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MINISTRY OF EDUCATION, SINGAPORE in collaboration with CAMBRIDGE ASSESSMENT INTERNATIONAL EDUCATION General Certificate of Education Advanced Level





CHEMISTRY

Paper 2 Structured Questions

8873/02

October/November 2022

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name in the spaces provided 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. DO NOT WRITE ON ANY BARCODES.

Section A Answer all the 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.

This document consists of 23 printed pages and 1 blank page.



Singapore Examinations and Assessment Board

Cambridge Assessment



Section A

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

1 (a) (i) Draw the 'dot-and-cross' diagram for a molecule of ammonia, NH₃.



(ii) State the bond angle in a molecule of ammonia and the name of the shape of the molecule.

Explain your answers using the Valence Shell Electron Pair Repulsion theory.

Bond angle is **107°**: Shape is **trigonal pyramidal**. Electron pairs around the central atom arrange themselves to be as far away from each other as possible to minimise inter-electronic repulsion. Order of repulsion: lone pair-lone pair > lone pair-bond pair > bond pair-bond pair. There are 3 σ bond pairs and 1 lone pair around the central nitrogen in NH₃, hence giving a trigonal pyramidal shape with a bond angle slightly smaller than 109.5°.

(iii) Deduce whether ammonia is a polar molecule.

Explain your answer.

Each **N–H bond is polar**. The **dipoles** due to the three N–H bonds **do not cancel** each other in the trigonal pyramidal arrangement. Hence ammonia is a **polar** molecule.

(b) (i) Draw a 'dot-and-cross' diagram for a molecule of nitrogen dioxide, NO₂.

Assume that each molecule contains a N–O single bond and a N=O double bond and that each oxygen atom has 8 electrons in its outer shell.

[1]

[1]

(ii) Suggest a value for the bond angle in a molecule of NO₂. Explain your answer.
 <u>130°</u>. This is because the **unpaired** electron on N will **occupy less space** than the two electron pairs, giving an angle larger than the ideal 120° for a trigonal planar. [1]
 [Total: 7]



(a) Electron affinity is a measure of the attraction of the nucleus for an incoming electron.

The factors which affect the attraction between the nucleus and the incoming electron are the same as those which affect ionisation energy: the charge on the nucleus, shielding by inner electrons and the distance of the outer electron shell from the nucleus.

The first electron affinity is defined as the amount of energy released when one mole of gaseous atoms gains one mole of electrons to form one mole of gaseous 1– ions.

$$X(g) + e^{-} \rightarrow X^{-}(g)$$

A stronger attraction between the nucleus and the electron releases more energy.

(i) Suggest what happens to the magnitude of the first electron affinity across Period 3 elements from sodium to chlorine. Explain your answer.

Across Period 3 from Na to Cl, first electron affinity involves adding one electron to the

valence shell of the gaseous atom of the element. Since nuclear charge increases

across the Period due to an increase in the number of protons in the nucleus, while

shielding remains essentially constant as the core electrons remains the same. Hence

effective nuclear charge experienced by the incoming electron increases across the

Period, resulting in stronger attraction between the nucleus and the incoming electron,

releasing more energy, giving a higher magnitude of the first electron affinity. [3]

(ii) Suggest an equation to represent the second electron affinity of X.

 $X^{-}(g) + e^{-} \rightarrow X^{2-}(g)$ [1]

(b) The charge on an electron is -1.60×10^{-19} coulombs.

Magnesium reacts with chlorine to form magnesium chloride, $MgCl_2$. Calculate the charge removed from one mole of magnesium atoms as they form one mole of magnesium chloride, $MgCl_2$. Show your working.

$$\begin{split} \text{Mg}(g) &\to \text{Mg}^{2*}(g) + 2e^{-} \\ \text{amount of electrons removed} = 2 \times \text{amount of Mg} \\ &= 2 \text{ mol} \\ \text{charge of 1 mole of electrons} = -1.60 \times 10^{-19} \times 6.02 \times 10^{23} \\ &= -96320 \text{ coulombs} \\ \text{charge removed from 1 mole of Mg atoms} = 2 \times -96320 \\ &= -192640 \text{ coulombs} \end{split}$$

charge removed = -192640 coulombs [2]

[Total: 6] [Turn over







3 Soaps and detergents are both used to clean many surfaces including skin.

The ions present in some water samples make it difficult for soap to work effectively because the ions in the water react with the soap. Detergents are not affected by these ions.

