H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME

CLASS

TUTOR'S NAME

CHEMISTRY

8873/02

Paper 2 Structured Questions

9 September 2024

2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces provided at the top of this page.
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.

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.

For Examiner's Use	
1	**/9**
2	**/8**
3	**/9**
4	**/10**
5	**/15**
6	**/9**
7/8	**/20**
Total	**/80**

This document consists of **26** printed pages.

For Examiner's Use

Section A

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

1 This question is about the chemistry of sodium and oxygen.

(a) **(i)** Define the term *first ionisation energy*.

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.....

.....[1]

(ii) Explain the following comparisons of ionisation energies.

- The first ionisation energy of Na (494 kJ mol^{-1}) is very much lower than that of oxygen (1310 kJ mol^{-1}).

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.....[2]

- The second ionisation energy of Na (4560 kJ mol^{-1}) is very much higher than its first ionisation energy (494 kJ mol^{-1}).

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.....[1]

(b) When sodium is burned in oxygen, both sodium oxide Na_2O and sodium peroxide Na_2O_2 are produced. The two products are strongly basic and form sodium hydroxide when reacted with water. Hydrogen peroxide is also formed in the reaction of sodium peroxide with water.

(i) Explain, in terms of electronegativity, why Na_2O and Na_2O_2 are strongly basic.

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.....[1]

(ii) Draw a dot-and-cross diagram and label the **two** different types of bonding present in sodium peroxide, Na_2O_2.

[2]

(iii) Explain why the melting point of Na_2O (1132 ^oC) is very much higher than that of Na_2O_2 (460 ^oC).

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.....[2]

[Total: 9]

2 For many compounds the enthalpy change of formation cannot be calculated directly. An indirect method based on enthalpy changes of combustion can be used.

The enthalpy change of combustion can be found by a calorimetry experiment in which the heat energy given off during combustion is used to heat a known mass of water and the temperature change recorded.

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

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.....[1]

(ii) Write the equation for the standard enthalpy change of combustion of ethanol, C_2H_5OH.

.....[1]

(b) In an experiment to determine the enthalpy change of combustion of ethanol, 0.288 g of ethanol was burned and the heat given off raised the temperature of 100 g of water by 16.3 ^oC.

(i) Calculate the standard enthalpy change of combustion of ethanol.

Assume that the process is only 80% efficient, the specific heat capacity of water is 4.2 J g^{-1} K^{-1}.

[3]

(ii) Other than heat loss to surroundings, suggest a reason why the value for the standard enthalpy change of combustion of ethanol determined by a simple laboratory calorimetry experiment is likely to be lower than the true value.

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.....[1]

(c) Some relevant standard enthalpy change of combustion values, $\Delta H_c^{\ominus}$, are given in Table 2.1.

Table 2.1

substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C(s)	–393.5
$H_2(g)$	–285.8
$C_3H_7OH(l)$	–2021.0

Using the data in Table 2.1, calculate the standard enthalpy change of formation of $C_3H_7OH(l)$, $\Delta H_f^{\ominus}$.

$$3C(s) + 4H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow C_3H_7OH(l) \qquad \Delta H_f^{\ominus}$$

[2]

[Total: 8]

3 When ethanoic acid reacts with ethanol to form ethyl ethanoate and water, the following equilibrium is established.

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l) \qquad \Delta H < 0$$

A student mixed 1.20 g (0.0200 mol) of ethanoic acid in a conical flask with 0.92 g of ethanol (0.0200 mol) and 1.80 g (0.100 mol) of water. He then carefully added 0.49 g of concentrated sulfuric acid, H_2SO_4. The flask was sealed with a bung and placed in a thermostatic water bath set at 25 ^oC for 5 days.

After 5 days, the student titrated the entire contents of the conical flask with 1.00 mol dm^{-3} aqueous NaOH, from a burette, adding phenolphthalein indicator to the flask. The indicator turned pink when 23.30 cm^3 of NaOH had been added.

(a) State the role of concentrated sulfuric acid.

.....[1]

(b) Calculate the number of moles of NaOH used in the titration.

