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CANDIDATE NAME	EUNOIA JUNIOR COLLEG	
CENTRE NUMBER	S	INDEX NUMBER
CHEMIST	ſRY	8873/02
Paper 2 Struc	tured Questions	October/November 2023 2 hours
Candidates ar	swer 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 18 printed pages and 2 blank pages.



Cambridge Assessment



Section A

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

1 (a) Complete Table 1.1 for each species.

Table 1.1

species	number of protons	number of neutrons	number of electrons	electronic configuration
²⁵ 12 ^{Mg}	12	13	12	1 s ² .2s ² .2p ⁶ .3s ²
$^{26}_{12}\text{Mg}^{2+}$	12	14	10	1 s ² .2s ² 2p ⁶
	······································	· · · · · · · · · · · · · · · · · · ·	k	[4]

(b) Magnesium oxide, aluminium oxide and sulfur(VI) oxide are each added to separate samples of dilute sulfuric acid and aqueous sodium hydroxide.

Write equations to show any reactions which occur.

	magnesium oxide
	$MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$
	MgO + NaOH \rightarrow no reaction
	aluminium oxide
	$Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$
	$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$
	sulfur(VI) oxide
	SO ₃ + H ₂ O \rightarrow H ₂ SO ₄ (sulfur(VI) oxide dissolves in water in dilute sulfuric acid)
	$SO_3 + 2NaOH \rightarrow Na_2SO_4 + H_2O$
	[4]
(c)	Explain why potassium is a better reducing agent than sodium.
	Potassium has a larger atomic radius than sodium. The valence electron in potassium is further
	away from the nucleus and thus less strongly attracted by the nucleus. Hence, potassium loses
	its valence electron more readily than sodium, and is a better reducing agent. [2]
	[Total: 10]











2 Water and carbon monoxide are produced when carbon dioxide reacts with hydrogen.

 $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$ ΔH is positive

(a) (i) Draw a 'dot-and-cross' diagram to show the bonding in a molecule of water.



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(ii) State and explain the bond angle in a molecule of water.

The central O atom has 2 σ bond pairs (b.p.) and 2 lone pairs (l.p.) of electrons arranged in a tetrahedral manner. As l.p.–l.p. repulsion > l.p.–b.p. repulsion > b.p.–b.p. repulsion, by VSEPR. the H–O–H bond angle is compressed from ideal 109.5° to <u>105°</u>. [2]

(iii) State whether carbon dioxide is a polar or non-polar molecule.

Explain your answer.

Carbon dioxide is a **non-polar** molecule. Despite the C=O bond being a polar bond due to the higher electronegativity of O compared to C, but due to the linear shape of the O=C=O molecule, the two bond dipoles cancel each other exactly. [2]

(iv) Explain why carbon dioxide is a gas at room temperature.

Non-polar CO_2 molecules are held together by weak instantaneous dipole-induced dipole attractions. Thus, little energy is needed to separate them, giving a low boiling point. [1]

(v) State what happens to the equilibrium yield of carbon monoxide when the temperature is increased.

Explain your answer.

Since the reaction is endothermic, when the temperature is increased, the position of equilibrium shifts to the right, to absorb energy in attempt to counter the increase in temperature, leading to an **increase** in the equilibrium yield of CO.

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(b) (i) Draw a Boltzmann distribution curve for the molecular energies of a gaseous reaction mixture.

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

Label the curve R.

[1]

- (iii) State what happens to the rate of the reaction when the temperature is increased.
 Explain your answer using the curves drawn in (b)(i) and (b)(ii).
 When temperature is increased, the average kinetic energy of the particles increases as seen in the shape of curve R compared to curve T. The frequency of collision
 - increases. In addition, the number of particles with energy greater or equals to E_a [2]

increases as shown by the shaded region. Both factors causes the frequency of

effective collision to increase and hence, the rate of reaction increases.





(c) Hydrochloric acid is a strong acid.

The equation for hydrochloric acid donating a proton is shown.

$$HCl(aq) \rightarrow H^{+}(aq) + Cl^{-}(aq)$$

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Carbon dioxide dissolves in water to form the weak acid, carbonic acid.

$$CO_2(g) + H_2O(I) \rightleftharpoons H_2CO_3(aq)$$

In a reaction where it behaves as an acid, carbonic acid can donate one proton, or it can donate two protons.

