H

RAFFLES INSTITUTION
2025 YEAR 6 TIMED PRACTICE
(ADAPTED FROM 2025 TJC Prelim)
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

CHEMISTRY

9729/02

Paper 2 Structured Questions

16 October 2025
2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

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

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided. Do not write anything in it.
You are reminded of the need for good English and clear presentation in your answers.

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

For Examiner's Use	
1	/ 10
2	/ 9
3	/ 9
4	/ 15
5	/ 11
6	/ 21
Total	/ 75

This document consists of **21** printed pages.

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

1 **(a)** In 1932, the American chemist Linus Pauling developed the most common scale of relative electronegativity (EN) values for the elements. The Pauling EN values of elements can be used to predict the chemical properties of compounds. The EN values of four Period 3 elements are given in Table 1.1.

Table 1.1

element	sodium	aluminium	phosphorus	chlorine
Pauling EN value	0.93	1.61	2.19	3.16

(i) Explain the difference in the Pauling electronegativity values of Na and C*l*.

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.... [2]

The ionic character of a bond is directly related to the electronegativity difference (ΔEN) between the bonded atoms. Fig. 1.1 shows the plot of percent ionic character against ΔEN for NaC*l*.

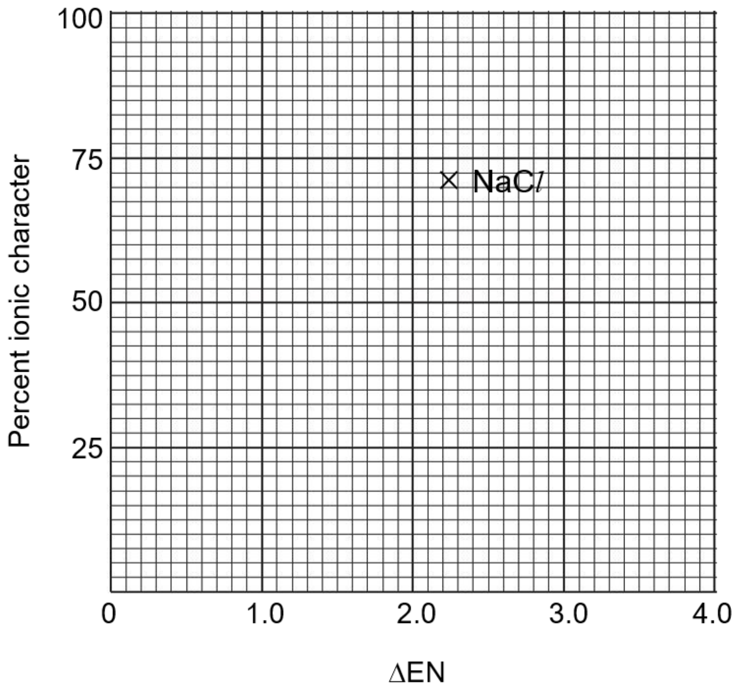

Fig. 1.1

(ii) Using the values in Table 1.1, calculate ΔEN for $AlCl_3$ and PCl_5 respectively. Hence plot the percent ionic character of $AlCl_3$ and PCl_5 on Fig. 1.1. Label your points clearly.

[2]

(iii) Explain the difference in bonding for NaC*l* and PCl_5 in terms of electronegativity.

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…… [2]

(b) **(i)** The polarity of bonds in covalent molecules is also affected by ΔEN. SeF_4 and BrF_3 are two fluorine-containing molecules. State whether SeF_4 or BrF_3 contains covalent bonds with a higher ionic character.

…… [1]

(ii) Using VSEPR theory, predict and explain the shape and bond angles of SeF_4. Illustrate the shape of SeF_4 with an appropriate diagram.

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…… [3]

[Total: 10]

2 PCl_5 is a Period 3 chloride commonly used as a chlorinating agent and catalyst in making organic compounds. Industrial production of PCl_5 involves the reaction of Cl_2 with PCl_3.

Reaction (1) $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

(a) Suggest, with an explanation, how the position of equilibrium and the composition of the equilibrium mixture might change when chlorine is added to the equilibrium system.