[1]

(c) Calculate the number of moles of NaOH that react with the H_2SO_4.

[1]

(d) Hence, calculate the number of moles of ethanoic acid present at equilibrium.

[1]

(e) Use the information given and the results of the calculations you have carried out to complete the table below.

If you were unable to obtain a value in **(d),** please use the value of 0.00500 mol. This is **not** the correct answer.

	$CH_3CO_2H(l)$	$C_2H_5OH(l)$	$CH_3CO_2C_2H_5(l)$	$H_2O(l)$
initial amount / mol				
change in amount / mol				
equilibrium amount / mol				

[1]

(f) Write an expression for the equilibrium constant, K_c, for this reaction. Use your answers in the table above to calculate the value of K_c. State the units, if any are appropriate.

[2]

(g) Explain what would happen to the total volume of NaOH added if the thermostatic water bath is set at 30 ^oC.

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.....[2]

[Total: 9]

4(a) The Periodic Table usually shows hydrogen on its own and not a member of a group.

(i) Suggest why the element hydrogen could be placed at the top of Group 1.

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.....[1]

(ii) Suggest why the element hydrogen is **not** placed at the top of Group 1, in terms of

- its structure
- one physical property related to its structure

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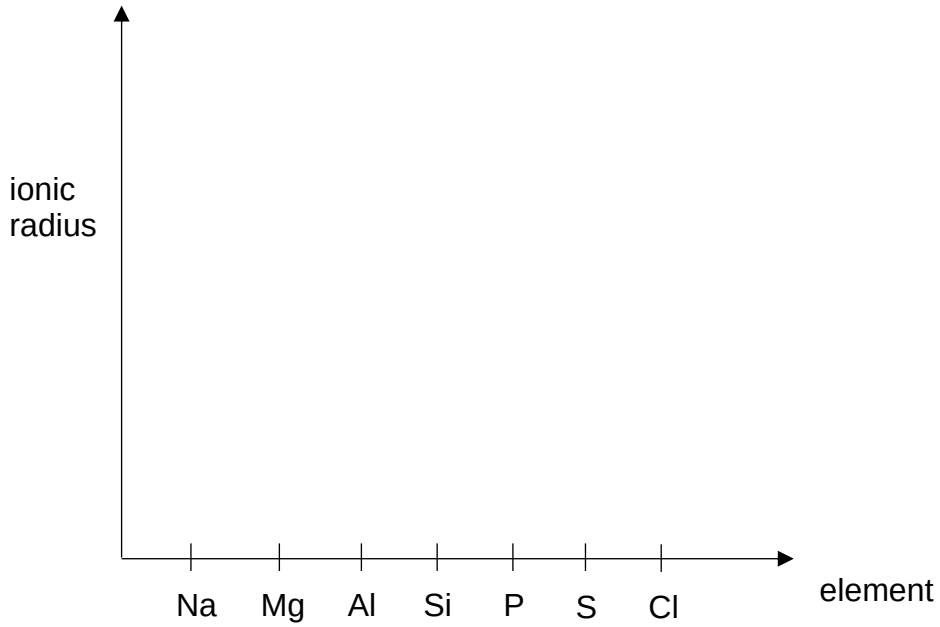
.....[2]

(b) On the following axes, sketch the variation of the ionic radius across Period 3 of the Periodic Table for the elements Na to Cl.



[2]

For Examiner's Use

(c) Describe the reactions, if any, of the chlorides NaCl, $AlCl_3$ and PCl_5 with water. Write equations for all the reactions that occur and suggest the pH of the resulting solutions. Relate the reactivity of these chlorides to their structure and bonding.