Δ

Hair shampoo contains detergent and anionic surfactant molecules.

After a few days of not washing hair, it feels greasy and looks dull. This is because the skin produces a covalently-bonded oily substance which coats and protects the hair and gives it a natural shine. But when the oily substance builds up it causes strands of hair to stick together and particles, such as dust and pollen, stick to it.

Detergent and anionic surfactant molecules in the shampoo have two distinct parts. Each molecule has a hydrophilic head which bonds to water molecules and a hydrophobic tail which bonds to the oily substance, as shown in Fig. 3.1.

hydrophilic head, < bonds to water

hydrophobic tail, bonds to oily substance

Fig. 3.1

The anionic surfactant molecules contain a negative charge at the hydrophilic head. This increases the solubility of the oily substance and so it does not bond to the hair. The oily substance, detergent and surfactants can be rinsed out of the hair with water.

To give the hair back its shiny look and soft feel, conditioners are often used after shampoo. Conditioners often contain cationic surfactant molecules which have a positive charge at the hydrophilic head. These cationic surfactant molecules bond to individual hair strands and do not rinse off the hair.

(a) One type of solid soap is called sodium stearate, $C_{18}H_{35}O_2Na$.

A solution of sodium stearate in water reacts with dissolved calcium and magnesium ions in water to form a solid scum.

Write an equation including state symbols for the reaction of sodium stearate with dissolved calcium ions.

 $2C_{18}H_{35}O_{2}Na(aq) + Ca^{2+}(aq) \rightarrow (C_{18}H_{35}O_{2})_{2}Ca(s) + 2Na^{+}(aq)$ [2]

(b) (i) Detergents are often made from chemicals found in crude oil (petroleum).

Suggest which elements are in the organic hydrophobic part of the detergent molecule.

carbon and hydrogen [1]

(ii) Suggest what type of bonding is within the hydrophobic part of the detergent molecule.

Explain your answer.

Non-polar covalent bonds as carbon and hydrogen are non-metals with similar

electronegativity. [1]

34



(iii) Suggest the forces of attraction that exist between the hydrophobic parts of the detergent molecule and the oily substance.

Instantaneous dipole-induced dipole attraction since the hydrophobic part of the

detergent molecule is hydrocarbon in nature, which is non-polar.

(c) Suggest the forces of attraction that exist between the hydrophilic parts of the detergent molecule and water.

Hydrogen bonding since the hydrophilic parts of the detergent molecule is able to bond

strongly with water, rinsing out with water. [1]

(d) Suggest the forces of attraction that exist between the cationic surfactant molecules in conditioners and hair.

Ionic bonding since the cationic surfactant molecules bond to the hair but do not rinse off,

the interaction with hair must be stronger than its ion-dipole interaction with water.

(e) Suggest why the cationic surfactants in conditioner cannot be rinsed off the hair and the anionic surfactants in shampoo can be rinsed off the hair.

The hair strands must have been negatively charged. The positive hydrophilic head of the

cationic surfactant forms strong electrostatic forces of attraction with the hair strands,

hence cannot be rinsed off. On the other hand, **repulsion** between the hair strands and the

negative hydrophilic head of the anionic surfactants facilitates their rinsing off the hair.

[Total: 9]





(a) A farmer finds that the shells of several eggs from his hens crack when they are picked up. He sends some eggs to a chemist to find the percentage of calcium carbonate in the eggshell. The eggshells of hens should be a minimum of 88% calcium carbonate so that they do not crack. If it is less than 88% then the feed given to the hens will need to be changed.