(i) Write the equation showing the equilibrium when carbonic acid donates one of its protons.

 $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ [1]

(ii) Write the expression for the equilibrium constant, K_c , for the reaction when carbonic acid donates **both** of its protons.

 $H_2CO_3(aq) \rightleftharpoons 2H^+(aq) + CO_3^{2-}(aq)$

$$\mathcal{K}_{c} = \frac{\left[\mathsf{H}^{+}\left(\mathsf{aq}\right)\right]^{2}\left[\mathsf{CO}_{3}^{2-}\left(\mathsf{aq}\right)\right]}{\left[\mathsf{H}_{2}\mathsf{CO}_{3}\left(\mathsf{aq}\right)\right]}$$

[2]

[Total: 16]





3 (a) Define the term mole.

The mole is the SI unit of amount of substance. One mole contains exactly 6.02×10^{23}

7

^|^{ ^} cæ [^] Á [^]} cãa ³ • [1]

(b) A company making steel nails wants the percentage of iron in each nail to be between 92% and 95%. If it is any higher or lower than this, then the nails are not very strong.

A scientist at the company tests the nails to see if they are of the expected composition.

A nail of mass 6.177 g is added to 250 cm³ of sulfuric acid. The sulfuric acid is in excess.

The iron reacts and forms a soluble iron(II) compound. Other substances in the nail do **not** react and are filtered out of the mixture.

 $25.0 \,\text{cm}^3$ of the iron(II) ion solution reacts exactly with $21.4 \,\text{cm}^3$ of $0.100 \,\text{mol}\,\text{dm}^{-3}$ potassium manganate(VII) solution.

 MnO_4^- + 5Fe²⁺ + 8H⁺ \rightarrow Mn^{2+} + 5Fe³⁺ + 4H₂O

Calculate the percentage of iron in the iron nail.

State whether the nail is of the composition expected.

Show your working.

Ùāj&^Ás@Áj^¦&^}cæ*^Áj,~Áš[}/Áş,Ás@ÁjæanjÁse Ájæ+*^¦Ás@eenjÁlÍÃÉAj,čoAj,~Ás@AJGÃ.JÍÃÁæ);*^Éas@A´ }æanjÁse Á<u>not</u>Áj,~Ás@Á&[{][•ãanj}Á*¢]^&c^åÉA

[4]

[Total: 5]



[3]



4 Kerosene is one of the fractions obtained from the fractional distillation of petroleum. It is commonly used as fuel for jet engines in aeroplanes.

8

Kerosene is a liquid mixture of hydrocarbons whose molecules contain between six and sixteen carbon atoms. These hydrocarbons are flammable. The equation for the combustion of one of these hydrocarbons is shown.

 $C_{13}H_{28}(I) + 20O_2(g) \rightarrow 13CO_2(g) + 14H_2O(g)$ $\Delta H_c = -46 \text{ kJg}^{-1}$

Scientists are investigating the possibility of replacing kerosene liquid with ammonia gas. Ammonia is less flammable than kerosene.

The ammonia gas is heated and passed over a catalyst where it is cracked into nitrogen and hydrogen. The hydrogen is burnt and the exhaust gases from the aeroplane contain **only** nitrogen and water vapour. The enthalpy of combustion is -22 kJ g^{-1} .

In the high temperatures present in a conventional jet engine, nitrogen usually reacts with oxygen and forms oxides of nitrogen. However, oxides of nitrogen are **not** present in the exhaust gases of an aeroplane powered by hydrogen derived from ammonia.

(a) (i) Construct a balanced equation for the cracking of ammonia into nitrogen and hydrogen.

 $2NH_3 \rightarrow N_2 + 3H_2$ ^[1]

(ii) State and explain in terms of oxidation numbers which element is being oxidised and which element is being reduced in (a)(i).

Nitrogen is being oxidised as the oxidation number of N increases from -3 in NH₃ to 0

in N_2 , while hydrogen is being reduced as the oxidation number of H decrease from +1

in NH₃ to 0 in H₂. [2]

(b) Cracking occurs at high temperatures and in the presence of a catalyst. This catalyst provides a surface for the reaction, lowers the activation energy and increases the rate of the reaction.