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..... [5]

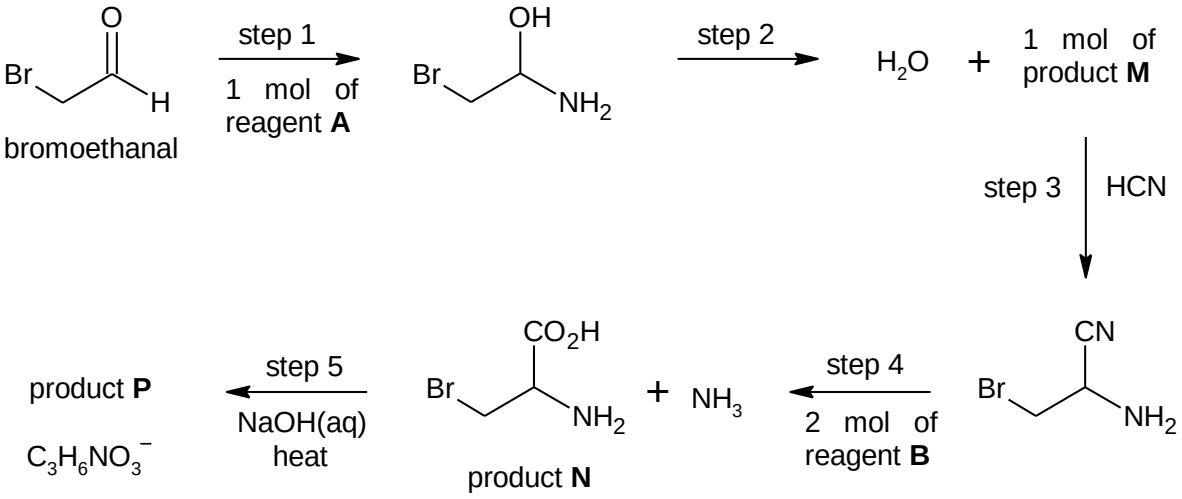
[Total: 10]

5 Compound **R** is a common molecule found in muscle cells.
It has the molecular formula $C_3H_7NO_3$.

(a) Suggest three functional groups that could **all** be present in **R** based on the formula.

.....[2]

(b) Compound **P**, $C_3H_6NO_3^-$, can be converted to **R** by adding one mol of HCl(aq) in an acid-base reaction. The synthesis route for compound **P** is shown below.



(i) Bromoethanal can be formed from ethanal.
State the reagent and conditions to carry out this conversion.

.....[1]

(ii) Product **M** contains a C=N double bond.
Suggest the types of reactions for steps 1 and 2.

step 1.....

step 2.....[1]

(iii) Draw the displayed structure of **M**.

[2]

(iv) Suggest the identities of reagents **A** and **B**.

reagent **A**.....

reagent **B**.....[2]

(v) State the IUPAC name for product **N**.

.....[1]

(vi) There are two reactions that occur simultaneously in step 5.
For each reaction, state the functional group that has reacted, and the type of reaction undergone.
Draw the structure of product **P**.

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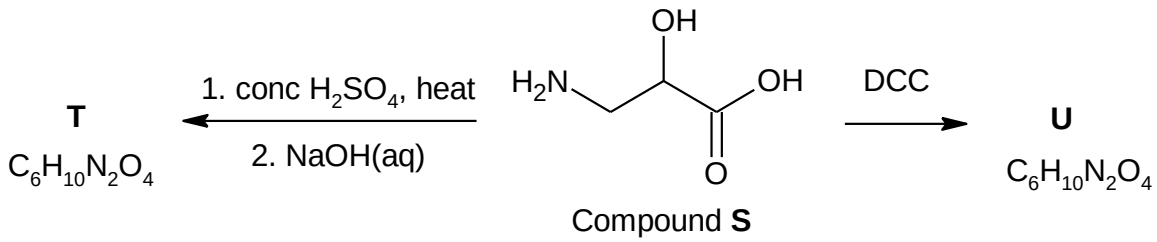
.....[3]

(c) An isomer of compound **R**, compound **S**, can undergo condensation to form two different products, **T** and **U**, with the same molecular formula.



Compound **S**

Both **T** and **U** are cyclic compounds.

Suggest the structures of **T** and **U**. Hence, state the type of isomerism they show.