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.... [2]

(b) x mol of Cl_2 gas is added to a 2 dm^3 vessel containing an equilibrium system of 0.4 mol of PCl_3, 0.25 mol of Cl_2 gas and 1.2 mol of PCl_5. The new equilibrium amount of PCl_5 is 1.28 mol.

(i) Write the K_c expression for reaction (1), giving its units.

.... [1]

(ii) Using the information given above, calculate K_c.

[1]

(iii) Hence calculate x, the amount of Cl_2 added.

[2]

(c) Period 3 oxides follow a similar trend in bonding as the Period 3 chlorides.

Describe the action of water on the oxides of sodium, aluminium and phosphorus, write equations for any reactions that occur, and suggest the pH of each solution formed.

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[Total: 9]

3 **(a)** Nitrogen exhibits a range of oxidation numbers in its compounds. A few of such species are NO, N_2O, NO_2, N_2 and NH_2OH.

(i) Draw the dot-and-cross diagram for NO_2.

[1]

0.074 g of hydroxylamine, NH_2OH, is dissolved in water. Excess solution of acidified iron(III) salt is added to the dissolved hydroxylamine to form a nitrogen-containing product and iron(II) ions. The iron(II) ions produced requires 44.8 cm^3 of 0.02 mol dm^{-3} acidified potassium manganate(VII) for complete reaction.

The reacting ratio of iron(II) ions and manganate(VII) ions is 5:1.

(ii) Calculate the amount of iron(III) reacted with hydroxylamine.

[1]

(iii) Determine the oxidation state of the nitrogen atom in the nitrogen-containing product. Hence deduce the identity of the nitrogen-containing product.

[2]

(iv) Construct a balanced ionic equation for the reaction of NH_2OH with Fe^{3+}.

[1]

(b) Figure 3.1 shows the second ionisation energies of nine consecutive elements **A** to **I** with atomic numbers below 20 in the Periodic Table. Labels **A** to **I** are not the atomic symbols of the elements.

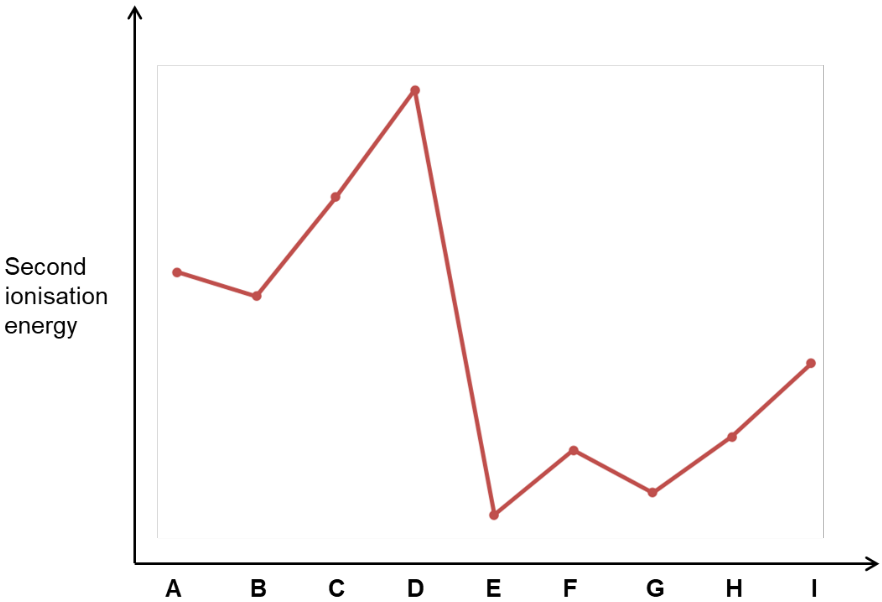

Fig. 3.1

(i) Define the *second ionisation energy* of element **F**.

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.... [1]

(ii) Suggest the identity of **B**. Explain how you arrived at your answer.

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.... [2]

(iii) Explain the difference in second ionisation energy between element **A** and element **B**.

