………………………………………………………………

……………………………………………………………………………………………………[1]

It leads to difficulty for building and maintain shells for calcifying organisms such as clams, oysters and corals etc. [1]

(e) K_c of equilibrium 2 for a sample of sea water collected increases when temperature is increased.

State the nature of equilibrium 2 as either endothermic or exothermic. Explain your answer.

………………………………………………………………………………………..…………

……………………………………………………………………………………………………...

………………………………………………………………………………………..…………

……………………………………………………………………………………………………[2]

Endothermic. [1]
When temperature increases, **position of equilibrium shift right** producing higher concentrations of products to **remove (excess) heat**. This results in increase in the value K_c. **[1]**

[Total: 9]

3 **(a)** $NaBiO_3$ is an oxidising agent with similar properties to $KMnO_4$.
Fig 3.1 shows an example of the use of $NaBiO_3$ as an oxidising agent.

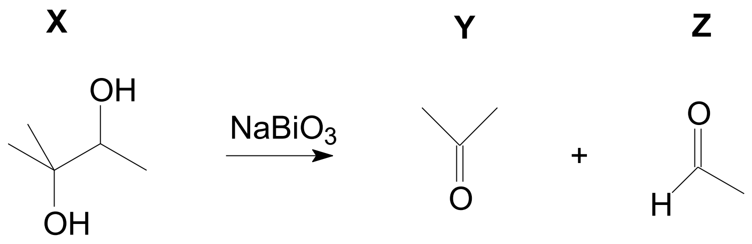


Fig. 3.1

(i) Explain why the reaction in Fig 3.1 is considered an oxidation reaction.

……………………………………………………………………………………

……………………………………………………………………………………[1]

Removal of H atoms from **X**. [1]

Or Oxidation number of carbons increased.

FYI:
+1 in **X** (tertiary alcohol) to +2 in **Y** and 0 in **X** (secondary alcohol) to +1 in **Z**

(ii) Identify the functional groups present in **X**, **Y** and **Z**.

X: ……………………………………

Y: ……………………………………

Z: ……………………………………

[3]

X: (tertiary and secondary) alcohol;
Y: ketone;
Z: aldehyde
[1] each correct

(iii) Compound **X** can be synthesised from 2,3-dibromo-2-methylbutane.

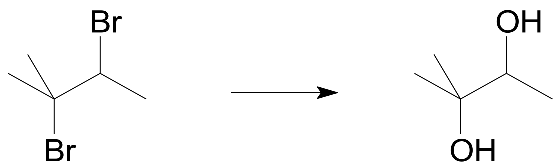


Fig. 3.2

Suggest the reagents and conditions for the reaction shown in Fig 3.2.

……………………………………………………………………………………[1]

Aqueous sodium hydroxide, heat [1]
(solvent must be included)

(iv) Suggest a simple chemical test to distinguish 2,3-dibromo-2-methylbutane and **Y**. State the observations clearly.

....

....

....

....[2]

Add aq NaOH to 2,4-dibromo-2-methylbutane and heat.
Add HNO_3 to remove excess NaOH.
To the reaction mixture, add $AgNO_3$. [1]

Cream ppt of AgBr formed in 2,4-dibromo-2-methylbutane but not in Y. [1]

(do not accept just using aq $AgNO_3$ with heating without hydrolysis.)

(b) $NaBiO_3$ can be used to determine the concentration of Mn^{2+}(aq). The ionic equation for the reaction is shown below.

$$2Mn^{2+} + 5BiO_3^- + 14H^+ \longrightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O$$

A student uses the following procedure in an experiment.

- Add 100.0 cm^3 of a saturated solution of Mn^{2+}(aq) to a graduated flask.
- Add distilled water to the flask to make a 1.00 dm^3 diluted solution.
- Titrate a 25 cm^3 sample of the diluted solution with 0.100 mol dm^{-3} $NaBiO_3$(aq).

The 25 cm^3 sample of the diluted solution of Mn^{2+}(aq) reacts completely with exactly 21.50 cm^3 of 0.100 mol dm^{-3} $NaBiO_3$(aq).

Calculate the concentration, in mol dm^{-3}, of Mn^{2+}(aq) in the saturated solution.

Show your working.

[3]

$n(NaBiO_3)$ = 21.50/1000 x 0.1 = 0.00215 mol
$n(Mn^{2+})$ = 2/5 x 0.00215 = 8.60 x 10^{-4} mol [1]
$[Mn^{2+}]$ in diluted solution = 8.60 x 10^{-4} / 0.025 = 0.0344 mol dm^{-3} [1]
$[Mn^{2+}]$ in saturated solution = 1000/100 x 0.0344 =0.344 mol dm^{-3} [1]

(c) The accuracy of an experiment can be improved by using a measuring apparatus with lower percentage error incurred during its measurement.