6

The chemist grinds the eggshells into a powder and then adds 3.62g of the eggshell powder to 100 cm^3 of $0.500 \text{ mol dm}^{-3}$ hydrochloric acid. The acid reacts with the calcium carbonate in the eggshell powder.

 $CaCO_{3}(s) + 2HCl(aq) \rightarrow CaCl_{2}(aq) + CO_{2}(g) + H_{2}O(I)$

The acid is in excess.

When the reaction stops, the chemist transfers the mixture to a volumetric flask and dilutes the solution to 250 cm³ with deionised water.

 $25.0 \,\text{cm}^3$ of this diluted solution requires $20.40 \,\text{cm}^3$ of $0.0500 \,\text{mol}\,\text{dm}^{-3}$ aqueous sodium hydroxide for complete reaction.

(i) Suggest how the chemist knows when the reaction between the eggshell powder and dilute hydrochloric acid is complete.

When the eggshell powder is not longer visible or is seen to have completely dissolved

and there is no more effervescence or bubbling observed.
[1]

(ii) Explain why the chemist does **not** use sulfuric acid to react with the calcium carbonate in the eggshell powder.

 $CaCO_{3}(s) + H_{2}SO_{4}(aq) \rightarrow CaSO_{4}(s) + CO_{2}(g) + H_{2}O(I)$

This is because the CaSO₄ formed being insoluble, will coat the surface of the eggshell

powder particles, preventing further reaction of the CaCO₃ inside the particle. [1]





(iii) Table 4.1 shows some data on six indicators.

indicator	colour in acid	colour in alkali	pH range of colour change
methyl orange	red	yellow	3.2 - 4.4
methyl red	red	yellow	4.8 - 6.0
bromocresol purple	yellow	purple	5.2 – 6.6
bromothymol blue	yellow	blue	6.0 - 7.6
phenolphthalein	colourless	pink	8.2 – 10.0
thymolphthalein	colourless	blue	8.8 – 10.5

Table 4	4.1	
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The volume of sodium hydroxide used to neutralise the hydrochloric acid is determined by titration.

State and explain which indicator is the most suitable for the neutralisation of hydrochloric acid by aqueous sodium hydroxide.

The pH when the strong acid, hydrochloric acid, is just neutralised by the strong base, aqueous sodium hydroxide, is **neutral at pH 7**. Hence an indicator with a pH range of colour change including pH 7, that is, **bromothymol blue**, is more suitable.

(iv) Calculate the number of moles of calcium carbonate in the eggshell powder.

amount of NaOH used = $\frac{20.40}{1000} \times 0.0500 = 1.02 \times 10^{-3}$ mol NaOH + HCl \rightarrow NaCl + H₂O amount of HCl in 25.0 cm of diluted solution = amount of NaOH used = 1.02×10 mol amount of HCl in 250 cm³ of diluted solution = $\frac{250}{25.0} \times 1.02 \times 10^{-3} = 1.02 \times 10^{-2}$ mol initial amount of HCl present = $\frac{100}{1000} \times 0.500 = 0.0500$ mol amount of HCl reacted with eggshell = $0.0500 - 1.02 \times 10^{-2} = 0.0398$ mol amount of CaCO₃ present in eggshell = $\frac{1}{2} \times \text{amount of HCl}$ reacted = $\frac{1}{2} \times 0.0398 = 0.0199$ mol

- [5]
- (v) Calculate the percentage of calcium carbonate in the eggshell. State if the farmer needs to change the feed.

mass of CaCO₃ in the eggshell = $0.0199 \times (40.1 + 12.0 + 16.0 \times 3) = 1.992$ g

percentage by mass of CaCO₃ in eggshell = $\frac{1.992}{3.62} \times 100 = \frac{55.0\%}{500}$

Since the percentage of calcium carbonate in the eggshell is less than 88%, the farmer **needs to change the feed**.





(b) (i) The percentage of calcium carbonate in the eggshell can also be calculated by heating the eggshell.

When the reaction is carried out in a closed system, an equilibrium is set up.

 $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

Deduce the effect of increasing the pressure on this equilibrium reaction.

Explain your answer.