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[Total: 9]

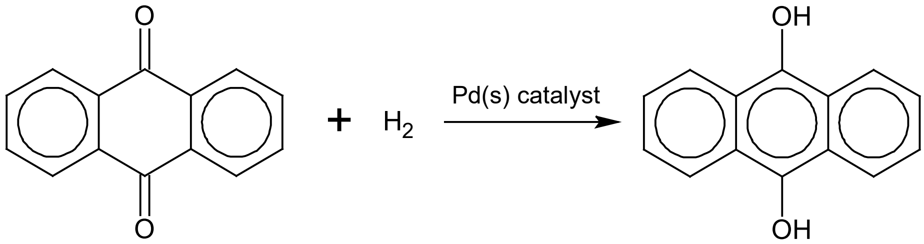
4 **(a)** Hydrogen peroxide, H_2O_2, finds its applications in a diversity of fields as it is considered an environmentally-friendly oxidising agent.

(i) Suggest why it is environmentally-friendly to use H_2O_2 as an oxidising agent.

.... [1]

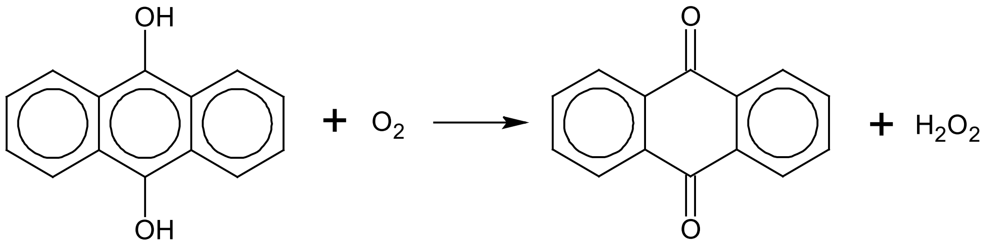
Today, most of the world's hydrogen peroxide is manufactured by the anthraquinone, $C_{14}H_8O_2$ process. This process involves the two steps shown below.

step 1:



Anthraquinone Anthrahydroquinone

step 2:



Anthrahydroquinone Anthraquinone

(ii) State the type of reaction in step 1.

.... [1]

(iii) In step 1, if Sn is used instead of Pd, compound **P**, $C_{14}H_{10}O$ is obtained. Suggest the structure of **P**.

[1]

(iv) Describe a chemical test that can be used to distinguish anthraquinone from anthrahydroquinone. State the observations and write a balanced equation for the reaction that occurred.

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At the end of step 2, only anthraquinone and H_2O_2 remain in the reaction mixture. H_2O_2 can be separated out from the reaction mixture by adding water to the reaction mixture.

(b) With reference to the interactions between relevant molecules, explain how the addition of water separates H_2O_2 from the reaction mixture.

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(c) **(i)** Palladium metal is often used as a heterogeneous catalyst.
Explain what is meant by a *heterogeneous* catalyst.

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

(ii) Explain how a ***heterogeneous*** catalyst increases the rate of reaction. Include a sketch of the Maxwell-Boltzmann distribution and use it to illustrate your answer.

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(d) Nanoparticles are particles with all its dimensions from 1 to 100 nm on the nanoscale. It is observed that the catalytic activity of palladium is vastly increased when the catalyst is finely divided into nanoparticles. These nanoparticles are usually deposited onto the surface of inert metal particles such as gold. This prevents the nanoparticles from being a health hazard.

(i) Explain why catalytic activity is vastly increased when nanoparticles of palladium are used.

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(ii) Predict how nanoparticles could present a risk to human health.

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

(iii) Explain how the deposition of palladium nanoparticles on gold particles prevents them from being a health hazard.

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

[Total: 15]

5 Copper is a first-row transition metal which has two stable isotopes, ^{63}Cu and ^{65}Cu, that exist naturally in mineral ores.

(a) Explain the trend of first ionisation energy of first-row transition metals.