This percentage error incurred for a **single** measurement of a volume of solution can be calculated by the following relationship.

$$\text{percentage error} = \pm \frac{\text{error of apparatus}}{\text{quantity measured}} \times 100\%$$

The smaller the percentage error incurred by the apparatus, the more accurate the measurement is, hence the more accurate the experiment is.

Table 3.1

Measuring apparatus	Error of each reading / cm^3	No. of readings done to measure the volume
pipette	±0.06	1
burette	±0.05	2

(i) Calculate the percentage errors involved in measuring 25 cm^3 of $Mn^{2+}(aq)$ using a pipette.

[1]

% error in pipette = (±0.06 ÷ 25.0) x 100% = **±0.240 % [1]**

(ii) Calculate the percentage errors involved in measuring 25 cm^3 of $Mn^{2+}(aq)$ using a burette.

[1]

% error in burette = [2 (±0.05) ÷ 25.0] x 100% = **±0.400 %**

Award credit to x2 in total error. [1]

(iii) Use your answer to explain if it is better to use a burette to measure 25.0 cm^3 of $Mn^{2+}(aq)$.

………………………………………………………………………………………....

……………………………………………………………………………..…..[1]

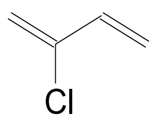
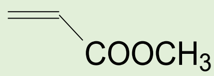
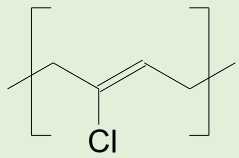
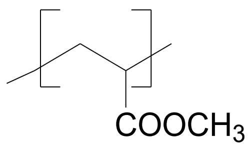
Pipette gives a <u>smaller percentage error</u>, hence it is <u>not better</u> to use burette for the titration. (Accept similar idea) [1]

[Total: 13]

4 **(a)** This question is about nylon 6, neoprene and acrylate polymer

(a) Complete the boxes in Table 4.1.

Table 4.1

Polymer	Nylon 6	Neoprene	Acrylate polymer
Name of monomer	6-aminohexanoic acid	2-chlorobuta-1,3-diene	methyl prop-2-enoate
Structural formula of monomer(s)	$H_2N(CH_2)_5COOH$		
Structural Repeat unit of polymer	$-HN(CH_2)_5CO-$	 [ ] is not necessary as long as the incomplete bondings at the side is clearly shown.	
Type of reaction used to form polymer	condensation	addition	addition
Reagents and condition	DCC	uv light	uv light

[7]

(b) Suggest an advantage of using nylon 6 to make sportwear?

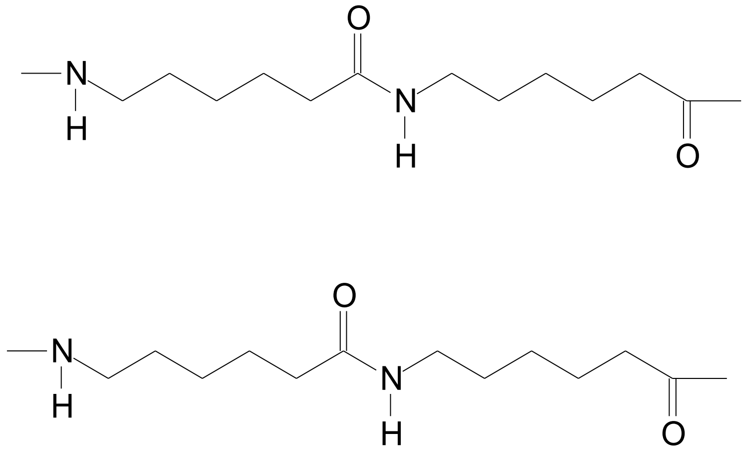
....[1]

Durable, strong, flexible, absorb moisture (any relevant advantages) [1]