Upon increasing the pressure, by Le Chatelier's Principle, the system will attempt to

counter this change by decreasing the pressure of CO₂, shifting the position of

equilibrium to the left side, with no gaseous particles. [2]

(ii) Calcium oxide reacts with water to produce a solution. The solution forms a white precipitate on reaction with carbon dioxide gas.

Suggest the equation for the reaction of calcium oxide with water. Include state symbols.

 $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ [1]

[Total: 14]







5 Geosmin is one of the chemicals responsible for the earthy smell after rain.

geosmin



(a) Deduce the molecular formula of geosmin.
C₁₂H₂₂O [1]
(b) Geosmin reacts with concentrated sulfuric acid at 170 °C.
(i) State the type of reaction which occurs.
elimination [1]
(ii) Suggest the structure of the product formed.



[1]

- (c) Geosmin reacts with ethanoic acid in the presence of concentrated sulfuric acid.
 - (i) State the type of reaction which occurs.

condensation [1]

(ii) Suggest the structure of the product formed.



[1]





(d) When grass is cut it releases chemicals which give the characteristic freshly-cut grass smell.

One of these chemicals is $CH_3CH_2CH_2CH=CHCH_2OH$.

(i) Draw and identify the *cis* and *trans* isomers of $CH_3CH_2CH_2CH=CHCH_2OH$.



[2]

(ii)	State what feature of the double bond allows this molecule to show <i>cis-trans</i> isomerism.
	Restricted rotation about the carbon-carbon double bond.
(iii)	Suggest a chemical test to confirm the presence of the alkene functional group in $CH_3CH_2CH_2CH=CHCH_2OH$.
	Add orange aqueous bromine. [1]
(iv)	For the chemical test suggested in (iii), state the observation that confirms the presence of the alkene functional group.
	Decolourisation of the orange aqueous bromine.
	[1]
	[Total: 10]





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(a) When magnesium reacts with dilute hydrochloric acid, the rate of reaction changes with time. The concentration versus time graph for this reaction is shown in Fig. 6.1.

concentration of HCl(aq)





Explain in term of particles why the rate of this reaction decreases with time.

As reaction proceeds, the number of H⁺(aq) particles per unit volume decreases with time as they collide and react with the Mg atoms on the surface of the solid Mg. The frequency of collision of H⁺(aq) with the Mg atoms decreases with time, leading to a decrease in the frequency of effective collision, and hence a decrease in the rate of reaction with time. [2]





(b) Some transition metals and their cations can act as catalysts in reactions.

When aqueous ethanedioic acid, $(COOH)_2$, reacts with acidified manganate(VII) ions, a different curve is obtained. This curve is shown in Fig. 6.2.



Fig. 6.2

The reaction starts slowly, speeds up and then slows down.

(i) An exothermic reaction can produce a curve of this shape.

Explain in terms of particles why an increase in rate may be seen during an exothermic reaction.

During an exothermic reaction, heat is released to the surrounding causing the particles

to move faster, resulting in an increase in the frequency of collision and hence the

frequency of effective collision. Secondly, the number of particles with energy greater

than or equals to the activation energy increases, resulting in an increase in the [2]

frequency of effective collision too. When the frequency of effective collision increases,

the rate is seen to increase.





(ii) This reaction is done in a water bath with a constant temperature of 60 °C.

The equation for this reaction is shown.

 $5(\text{COOH})_2(\text{aq}) + 2\text{MnO}_4^-(\text{aq}) + 6\text{H}^+(\text{aq}) \rightarrow 2\text{Mn}^{2+}(\text{aq}) + 10\text{CO}_2(\text{g}) + 8\text{H}_2\text{O}(\text{I})$ Suggest why the rate of this reaction is low at the beginning and increases during the reaction. Iow rate at the beginningThe activation energy of the reaction between (COOH)_2... and MnO_4^- is very high and there is no Mn²⁺ catalyst present. Hence, despite heating to 60 °C, the proportion of reacting particles with energy higher than or equal to the activation is low, leading to a low rate at the beginning. Increasing rate during the reaction ...Mn²⁺ acts as a catalyst, providing an alternative reaction pathway with lower activation energy. As reaction proceeds, the concentration of Mn²⁺ increases, causing the proportion of reacting particles with energy higher than or equals to this lower activation energy to increase, hence increasing the rate. [2] Suggest what causes this reaction to stop. This reaction stops when at least one of the reactant is completely used up.