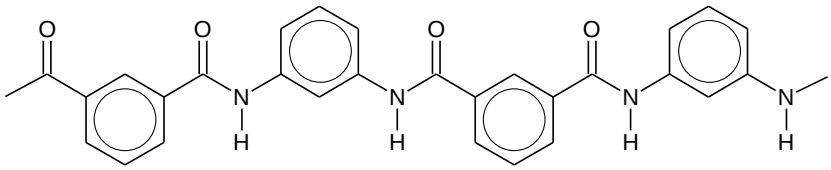
T	**U**

type of isomerism .....[3]

[Total: 15]

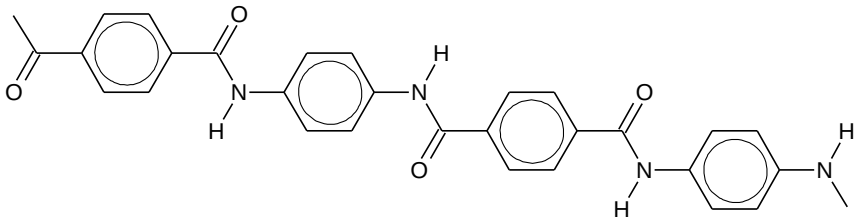
Question 6 starts on the next page.

6 Aramid fibres, are a class of heat-resistant and strong synthetic fibres. There are two main types of aramid fibres. Meta-aramid fibres were produced by the DuPont company in the early 1960s under the trade name Nomex®. Nomex® fibres can be spun and woven, similarly to normal cotton fibres, hence are used in the manufacture of apparel. Unlike cotton fibres, Nomex® showed excellent resistance to heat, as it neither melts nor ignites in normal levels of oxygen, hence found extensive use in the production of protective clothing.



a section of a Nomex® polymer chain in meta-aramid fibres

In 1965, scientists at DuPont discovered a new method of producing an almost perfect polymer chain which they named Kevlar®. Using para-aramid fibres, the simple repetitiveness in the molecular structure allows the formation of rigid rod-like molecules.



a section of a Kevlar® polymer chain in para-aramid fibres

Polymer fibres are formed in a process called spinning. Under high pressure, polymer chains are pushed through tiny openings to form solid fibres. In high concentrations, rod-like polymer chains can align in highly ordered arrangements. This imparts extremely high tensile strength and thermal stability. Kevlar® has five times the tensile strength of steel and is well-known for its use in bullet-proof vest.

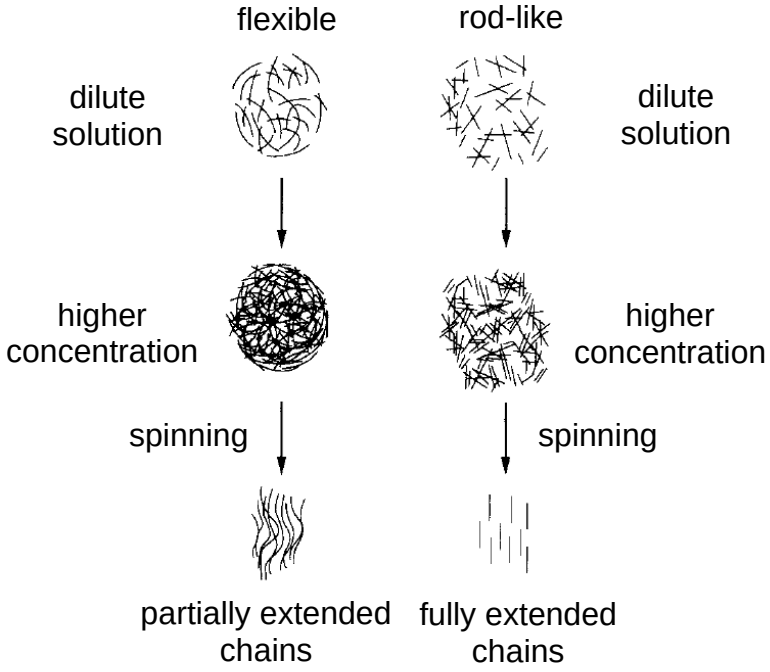


Fig. 6.1 Differences in behaviour during spinning between flexible and rod-like polymers

(a) Suggest one difference and one similarity in the monomers of a meta-aramid polymer and a para-aramid polymer.

difference……

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.....

similarity……

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.....[2]

(b) **(i)** **Fig. 6.2** shows two adjacent chains of meta-aramid polymer.