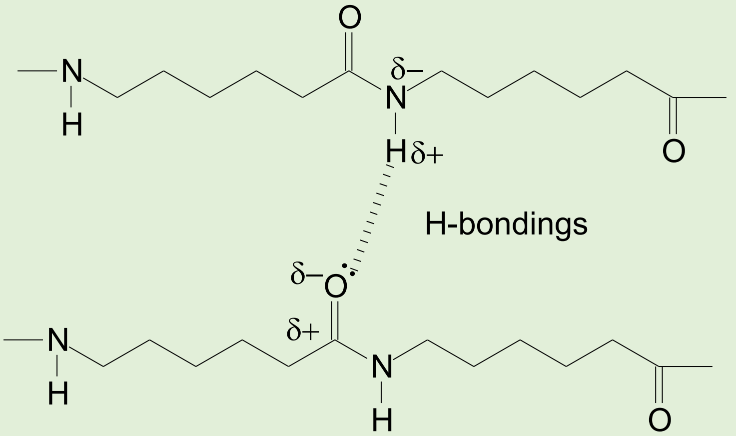
(c) The melting point of nylon 6 is high at 218 °C.

Complete the diagram below with relevant lone pair and partial charges, to explain its high melting point.

State the type of interaction between the two polymeric chains.



[2]

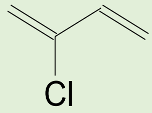


[1] lone pair and H-N
[1] labelling/state H-bonding

(d) Neoprene is a synthetic latex. In a sample of neoprene, the average molecular mass of a polymer is 10000.

Using the information in Table 4.1, calculate the molecular mass of the monomer and hence calculate number of moles of monomers required to form an average polymer.

[2]



C_4H_5Cl

Mr of a monomer = 4(12.0) + 5.0 + 35.5 = 88.5 [1]

No. of moles of monomers = 10000/88.5 = 113 [1] (ecf)

[Total: 12]

5 **(a)** Hydrogen and chlorine react violently to form hydrogen chloride gas.

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

(i) Draw a Boltzmann distribution curve for the molecular energies of the above gaseous reaction mixture at 293 K.

Label the curve **P**. Label the activation energy E_a.

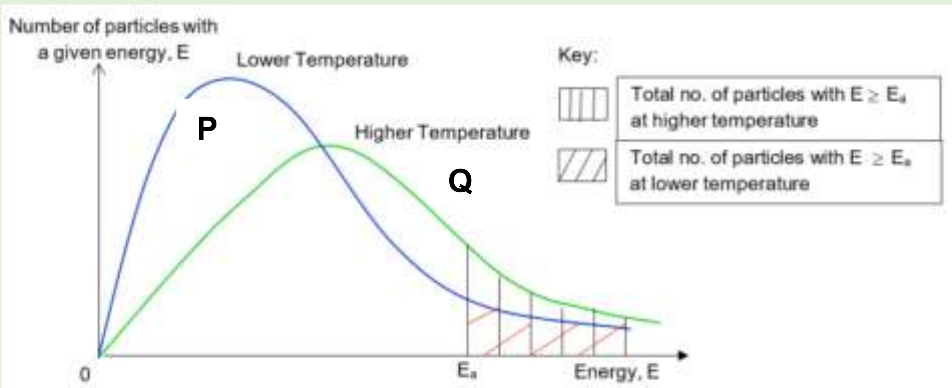
number of molecules

energy

[2]

(ii) On the same axes, draw a second Boltzmann distribution curve for the molecular energies of the same gaseous reaction mixture at 350 K.

Label the curve **Q**. [1]



(i)
[1] Correct shape of curve + start at origin (ignore absent of '0')
[1] Label E_a , shading and legends

(ii)
[1] Maximum pt of curve Q is lower and to the right of that of curve P

(iii) State what happens to the rate of the reaction when the temperature is decreased.

Explain your answer using the curves drawn in **(a)(i)** and **(ii)**.

…………………………………………………………………………………………

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…………………………………………………………………………………………

…………………………………………………………………………………………[2]

When **temperature increases from P to Q**, the average kinetic energy of the molecules decreases.

- As shown on the diagram, the number of reactant molecules with energy greater than or equal to the activation energy, E_a, increases significantly.
- This results in an increase in the frequency of effective collisions.[1]
- The rate constant, *k*, increases and
- hence rate of reaction increases.[1]

(c) Alkenes undergo hydrogenation, an example of which is shown with styrene.

Styrene is an aromatic hydrocarbon that is a precursor to polystyrene, an important synthetic material that is used in the making of many substances such as, rubber, insulation and fiberglass.

The diagram below shows an energy cycle involving hydrogenation of styrene.