[Total: 7]

(iii)







7 (a) Hydrogen has three isotopes, ${}_{1}^{1}H$, ${}_{1}^{2}H$ and ${}_{1}^{3}H$.

Explain the meaning of the term isotope. Use the three isotopes of hydrogen as examples to explain your answer.

Isotopes are nuclides having the same number of protons but different number of neutrons.

¹₁H, ²₁H and ³₁H all possesses 1 proton, but 0, 1 and 2 neutrons in the nucleus respectively.

......[2]

(b) Boron has only two naturally occurring stable isotopes, ¹⁰B and ¹¹B.

The relative atomic mass of a sample of boron which contains only these two isotopes is 10.8.

Calculate the relative abundance of each of the two stable isotopes.

Show your working.

Let the percentage abundance of ¹⁰B be x%. Hence the percentage abundance of ¹¹B is (100–x)%.

 $\frac{x}{100} \times 10 + \frac{100 - x}{100} \times 11 = 10.8$ 10x + 1100 - 11x = 1080x = 20.0

Hence, percentage abundance of ¹⁰B is <u>20.0%</u>, while that of ¹¹B is <u>80.0%</u>.

(c) Complete the electronic configuration of each species.

²³ ₁₁ Na ⁺	$1s^2 \frac{2s^2 2p^6}{2s^2 2p^6}$	
³² 16 S²	$1s^2 \frac{2s^2 2p^6 3s^2 3p^6}{2s^2 3p^6}$	
⁶⁰ 27 Co	$1s^2 \frac{2s^2 2p^6 3s^2 3p^6 3d^7 4s^2}{1s^2}$	[3]

[Total: 7]

[2]





15 Section B

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

8 (a) State what is meant by each of the terms ionic bond, covalent bond and metallic bond.
 Include electrostatic attraction in each of your answers.

ionic bond <u>Electrostatic forces of attraction between oppositely charged ions</u>. covalent bond <u>Electrostatic forces of attraction between two nuclei and their shared pair of</u>... electrons.

metallic bond <u>Electrostatic forces of attraction between the sea of delocalised electrons</u> and the residual cations.

(b) Explain why diamond has a melting point of approximately 4000 °C and methane has a lower melting point of –182 °C.

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

Diamond has a giant covalent structure, where each carbon atom is tetrahedrally bonded to four other carbon atoms in an extended covalent lattice by strong single covalent bonds. In order to melt diamond, all the strong C–C bonds in the lattice must be broken, hence a large amount of energy is needed, resulting in a very high melting point of ~4000 °C. Methane has a simple covalent structure, where each carbon atom is tetrahedrally bonded to four hydrogen atoms by strong C–H bonds giving discrete CH_4 molecules. As the C–H bond is non-polar, the resulting non-polar CH_4 molecules are held together by weak instantaneous dipole-induced dipole forces of attraction. Melting of methane involves overcoming these weak intermolecular forces of attraction, which requires very little energy, hence the very low melting point of –182 °C.



c) Bonds in a carbon dioxide molecule are made using s orbitals and p orbitals.

Draw labelled diagrams to show the ways in which these two orbitals can be used to make a σ bond and a π bond.



[2]

(d) The expression for K_c for an equilibrium reaction is shown.

$$K_{c} = \frac{[A]^{2}[B]}{[C][D]^{3}}$$

(i) Deduce the equation which represents this equilibrium.

- (ii) Deduce the units of K_c . units of $K_c = \frac{(\text{mol } dm^{-3})^2 (\text{mol } dm^{-3})}{(\text{mol } dm^{-3})^3} = \text{mol}^{-1} dm^3$ units of $K_c = \dots \text{mol}^{-1} dm^3$ [1]
- (iii) When the equilibrium is established at a lower temperature, the value of K_c increases.