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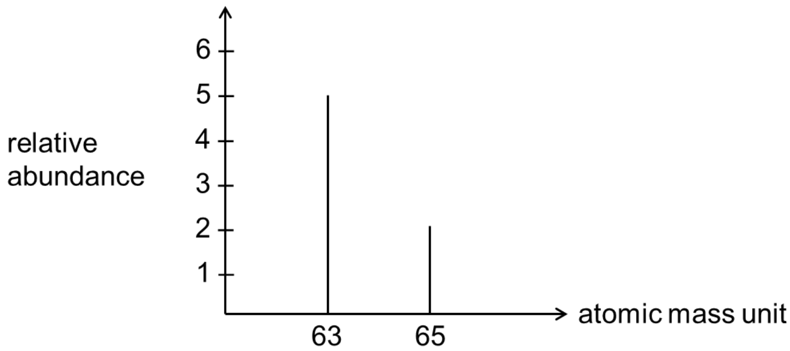
……… [2]

(b) A sample of mineral ore containing the two isotopes of copper is run in a mass spectrometer to determine their relative amounts. The following mass spectrum is obtained.



(i) Define the term *isotope*.

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(ii) Using Fig. 5.1, determine the relative atomic mass, A_r, of copper. Give your answer to 4 decimal places.

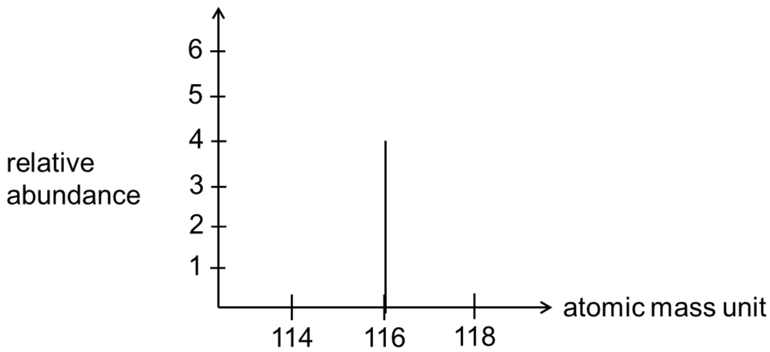
[1]

Chlorine and bromine each has two naturally occuring isotopes. Their relative abundance are shown below.

Table 5.1

element	isotope	relative abundance
chlorine	^{35}Cl	75%
	^{37}Cl	25%
bromine	^{79}Br	50%
	^{81}Br	50%

The following *incomplete* mass spectrum is obtained from a sample of BrCl where only the abundance for atomic mass unit of 116 is shown.



(iii) Identify the species responsible for the atomic mass unit of 114, 116 and 118, taking into consideration the various isotopes.

[2]

(iv) Hence, calculate the relative abundance of BrCl with atomic mass unit of 114 and 118, and complete Fig 5.2.

[2]

(c) Most of the world's copper comes from the mining of copper-containing minerals. Two such minerals are bornite, Cu_5FeS_4, and chalcopyrite, Cu_xFeS_y, where x and y are integer values to be determined.

Bornite and chalcopyrite react with concentrated HNO_3 as follows.

$$Cu_5FeS_4 + 26HNO_3 \rightarrow Fe(NO_3)_3 + 5Cu(NO_3)_2 + 4S + 13NO_2 + 13H_2O$$

$$Cu_xFeS_y + (6 + 4x)HNO_3 \rightarrow Fe(NO_3)_3 + xCu(NO_3)_2 + yS + (3 + 2x)NO_2 + (3 + 2x)H_2O$$

(i) Explain the role of HNO_3 in the above reactions.

....

.... [1]

(ii) When 1 mole each of bornite and chalcopyrite were fully reacted with HNO_3, bornite produced 64.2 g *more* sulfur precipitate and 182 dm^3 *more* nitrogen dioxide than chalcopyrite, at standard temperature and pressure.
Determine the values of x and y.

[2]

[Total: 11]

6 Polymers are macromolecules which consist of chains built up from small molecules known as monomers, with at least 100 repeating units. In general, polymers can be made via addition or condensation reactions.

The characteristic properties exhibited by polymers are the result of their unique structure and bonding. Not all polymers are biodegradable, which poses difficulty in recycling them.

The monomers and biodegradability of addition and condensation polymers are shown in Table 6.1.