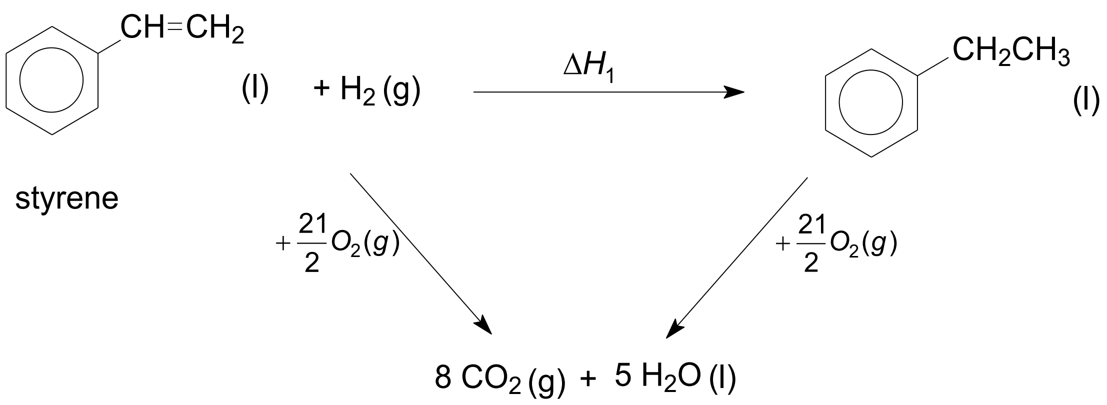


Fig. 5.1

(i) Define the term *standard enthalpy change of combustion*.

………………………………………………………………………………………………

………………………………………………………………………………………………[1]

Standard enthalpy change of combustion (ΔH_c^{θ}) of a substance is the **energy evolved** when ***one mole*** of the substance is ***completely burnt* in oxygen** under **standard conditions**. [1]

(ii) Use the following data and Fig 5.1 to calculate the standard enthalpy change of hydrogenation of styrene, ΔH_1.

$\Delta H_c^{\ominus}$ hydrogen = –286 kJ mol^{-1}

$\Delta H_c^{\ominus}$ styrene = –4393 kJ mol^{-1}

$\Delta H_c^{\ominus}$ ethylbenzene = –4562 kJ mol^{-1}

[2]

ΔH_1 = $\Delta H_C^{\ominus}$ (styrene) + $\Delta H_C^{\ominus}$ (H_2) – $\Delta H_C^{\ominus}$ (ethylbenzene) [1]

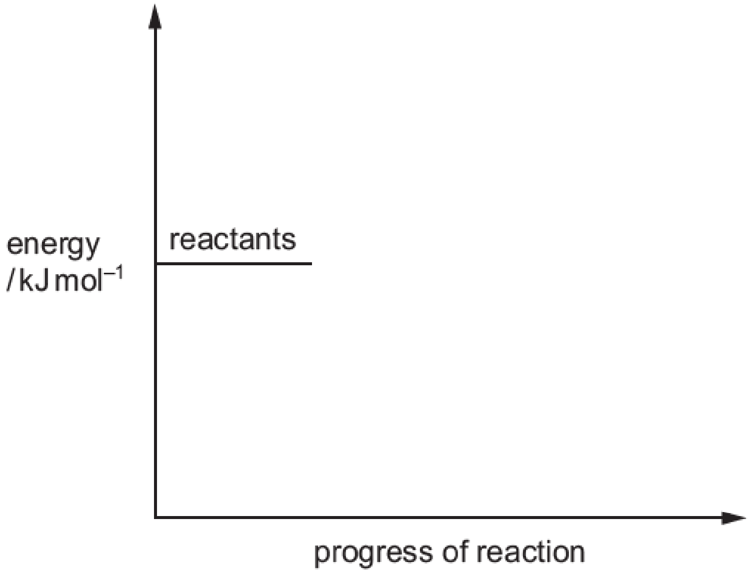
= (–4393) + (–286) – (–4562)

= **–117 kJ mol^{-1}** [1]