State and explain what can be deduced about this equilibrium reaction.

 $K_{\rm c}$ increases means that the position of equilibrium shifted to the right at a lower

temperature. The forward reaction must have been exothermic, hence favoured

giving out heat in attempt to counter the lower temperature. [2]

(e) KMnO₄ reacts with sodium sulfite and water. The reaction can be represented by the equation shown.

 $3Na_2SO_3 + 2KMnO_4 + H_2O \rightarrow 3Na_2SO_4 + 2MnO_2 + 2KOH$

Identify the species being oxidised and the species being reduced in this reaction. Include the oxidation numbers in your answer.

The sulfite ion SO_3^{2-} is oxidised as the oxidation number of sulfur increases from +4 in

 SO_3^{2-} to +6 in SO_4^{2-} .

The manganate(VII) ion MnO₄- is reduced as the oxidation number of manganese

decreases from +7 in MnO_4^- to +4 in MnO_2 . [2]





(f) (i) Define the standard enthalpy change of formation.

Standard enthalpy change of formation of a compound is the energy change when one

mole of the compound is formed from its constituent elements, all in their standard

states at 1 bar and 1 mol dm⁻³, at a specified temperature. [1]

(ii) A scientist made glucose from carbon, hydrogen and oxygen.

$$6C(s) + 6H_2(g) + 3O_2(g) \longrightarrow C_6H_{12}O_6(s)$$

The enthalpy change of formation of this reaction is difficult to measure directly.

Calculate the standard enthalpy change of formation of glucose using the data in Table 8.1 and the energy cycle in Fig. 8.1.

$\Delta H_{c}^{\Theta}(g ucose(s)) / kJmol^{-1}$	-2801
$\Delta H_{f}^{\Theta}(H_{2}^{O}(I)) / kJ mol^{-1}$	-286
$\Delta H_{f}^{\Theta}(CO_{2}(g)) / kJmol^{-1}$	393.5

Table 8.1





$$\begin{split} \Delta H_{f}^{\oplus} \left(glucose\left(s\right) \right) &= 6 \Delta H_{f}^{\oplus} \left(CO_{2} \left(g\right) \right) + 6 \Delta H_{f}^{\oplus} \left(H_{2}O(I) \right) - \Delta H_{c}^{\oplus} \left(glucose\left(s\right) \right) \\ &= 6 \times \left(-393.5 \right) + 6 \times \left(-286 \right) - \left(-2801 \right) \\ &= -1276 \text{ kJ mol}^{-1} \end{split}$$

[3]

[Total: 20]

[Turn over

2 e

9 (a) State and explain the trend in volatility down Group 17.

Down Group 17, the number of electrons and hence the size of the electron cloud in the diatomic X₂ molecules increases. The polarisability of the X₂ molecules increases, resulting in stronger instantaneous dipole-induced dipole attractions between the X₂ molecules. Hence, more energy is needed to overcome the stronger intermolecular forces of attraction in order to vapourise to give X₂(g) molecules. Thus **volatility decreases** down Group 17. [3]

- (b) Reactivity decreases down Group 17.
 - (i) Write an ionic equation for the reaction of chlorine gas with aqueous potassium iodide.
 Cl₂(g) + 2I⁻(aq) → I₂(aq) + 2Cl⁻(aq) [1]
 - (ii) State which substance in this reaction is the reducing agent.

Explain your answer.

I⁻ is the reducing agent. This is because it reduces Cl from a 0 oxidation state in Cl_2 to

- <u>-1 in Ct</u>. [1]
- (c) State and explain the trend in thermal stability of the hydrides of Group 17.

Include data from the Data Booklet in your answer.

Thermal stability of the hydrides of Group 17 **decreases** down the Group. This is because

the H–X bond becomes weaker down the Group, requiring less energy to break the bond, as

seen in the decrease in H–X bond energy from 562 kJ mol⁻¹ for HF, to 431 kJ mol⁻¹ for HC $l_{\rm L}$

- to 386 kJ mol⁻¹ for HBr, to 299 kJ mol⁻¹ for HI. [2]
- (d) Hydrogen chloride dissolves in water to form hydrochloric acid.