Table 6.1

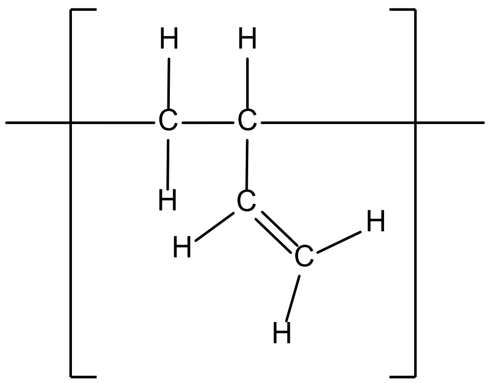
	addition polymer	condensation polymer
monomers	molecules containing C=C bonds	molecules containing two functional groups
biodegradability of polymer	generally difficult to biodegrade	generally biodegradable

(a) The outer layers of some golf balls are made from a polymer called polyisoprene. The isoprene monomer is a non-cyclic branched hydrocarbon with five carbon atoms. One mole of isoprene reacts with two moles of Br_2 in CCl_4.

Suggest a possible structure of isoprene.

[1]

(b) The insides of some golf balls are made from a mixture of three other polymers, **X**, **Y** and **Z**. The repeating unit for polymer **X** is shown.

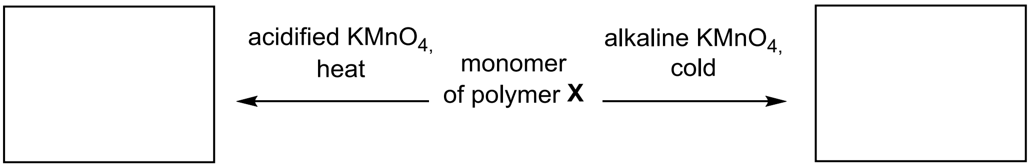


(i) The molecular formula of the monomer of **X** is C_4H_6.

Give the systematic name of the monomer used to make **X**.

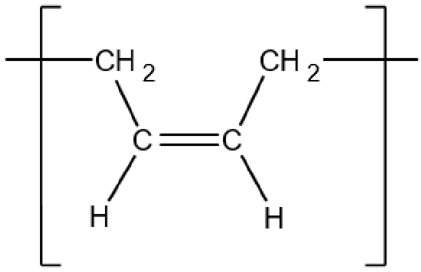
.... [1]

(ii) Draw the carbon-containing products formed when the monomer undergoes the reactions below.



[2]

(c) (i) Polymers **Y** and **Z** are stereoisomers. One of the polymers has a repeating unit with the structure shown.



State the type of stereoisomerism and explain why it arises.

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(ii) Draw the structure of the repeating unit of the other polymer.

repeating unit of the other polymer

[1]

Table 6.2 shows some properties of polymers **Y** and **Z**.

Table 6.2

	polymer **Y**	polymer **Z**
arrangement of polymer chains	crystalline with regular repeating pattern	amorphous with random arrangement
rigidity	high	low
melting point	75 to 135 °C	–25 to 12 °C

(iii) By referring to the information in Table 6.2, identify whether polymer **Y** or **Z** has the repeating unit in **(c)(i)**.

.... [1]

(d) Golf balls recovered from lakes and ponds can be used again even after being in water for several years. Suggest why these golf balls do not biodegrade.

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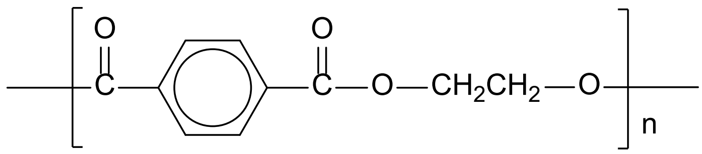
.... [2]

(e) Another polymer, poly(ethylene terephthalate), PET, is commonly used to make shirts worn by golfers. The structure of PET is shown below where n is the number of repeating units in the polymer chain. One of the two monomers used to synthesise PET is benzene-1,4-dicarboxylic acid.