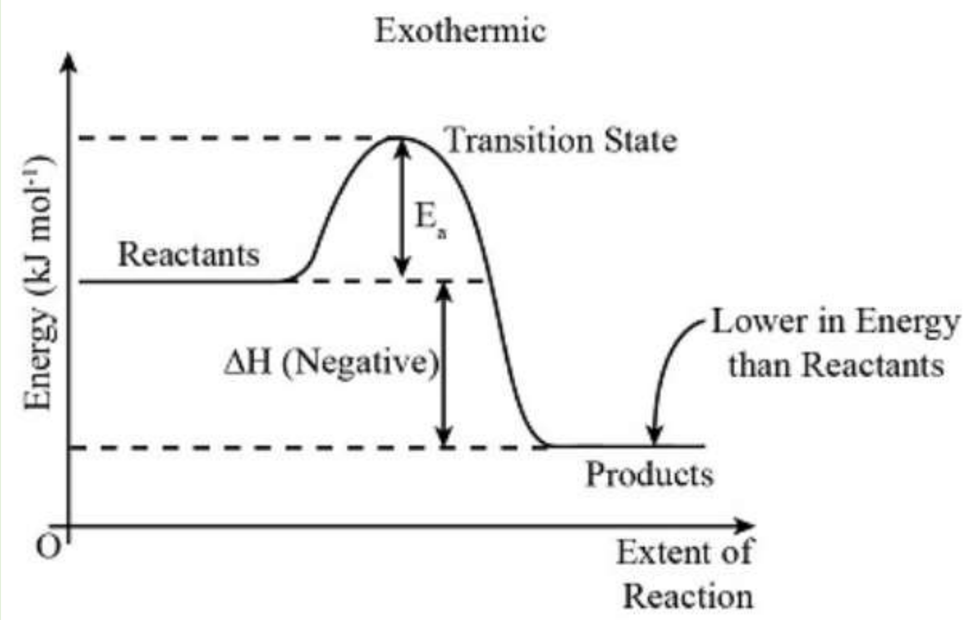
Q5: E: 1 M:7

(iii) Hydrogenation of alkenes is a one-step reaction.

Using your answer in **(c)(ii),** complete the reaction pathway diagram for the reaction of styrene and hydrogen.
Label the E_a and ΔH_1 clearly in your diagram.



[2]



Correct shape (ecf) **[1]**
Correct labeling of E_a and ΔH_1 **[1]**

[Total: 10]

6 Carbon can exist as graphene and nanotubes.

Graphene is one atom thick and it can be rolled into carbon nanotubes. These nanotubes can be used as biosensors implanted in the human body due to its high electrical conductivity, high durability, low density and are absence of toxic metals. The current way to manufacture graphene involves separating carbon thin layers by chemical or mechanical exfoliation, forming a dry powder.

Graphene and nanotubes are considered *nanomaterials*.

(a) Suggest what is meant by the term *nanomaterials*.

....

....[1]

A nanomaterial is a material with **at least one dimension** on the nanoscale within **1-100 nm /10^{-7} – 10^{-9} m**. [1]

(b) Explain the properties of a single carbon nanotube.

- As a good conductor of electricity

....

....[1]

One delocalised electron in each carbon atom that act as mobile (electrical) charge carriers. [1]

- Has high durability

....

....[1]

Presence of extensive network of strong covalent bonding between each carbon. [1]

(c) Suggest a disadvantage of using graphene on a large scale.

....

....[1]

Graphene powder in nanoscale are extremely small in size and they are much more readily taken up/inhaled by the human body, hence there is a risk of damaging body cells/nanoparticles pose a health risk for humans. [1]

Mark for idea that nanoparticles are small, easily absorbed, damage cells

https://www.graphiteflake.com/graphene-52/

Section B

Answer **one** question in this section in the spaces provided.

7 **(a)** A thermometric titration was carried out to determine the enthalpy change of reaction of $NaHCO_3$ and NaOH, $\Delta H_{reaction}$.

$$NaHCO_3(aq) + NaOH(aq) \longrightarrow Na_2CO_3(aq) + H_2O(l) \qquad \Delta H_{reaction}$$

In this titration, the initial temperature of a 40.0 cm^3 sodium hydrogencarbonate solution before the addition of sodium hydroxide is added is measured and recorded.

5.0 cm^3 portions of 1.50 mol dm^{-3} aqueous sodium hydroxide are added to the polystyrene cup. The temperature of the solution in the cup is measured after each addition. The maximum temperature occurs when complete neutralisation has been achieved.

The results are shown in Fig. 7.1.