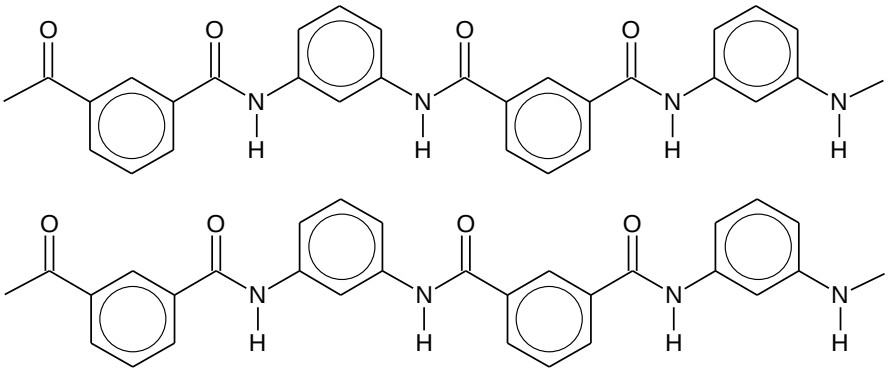


Fig. 6.2

On **Fig. 6.2**, draw and label the intermolecular forces of attraction that enables meta-aramid polymers to display high thermal stability. [1]

(ii) The diagram below shows two adjacent chains of para-aramid polymer.

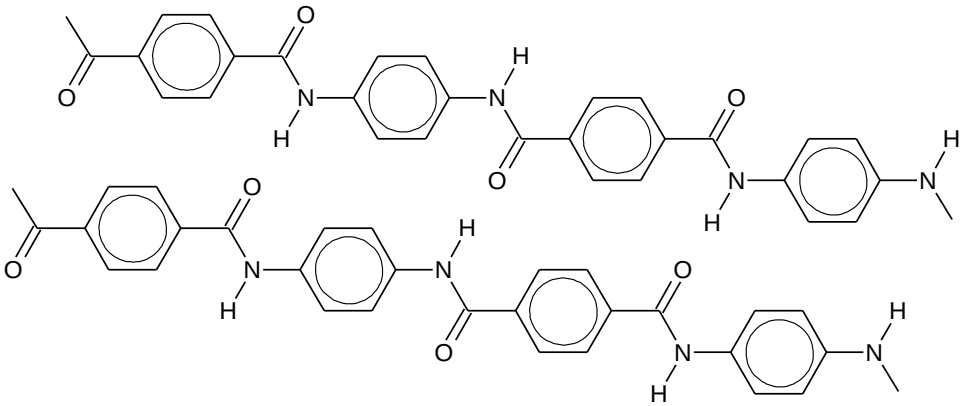
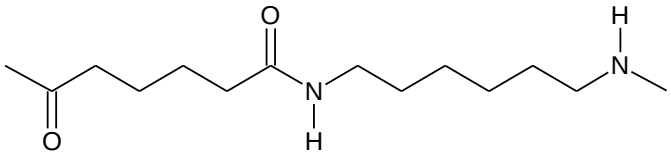


Fig. 6.3

On **Fig. 6.3**, draw and label the **additional** intermolecular forces of attraction not present or only weakly present in **Fig. 6.2**. [1]

(iii) Nylon-6,6 polymers have "flexible" chains whereas para-aramid polymers have chains described as "rod-like". Explain why.



a section of a nylon-6,6 polymer

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.....[2]

(iv) Suggest and explain why Kevlar® polymer have higher tensile strength than Nomex® polymer.

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.....[1]

(c) Nomex® polymers are used in fire-retardant garments. Upon heating, Nomex® fibres undergo a charring process, creating a carbonaceous layer similar to graphene sheets that can absorb heat and prevents further heat from entering the garment. Small gaseous molecules are evolved in the charring process.

(i) Suggest and explain how the carbonaceous layer can absorb large amounts of heat.

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.....[1]

(ii) Suggest the identity of two molecules formed during the charring process that are hazardous.