Suggest another role of this catalyst.

To catalyse the reduction of any oxides of nitrogen formed in the jet engine back to N₂. [1]

(c) Suggest and explain **one** advantage and **two** disadvantages of aeroplanes carrying tanks of ammonia instead of tanks of kerosene.

advantage As ammonia is less flammable than kerosene, there is less danger of a jet fire

and impending explosion should there be a fuel leakage, making ammonia a safer fuel.

disadvantage 1 As ammonia is a gas, which must be compressed and stored at high

pressure, the tanks of ammonia must be thick-walled, making the tanks much heavier.

disadvantage 2 As about half the energy is released per gram of ammonia compared to

kerosene, about twice the mass of ammonia is needed as fuel, making the tanks heavier.





(d) Suggest and explain **one** reason why aeroplanes using ammonia as a fuel are better for the environment than aeroplanes using kerosene.

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The exhaust from aeroplanes using ammonia as a fuel contains only N_2 and $H_2O(g)$, which

are environmentally benigne, while that using kerosene contains CO₂, a greenhouse gas. [1]

(e) Suggest a reason why hydrogen is made from ammonia in the aeroplane instead of the aeroplane carrying tanks of hydrogen gas.

Hydrogen gas is highly flammable rendering its transportation and storage in danger of

explosion. In addition, due to the extremely low density of hydrogen gas, it must be [1]

compressed and stored at extremely high pressures, which is very costly. [Total: 9]



5 The first ionisation energies for the elements sodium to potassium are shown in Fig. 5.1.





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

	First ionisation energy is the energy required to remove one mole of electrons from	•••••
	one mole of neutral gaseous atoms to give one mole of gaseous ions each with a	*****
	charge of 1+.	[2]
(ii)	Write an equation to represent the first ionisation energy of sodium.	
	$Na(g) \rightarrow Na^+(g) + e^-$	[1]

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b) Explain the trend and variation in first ionisation energy of the elements sodium to potassium as shown in Fig. 5.1.

Across period 3 from $_{11}$ Na ([Ne] 3s¹) to $_{18}$ Ar ([Ne] 3s² 3p⁶), the first ionisation energy generally increase as the nuclear charge increases due to increasing number of protons in the nucleus, while the shielding effect is roughly the same since they have the same [Ne] core of electrons which shields the valence 3s and 3p electrons from the nucleus. As a result, the effective nuclear charge generally increases across period 3, causing the valence electrons to be more strongly attracted to the nucleus and more energy is required to remove the first valence electron. There is a dip in the first ionisation energy from 12Mg ([Ne] 3s²) to 13Al ([Ne] 3s² 3p¹) since the electron removed from Al resides in the higher energy 3p orbital compared to the 3s orbital for Mg. Hence less energy is required to remove the 3p electron. There is another dip in the first ionisation energy from $_{15}P$ ([Ne] $3s^2 3p^3$) to $_{16}S$ ([Ne] $3s^2 3p^4$) since the 3p electron removed from S is paired with another 3p electron in one of the 3p orbital, which suffers from interelectronic repulsion and hence, less energy is required to remove this paired 3p electron in S compared to the unpair 3p electron in P. There is a large dip the first ionisation energy from $_{18}$ Ar ([Ne] $3s^2 3p^6$) in period 3 to ₁₉K ([Ar] 4s¹) in period 4 due to the additional shell of now core 3s and 3p electrons, which help to shield the valence 4s electron in K from the additional proton in the nucleus compared to Ar. The first ionisation energy of K is even lower than that of Na, both in group 1, as the valence 4s electron in K is in a quantum shell that is further away from the nucleus than that for the valence 3s electron in Na, hence less strongly attracted by the nucleus.

[Total: 11]





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Ibuprofen, naproxen and diclofenac are three commonly used anti-inflammatory drugs which reduce redness, swelling and pain in the human body.



ibuprofen

naproxen

diclofenac

The dosages and costs of these three drugs are shown in Table 6.1.

Table	6.1	
-------	-----	--

drug	dosage	cost
diclofenac	50 mg two times per day	\$0.50 per 25 mg tablet
ibuprofen	400 mg three times per day	\$0.10 per 200 mg tablet
naproxen	250 mg three times per day	\$1.20 per 250 mg tablet

(a) (i) State the molecular formula of diclofenac.