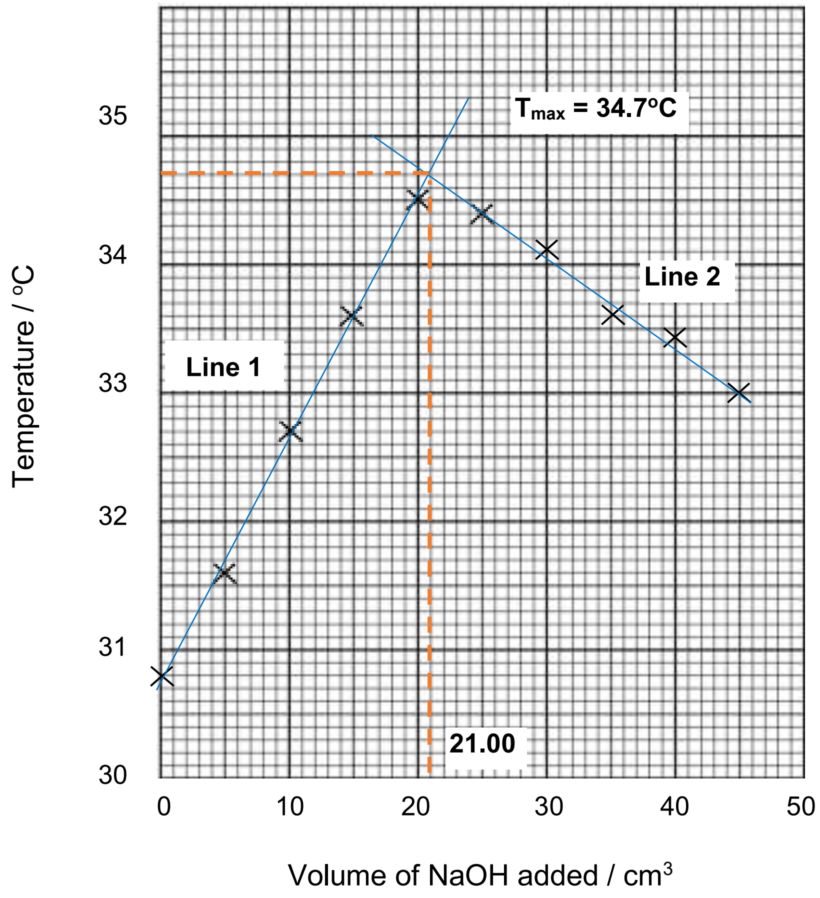


Fig. 7.1

(i) Draw two separate straight lines of best fit.

The first line should take into account the increasing temperatures.

The second line should take into account the decreasing temperatures.

Extend the lines until they intersect (cross).

Use your graph to determine the maximum temperature rise, ΔT_{max}, of the experiment.

Show your working.

[2]

ΔT_{max} = 34.7 – 30.8 = 3.9 °C

[1] for both best fit straight lines
[1] correct ΔT_{max}

Note: Random error is considered when drawing Line 2
T_{max} is higher than all the points since it is an extrapolated value.

(ii) Use your graph to determine the volume of sodium hydroxide, V_{NaOH}, required to neutralise the acid.

Show on your graph how you determined the value.

[1]

V_{NaOH} = 21.00 cm^3

[1] working + correct value

(iii) Using your answers to **(a)(i)** and **(a)(ii)**, calculate the energy, in kJ, evolved during the reaction.

You should assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and the density of each solution is 1.00 g cm^{-3}.

[1]

Heat evolved = m c ΔT_{max}
= (40 + 21) x 4.18 x 3.9
= 994.4
= 990 J [1] ecf

(iv) Using your answer to **(a)(iii)**, calculate a value for the enthalpy change of reaction, $\Delta H_{reaction}$, in kJ mol^{-1}.

[3]

The point where Line 1 and Line 2 intersect shows the stoichiometry of the reaction between $NaHCO_3$ and NaOH.

Hence, number of moles of NaOH = $\frac{21.00}{1000}$ x 1.50 = 0.0315 mol

$\Delta H_r = -q/n_{NaOH} = -\frac{994.4}{0.0315} = -3.16 \times 10^4 \text{ J mol}^{-1} = -31.6 \text{ kJ mol}^{-1}$

[1] correct number of moles of NaOH
[1] correct final answer with correct sign
[1] correct conversion to kJ mol^{-1}
Allow ecf

(b) State and explain the difference in the radii of each of the pairs of species in **(b)(i)** and **(b)(ii)**.

The radii can be found in the *Data Booklet*.

(i) Atomic radii of a magnesium atom and a phosphorus atom.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[3]

Atomic radius of Mg atom is **larger** than that of a P atom[1]

- **Nuclear charge: P > Mg** .
- **Shielding effect** between nucleus and valence electrons is **similar/remains approximately constant** since successive elements in the period have **an additional electron in the same valence shell / same number of inner shells / same number of electronic shell** [1]
- There are **stronger** (electrostatic) **forces of attraction** between the **nucleus and the valence electrons** in Mg than in P. [1]

(ii) Ionic radii of a sodium ion and a phosphorus ion.