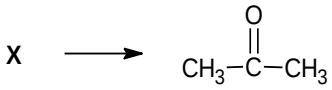
.....[1]

[Total: 9]

Section B

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

7(a) Alcohol **X** reacts with acidified potassium dichromate(VI), $K_2Cr_2O_7$ to form propanone.



The relevant half-equation for dichromate ion in the above reaction is as follows.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

(i) Explain, in terms of the change in oxidation number of chromium, the role of potassium dichromate(VI) in the reaction with alcohol **X**.

.....

.....

.....[1]

(ii) Draw the skeletal formula of alcohol **X**.

[2]

(iii) Write the half-equation for the oxidation reaction of alcohol **X** to propanone. Hence, construct an ionic equation for the reaction between dichromate(VI) ions and alcohol **X** in acidic solution.

[2]

A 10.0 cm^3 sample of alcohol **X** was mixed with dilute sulfuric acid and made up to a volume of 250 cm^3 in a volumetric flask.

A 25.0 cm^3 portion of this diluted solution was pipetted into a conical flask and heated. A few drops of N-phenylanthranilic acid indicator was added to the flask. 0.0100 mol dm^{-3} aqueous potassium dichromate(VI) was run from the burette into the conical flask until a distinct colour change was observed. The titration was repeated to obtain two consistent results (i.e. at least two titres that are within 0.10 cm^3 of each other).

The results are shown in Table 7.1.

Table 7.1

	1	2	3
initial burette reading / cm^3	0.00	21.40	0.00
final burette reading / cm^3	21.40	43.35	21.50
titre / cm^3			

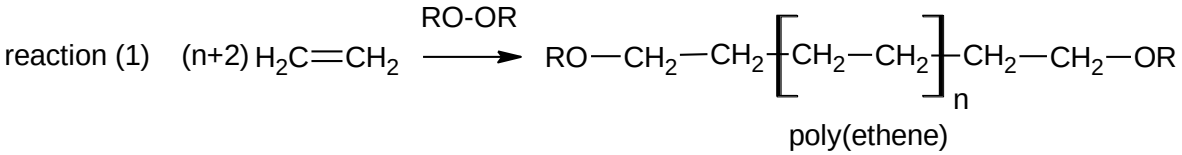
(iv) Complete Table 7.1 and use the consistent results to obtain the average volume of aqueous potassium dichromate(VI). Show clearly how you obtained this volume.

[2]

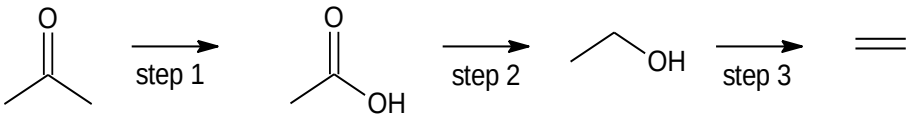
(v) Use your answers in **(iii)** and **(iv)**, calculate the concentration of alcohol **X** in the sample.

[2]

(b) Poly(ethene) is a polymer made by heating ethene molecules with a small amount of benzoyl peroxide (RO-OR) initiator.



Ethene can be manufactured from propanone in a series of steps.



(i) Explain what is meant by the term *polymer*.

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.....[1]

(ii) State the types of reactions which occur in reaction (1) and step 2.

reaction (1) .....

step 2.....[2]

(iii) Suggest reagents and conditions needed for step 3.

.....[1]

(iv) Calculate the enthalpy change for the reaction in reaction (1) if the value of n is 10. Use relevant information from the *Data Booklet*. Show your working.

[2]

(c) Using a different catalyst and pressure, ethene can be polymerised to produce two types of polyethene – low-density polyethene (LDPE) and high-density polyethene (HDPE).

Table 7.2 shows the estimated melting points of polyethene.

Table 7.2

polymer	melting point / °C
low density poly(ethene), LDPE	108
high density poly(ethene), HDPE	135

Explain the differences in melting point of these polymers in terms of their structures and intermolecular forces between the chains. You may draw simplified diagrams of LDPE and HDPE to explain the difference in their melting points. Structural formulae of these polymers are **not** required.