PET

Atom economy is a measure of the amount of starting materials which are in the final desired product.

$$\text{percentage atom economy} = \frac{M_r \text{ of the final desired product}}{\text{total } M_r \text{ of all reactants}} \times 100\%$$

(i) Suggest why chemists usually aim to design production methods with a high percentage atom economy.

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.... [1]

(ii) Explain how the percentage atom economy of the reaction to form PET compares with that of polymer **X**.

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.... [1]

(f) Figure 6.1 shows a two-step synthesis of benzene-1,4-dicarboxylic acid from methylbenzene. State the reagents and conditions for each step and draw the structure of the intermediate.

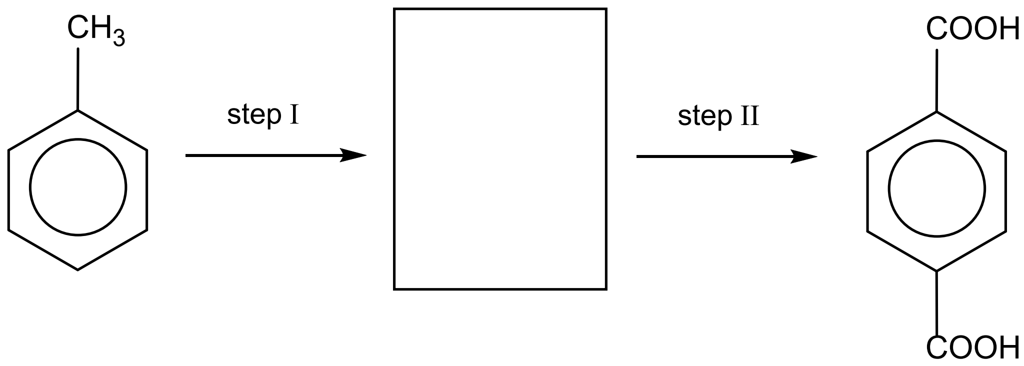

Fig. 6.1

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(g) Benzene-1,2-dicarboxylic acid molecules can also be found in the product mixture in **(f)**.

Table 6.3

	$\Delta H^\ominus$ / kJ mol^{-1}
standard enthalpy change of formation of $H_2O(l)$	–286
standard enthalpy change of combustion of benzene-1,2-dicarboxylic acid, $C_6H_4(COOH)_2(s)$	–3220
standard enthalpy change of combustion of benzene-1,4-dicarboxylic acid, $C_6H_4(COOH)_2(s)$	–3190

(i) Use relevant data from Table 6.3 to deduce whether benzene-1,2-dicarboxylic acid or benzene-1,4-dicarboxylic acid is more energetically stable under standard conditions. Explain your answer.

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(ii) The standard enthalpy change of atomisation of carbon is +715 kJ mol^{-1}.

Use this information and the *Data Booklet* to calculate a value for the standard enthalpy change of combustion of carbon.

[2]

(iii) The standard enthalpy change of formation of benzene-1,2-dicarboxylic acid, **x**, cannot be determined via direct experiment. Using relevant data from Table 6.3 and your answer to **(g)(ii)**, draw an energy cycle to determine a value for **x**. Show your working clearly.

If you were unable to calculate a value for the standard enthalpy change of combustion of carbon in **(g)(ii)**, you should use –450 kJ mol^{-1}. This is **not** the correct answer.

[2]

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

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

The molarity of a buffer is defined as the *total* number of moles of buffering solutes in 1 dm^3 of solution. For example, a 1 dm^3 buffer solution containing 0.3 mol of CH_3COOH and 0.2 mol of CH_3COO^- will have a molarity of 0.5 mol dm^{-3}.

Potassium hydrogen phthalate is a salt that contains the monoanion of benzene-1,2-dicarboxylic acid, HA^-.

(ii) 250 cm^3 of buffer solution at pH 5.0 is prepared by adding 0.1 mol dm^{-3} NaOH(aq) to solid potassium hydrogen phthalate and the resulting solution is made up to 250 cm^3. The molarity of this buffer is 0.1 mol dm^{-3}.

Given that the pK_a of the monoanion of benzene-1,2-dicarboxylic acid, HA^-, is 5.40, calculate the volume of NaOH(aq) required.

[2]

[Total: 21]