……………………………………………………………………………..…………

……………………………………………………………………………..………[1]

Ionic radius of P^{3-} is **greater** than Na^+.

- P^{3-} has **one more filled principal quantum shell** [1] compared to Na^+.

- **Nuclear charge of P^{3-} is greater than that of Na^+**, but **shielding effect is greater** as well.
- The valence electrons in P^{3-} are **further** from the nucleus than in Na^+.
- There are **weaker** (electrostatic) **forces of attraction** between the nucleus and the valence electrons in P^{3-} in that in Na^+.

Modified 2021/II/7(a)(i)+(a)(ii)

(c) The shapes of the covalent molecules CCl_4 and PCl_3 are different.

Using the VSEPR theory, draw and explain the shape and bond angle of

CCl_4 molecule

[1]

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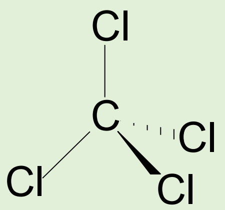
……………………………………………………………………………………[2]



[1] ignore wedge and dash

There are **4 bond pairs around the central C atom**. To **minimise repulsion and maximise stability**, the 4 bond pairs are **arranged as far apart as possible** in a **tetrahedral shape** and the **bond angle is 109.5°.**

[1] for correct number of bond pairs and VSEPR theory
[1] for correct shape and bond angle

PCl_3 molecule

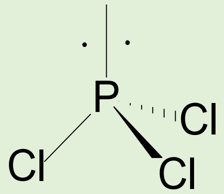
[1]

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………[2]



[1] ignore wedge and dash
Must show lone pair in the correct orientation

In PCl_3, has **3 bond pairs and one of the electron pair is a lone pair** giving **trigonal pyramidal shape**.

Lone pair-bond pair repulsion in PCl_3 is stronger than bond pair-bond pair repulsion in $SiCl_4$.

Hence, the bond pairs are pushed closer together and **bond angle in PCl_3 is 107°**.

[1] for correctly identifying the difference in number and type of electron pairs
[1] for explaining that lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion and NH_3 has a smaller bond angle.

(d) Elements in Group 17 are known as halogens. These elements readily react with Group 1 metals to form important halide salts such as sodium chloride.

The table below shows the results of experiments in which the halogens, Cl_2, Br_2 and I_2 were added to separate aqueous solutions containing Cl^-, Br^- and I^- ions.

	X⁻ (aq)	**Y⁻** (aq)	**Z⁻** (aq)
X_2	-	no reaction	**Z_2** formed
Y_2	**X_2** formed	-	**Z_2** formed
Z_2	no reaction	no reaction	-

Based on the results in the given table, identify **X_2**, **Y_2** and **Z_2**.

X_2 is ………………….. Y_2 is …………………… Z_2 is ……………………..

[1]

X_2 is bromine, Y_2 is chlorine, Z_2 is iodine **[1]**

FYI: Y_2 is the strongest oxidising agent since it can oxidised both X^- and Z^-.

X_2 is a stronger oxidising agent that Z_2, since it can oxidised Z^-.

(e) Halogens react with hydrogen gas to form hydrogen hydrides. State and explain the trend in thermal stability of these hydrides of Group 17.

Include data from the *Data Booklet* in your answer.

…………………………………………………………………………………………………

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…………………………………………………………………………………………………[3]

BE (H-Cl) = + 431 kJ mol^{-1} > BE (H-Br) = + 366 kJ mol^{-1} > BE (H-I) = + 299 kJ mol^{-1} [1]

Since, bond energy of H-X decreases down the group, energy required to break the H-X bond decreases, [1] with BE values

hence thermal stability decreases from HCl to HBr to HI. [1]

[Total: 20m]

8 **(a)** Hydrogen cyanide dissolves in water to form the weak acid hydrocyanic acid, HCN(aq) while sodium cyanide dissolves in water to form a weak alkaline solution.

The following equilibrium illustrates the acid dissociation of hydrogen cyanide in water.

$$HCN(aq) + H_2O(l) \rightleftharpoons CN^-(aq) + H_3O^+(aq) \quad K_a$$

(i) Define the terms acid and base using BrØnsted-Lowry theory of acids and bases.

……………………………………………………………………………………

……………………………………………………………………………………[1]

An **acid** is defined as a **proton (H^+) donor**.
A **base** is defined as a **proton acceptor**.[1]

(ii) Identify the one conjugate acid-base pair in the reaction occurring in the equilibrium.