Hydrochloric acid is a strong Brønsted-Lowry acid.

(i) Explain the meaning of the term strong Brønsted-Lowry acid.

A strong Brønsted-Lowry acid is one which **completely dissociates** in water to give

- H⁺(aq) ions. [1]
- (ii) Calculate the pH of 0.0124 mol dm⁻³ hydrochloric acid. Give your answer to three significant figures.

 $pH = -lg[H^{+}(aq)] = -lg(0.0124)$ = **1.91**





(e) Sodium and sulfur are both in Period 3 of the Periodic Table.

The melting point of sodium oxide is 1275°C and of sulfur trioxide is 17°C.

(i) Explain how the electronegativity of these elements influences the bonding in each oxide.

As O is highly electronegative, Na with a much lower electronegativity results in ionic

bonding, while S with a moderate electronegativity results in polar covalent bonding. [1]

(ii) Explain the difference in melting points of the two oxides. Include the structure of each oxide in your answer.

Na₂O has a giant ionic structure with strong electrostatic forces of attraction between

the oppositely charged Na⁺ and O²⁻ ions in the lattice. Hence, large amount of energy

is required to overcome the strong ionic bonds giving a high melting point of 1275 °C.

 SO_3 has a simple covalent structure where discrete non-polar SO_3 molecules are held

together by weak instantaneous dipole-induced dipole attractions. Hence, a small

amount of energy is required to overcome the weak intermolecular forces giving a [4] lower melting point of 17 °C.

* 0015974195220 *



20

(f) A student does an experiment to find the enthalpy change of combustion of ethanol.

The apparatus is shown in Fig. 9.1.





The student burns the ethanol for 10 minutes.

Table 9.1 shows the data recorded by the student.

mass of water / g	150
initial temperature of water / °C	22.5
final temperature of water / °C	44.0
initial mass of spirit burner and ethanol /g	49.63
final mass of spirit burner and ethanol /g	48.98

The specific heat capacity of water is $4.18 \text{ Jg}^{-1} \text{ K}^{-1}$.

(i) Calculate the energy given out by the ethanol. Use the data in Table 9.1.

energy given out by ethanol = $mc\Delta T = 150 \times 4.18 \times (44.0 - 22.5)$ = 13480.5 J , \approx **13500 J**

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[1]



(ii) Calculate the enthalpy change of combustion of the ethanol, $\Delta H_c(C_2H_5OH)$. mass of ethanol used = 49.63 - 48.98 = 0.65 g amount of ethanol used = $\frac{0.65}{12.0 \times 2 + 1.0 \times 6 + 16.0}$ = 0.01413 mol ethalpy change of combustion of ethanol = $-\frac{13480.5}{0.01413}$ J mol⁻¹ = -954034 J mol⁻¹

21

 $\approx -954 \text{ kJ mol}^{-1}$



[2]

* 0015974195222 *



(g) The enthalpy change of combustion of four alcohols are shown on the graph in Fig. 9.2.

22



Fig. 9.2





(i) On the grid, plot the value for the enthalpy change of combustion calculated in (f)(ii).

If you were unable to obtain a value in **f(ii)**, please use the value of –14690.3 J. This is **not** the correct answer. Draw the best-fit straight line.

(ii) Describe the relationship between the enthalpy change of combustion and the number of carbon atoms in the alcohol.

The enthalpy change of combustion decreases linearly, that is, becomes more

exothermic, with the number of carbon atoms in the alcohol.

(h) The value the student obtained for the enthalpy change of combustion in (f)(ii) is less negative than the actual value.

Suggest what might have caused this value to be less negative than expected. Do not include errors in measurement.

Not all the heat produced from the combustion of ethanol is transferred to the water.

Substantial heat is lost to the surrounding, including the tripod, wire gauze and beaker. [1]

[Total: 20]

[1]





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