	C ₁₄ H ₁₁ C <i>l</i> ₂ NO ₂	[1]
(ii)	Calculate the molecular mass of diclofenac.	
	molecular mass = $12.0 \times 14 + 1.0 \times 11 + 35.5 \times 2 + 14.0 + 16.0 \times 2$	

$$= 296.0 \,\mathrm{g}\,\mathrm{mol}^{-1}$$

[1]

[1]

(iii) Calculate the percentage by mass of carbon in diclofenac.

% by mass of C in diclofenac = $\frac{12.0 \times 14}{296.0} \times 100\%$ = 56.8%



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b) Calculate the daily cost of treatment for each drug.

diclofenac

daily cost =
$$2 \times \frac{50 \text{ mg}}{25 \text{ mg/tablet}} \times \frac{\$0.50}{\text{tablet}} = \frac{\$2.00}{\$2.00}$$

ibuprofen

daily cost =
$$3 \times \frac{400 \text{ mg}}{200 \text{ mg/tablet}} \times \frac{\$0.10}{\text{tablet}} = \$0.60$$

naproxen

[2]

- (c) When each drug dissolves in water it forms hydrogen bonds with the water molecules.
 - (i) Name the functional group which is common to all three drugs.

Do not include benzene or an alkyl group.

- Carboxylic acid [1]
- (ii) The functional group identified in (c)(i) is largely responsible for the solubility of the drug in water.

Naproxen is less soluble than ibuprofen.

Explain why.

Both drugs have one $-CO_2H$ group, but naproxen has a larger non-polar hydrocarbon skeleton of two fused benzene rings, which does not interact favourably with water. [1]

(iii) The drugs are often sold as sodium salts.

Suggest which part of a diclofenac molecule reacts with sodium hydroxide to form a sodium salt.

The carboxylic acid, –CO₂H, group [1]

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

Infra-red absorptions are useful in identifying functional groups present in molecules.

One of the bonds in one of the drugs absorbs in the range 3300-3500 cm⁻¹.

Suggest the bond which absorbs in this range and which drug contains this bond.

bond <u>N-H bond</u> drug <u>dichofenac</u>

[1]

[Total: 9]

[Turn over



[3]



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Section B

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

7 (a) (i) Define the term bond energy.

Bond energy is the energy required to break one mole of a gaseous covalent bond by homolysis, averaged over a number of chemical species containing that type of bond

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

 $(CH_3)_3CH$ reacts with bromine to form $(CH_3)_3CBr$.

$$(CH_3)_3CH(g) + Br_2(g) \rightarrow (CH_3)_3CBr(g) + HBr(g)$$

Using bond energies, calculate the enthalpy change of this reaction in kJ mol⁻¹.

enthalpy change = $\sum B.E.(bonds broken) - \sum B.E.(bonds formed)$ = B.E.(C-H) + B.E.(Br-Br) - {B.E.(C-Br) + B.E.(H-Br)} = 410 + 193 - (280 + 366) = <u>-43 kJ mol^{-1}</u>

(b) $(CH_3)_3CBr$ reacts with sodium hydroxide.

 $(CH_3)_3CBr(aq) + NaOH(aq) \rightarrow (CH_3)_3COH(aq) + NaBr(aq)$

Two experiments are done using these reagents.

In reaction 1, the concentration of NaOH is in excess and the concentration of $(CH_3)_3CBr$ is measured every 20 seconds for 160 seconds.

In reaction 2, the concentration of $(CH_3)_3CBr$ is in excess and the concentration of NaOH is measured every 20 seconds for 160 seconds.

The results are shown in Table 7.1.

Table 7.1

time/s	reaction 1 [(CH ₃) ₃ CBr]/moldm ⁻³	reaction 2 [NaOH]/moldm ³
0	1.00	1.00
20	0.74	0.90
40	0.58	0.80
60	0.42	0.70
80	0.32	0.60
100	0.24	0.50
120	0.18	0.40
140	0.13	0.30
160	0.11	0.20



(i) On the grid, plot a graph of $[(CH_3)_3CBr]$ against time.

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Label the line $[(CH_3)_3CBr]$.