……………………………………………………………………………………

……………………………………………………………………………………[1]

base: OH^- conjugate acid: H_3O^+
or acid: HCN conjugate base: CN^-
[1]

(iii) Write an equation to explain why sodium cyanide dissolves in water to form a weak alkaline solution.

……………………………………………………………………………………[1]

$NaCN + H_2O \rightleftharpoons HCN + NaOH$ [1]
[accept single direction arrow.
Accept equation shown without spectator ions.]

(iv) For hydrocyanic acid, pK_a = 4.79 at 25°C.

Calculate the value of K_a for hydrocyanic acid at 25°C.

[1]

$K_a = 10^{-4.79}$
$= 1.62 \times 10^{-5}$ mol dm^{-3} [1]

(b) The table below lists the melting points of some compounds.

compound	melting point/°C
HCN	-13.4
H_2O	0
NaCN	564

Explain as fully as you can the differences in their melting points.

Include the bonding and structure of each substance in your answer.

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……………………………………………………………………………………………[3]

HCN is a simple molecule. Lowest energy is required for overcoming the weakest permanent dipole-permanent dipole attractions between its molecules during melting. [1]

H_2O is a simple molecule. It requires more energy than HCN to overcome the stronger extensive hydrogen bonding between its molecules. [1]

NaCN has a giant ionic lattice structure. It requires most energy to overcome the strong electrostatic attractions between Na^+ and CN^- resulting its highest melting point. [1]

[1] correct solid structure

(c) 3-bromopropene can be hydrolysed by aqueous sodium hydroxide to form alcohols.

Three sets of experiments were carried out to investigate the kinetics of this reaction:

Table 8.1

Experiment	$[CH_2{=}CHCH_2Br]$ / mol dm^{-3}	[NaOH] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.10	0.20	0.01

2	0.20	0.10	0.02
3	0.30	0.20	0.03

(i) Use data from Table 8.1 to determine the order of reaction with respect to CH_2=$CHCH_2Br$ and NaOH and hence deduce the rate equation for this reaction.

Let rate = k[CH_2=$CHCH_2Br$]^m[NaOH]^n

Using results of experiments 1 and 3, $\frac{0.03}{0.01} = \frac{k(0.30)^m(0.20)^n}{k(0.10)^m(0.20)^n}$

m = 1

Order of reaction with respect to CH_2=$CHCH_2Br$ = **1** [1]

Using results of experiments 1 and 2, $\frac{0.02}{0.01} = \frac{k(0.20)^1(0.20)^n}{k(0.10)^1(0.10)^n}$

n = 0

Order of reaction with respect to NaOH = **0** [1]

Rate = k[CH_2=$CHCH_2Br$] [1]

[3]

(ii) Using your answer from **(c)(i)**, calculate the value of the rate constant, *k*. include its units.

Using data from Expt 1:

iv.01= *k* (0.1)

k = **0.1 s^{-1}**

[1] correct substitution of experimental data (ecf)
[1] correct units (ecf)

[2]

(d) When an ester **A**, $C_7H_{14}O_2$, is heated with aqueous HC*l*, two products **B**, $C_3H_4O_2$, and **C**, $C_4H_{10}O$, are formed.

B turns moist blue litmus paper red.

C reacts with concentrated sulfuric acid to form three isomeric compounds that decolourise bromine water.

(i) State the type of reaction ester **A** undergoes.

....[1]

A with aqueous HCl: **(acid) hydrolysis** [1]

(ii) Suggest the structure for **B**.

[1]

B: CH_3COOH [1]

(iii) Draw the displayed formula of **C**. Explain your answer.

[2]

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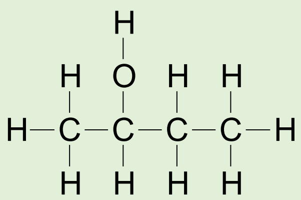


[1] correct identity [1] correct displayed formula

C undergoes **elimination/dehydration** with conc H_2SO_4 to form **alkene**.
Alkenes undergoes **addition** with aq bromine.

Any 2 keypoints [1]

(iv) Hence, using your answers in **(d)(ii)** and **(d)(iii)**, draw the structural formula of compound **A**.

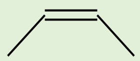
[1]

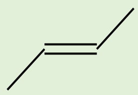
A: $CH_3CH_2COOCH(CH_3)CH_2CH_3$ [1]

(v) Two of the isomeric products that decolourise bromine water differ only in their arrangement in space.

Draw the skeletal formulae of these two isomers.

[2]





Either [1] each or
[1] correct alkene
[1] skeletal formula

[Total: 20]