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.....[3]

(d) An oil spill occurred in June 2024 after a digger collided with a stationary bunker vessel, causing oil from the vessel's damaged cargo tank to spill into the sea water. The clean-up effort, which has impacted parts of Singapore's shores, has teams of workers employed to remove oil-covered sand from the beach using sorbent pads and shovels.

There are various types of materials used in sorbent pads, including poly(propene), which can be made into sheets to absorb oil.

(i) Explain why propene, the monomer of poly(propene), is unable to exist as cis and trans isomers.

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.....[1]

(ii) Suggest the forces of attraction that exist between poly(propene) in sorbent pads and oil molecules.

.....

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.....[1]

[Total: 20]

8(a) Hypophosphorous acid, H_3PO_2 is an inorganic acid.

1.77 g of hypophosphorous acid was dissolved in water and made up to 250 cm^3 of aqueous solution. 25.0 cm^3 of the diluted solution required 26.75 cm^3 of 0.100 mol dm^{-3} sodium hydroxide for neutralisation.

(i) The basicity of an acid is defined as the number of hydrogen ions which can be given out by one molecule of that acid. HCl, H_2SO_4 and H_3PO_4 are examples of monobasic, dibasic and tribasic acids respectively.

Determine the mole ratio of hypophosphorous acid and sodium hydroxide, hence deduce the basicity of the acid.

[2]

(ii) The diluted solution of hypophosphorous acid is found to have a pH of 2.9.

Determine by calculation whether hypophosphorous acid is a weak or strong acid.

[2]

(iii) Using your answer in **(a)(i)**, draw a 'dot-and-cross' diagram to show the bonding in hypophosphorous acid. State the O-P-O bond angle.

[2]

(b) The conjugate base of hypophosphorous acid is $H_2PO_2^-$.

$H_2PO_2^-$ is a strong reducing agent. It can be used to reduce metal cations without the need for electrolysis.

Under alkaline conditions, $H_2PO_2^-$ reduces Ni^{2+} to Ni and is itself oxidised to HPO_3^{2-}.

(i) Write a half-equation for the oxidation of $H_2PO_2^-$ to HPO_3^{2-}, under alkaline conditions.

.....[1]

(ii) Using your answer to **(b)(i)**, construct a balanced equation for the reaction between $H_2PO_2^-$ and Ni^{2+}.

.....[1]

(iii) The high conductivity of nickel is a consequence of its electronic configuration. Complete the electronic configuration of a nickel atom, Ni.

$1s^2$ .....[1]

(iv) Using your answer to **(b)(iii)**, state the number of unpaired electrons of a nickel atom, Ni in its ground state.

.....[1]

(c) $H_2PO_2^-(aq)$ reacts with $OH^-(aq)$.

$$H_2PO_2^-(aq) + OH^-(aq) \rightarrow HPO_3^{2-}(aq) + H_2(g)$$

Table 8.1 shows the results of a series of experiments used to investigate the rate of this reaction.

Table 8.1

experiment	$[H_2PO_2^-(aq)]$ / mol dm^{-3}	$[OH^-(aq)]$ / mol dm^{-3}	volume of H_2 produced in 60 s / cm^3
1	0.40	2.00	6.4
2	0.80	2.00	12.8
3	1.20	1.00	4.8

(i) *Use of the Data Booklet is relevant to this question.*

The volume of H_2 was measured under room conditions.

Use the molar volume of gas, V_m to calculate the rate of reaction for experiment 1 in mol dm^{-3} s^{-1}.

[1]

(ii) Use data from Table 8.1 to determine the order of reaction with respect to $H_2PO_2^-$ and OH^- respectively and hence deduce the rate equation for this reaction.

[3]

(iii) Use your answer to **(c)(ii)** and the data from experiment 1 to calculate a value for the rate constant, *k* and state its units.

[2]

(iv) Sketch a graph of $[H_2PO_2^-]$ against time for this reaction when $[OH^-]$ is in large excess.

[1]

[Turn Over

(v) A student suggests that the reaction between $H_2PO_2^-$(aq) and OH^-(aq) might happen more quickly in the presence of a heterogeneous catalyst.

Outline the mode of action of a heterogeneous catalyst.

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.....[3]

[Total: 20]

[End of Paper]