- (ii) On the same grid, plot a graph of [NaOH] against time.Label the line [NaOH].
- (iii) Deduce the order of reaction with respect to $(CH_3)_3CBr$.

Use the graph to explain your answer.

Since the graph of $[(CH_3)_3CBr]$ against time shows that the reaction has a constant half-life of 48 s, the reaction is <u>first order</u> with respect to $(CH_3)_3CBr$. [2]

(iv) Deduce the order of reaction with respect to NaOH.

Use the graph to explain your answer.

Since the graph of [NaOH] against time is a straight line with constant rate of reaction, the reaction is **zero order** with respect to NaOH. [2]

[2]

[3]



(v) The rate of reaction is 9.75×10^{-7} moldm⁻³ s⁻¹ when [(CH₃)₃CBr] is 0.15 moldm⁻³ and [NaOH] is 0.25 moldm⁻³.

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Calculate the rate constant for this reaction and state its units. rate = $k [(CH_3)_2 CBr]$

$$k = \frac{\text{rate}}{\left[\left(CH_{3}\right)_{3} CBr\right]}$$

= $\frac{9.75 \times 10^{-7} \text{ mol dm}^{-3} \text{ s}^{-1}}{0.15 \text{ mol dm}^{-3}}$
= **6.50** × **10**⁻⁶ s⁻¹

- (c) Sodium hydroxide is a strong Brønsted-Lowry base.
 - (i) Define the term strong Brønsted-Lowry base.

A strong Bronsted-Lowry base is a compound which is completely protonated by H⁺.

(ii) State the mathematical expression for pH.

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

A buffer solution is prepared by dissolving ammonium chloride in aqueous ammonia.

 $\begin{aligned} \mathsf{NH}_3(\mathsf{g}) + \mathsf{H}_2\mathsf{O}(\mathsf{I}) &\longrightarrow \mathsf{NH}_4^+(\mathsf{aq}) + \mathsf{OH}^-(\mathsf{aq}) \\ \mathsf{NH}_4\mathsf{Cl}(\mathsf{s}) + \mathsf{aq} &\longrightarrow \mathsf{NH}_4^+(\mathsf{aq}) + \mathsf{Cl}^-(\mathsf{aq}) \end{aligned}$

(iii) Explain what is meant by the term *buffer solution*.

A buffer solution is a solution which is able to resist a change in pH (*i.e.* pH remains

almost unchanged) when a small amount of acid or base is added to it. [1]

(iv) Write an equation to show what happens when a small amount of aqueous sodium hydroxide is added to the buffer solution.

 $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ [1]

[Total: 20]

[2]

[1]





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(a) Explain in terms of bonds why a reaction is exothermic.

A reaction is exothermic when more energy is given out during the formation of new bonds

in the products, compared to energy taken in to break the bonds in the reactants.

(b) Butane, C_4H_{10} , is a type of LPG (liquid petroleum gas) which is used in portable gas heaters.

An energy cycle involving the burning of butane under standard conditions is shown in the diagram.



(i) State the name of the enthalpy change ΔH_1 .

standard enthalpy change of formation of gaseous butane

(ii) Write an equation to show the relationship between the ΔH_1 , ΔH_2 and ΔH_3 shown in the diagram.

 $\Delta H_2 = 2\Delta H_1 + \Delta H_3 \tag{1}$

(iii) Use the data and your answer from (b)(ii) to calculate a value, in kJ mol⁻¹, for ΔH_1 .

 $\Delta H_c^{\Theta} \text{ butane } = -2878 \text{ kJ mol}^{-1}$ $\Delta H_c^{\Theta} \text{ carbon } = -393 \text{ kJ mol}^{-1}$ $\Delta H_c^{\Theta} \text{ hydrogen } = -286 \text{ kJ mol}^{-1}$

Show your working.

$$\Delta H_{2} = 8\Delta H_{c}^{\oplus} \text{ carbon} + 10\Delta H_{c}^{\oplus} \text{ hydrogen} = 8(-393) + 10(-286) \text{ kJ mol}^{-1}$$

= -6004 kJ mol⁻¹
$$\Delta H_{3} = 2\Delta H_{c}^{\oplus} \text{ butane} = 2(-2878) \text{ kJ mol}^{-1}$$

= -5756 kJ mol⁻¹
$$\Delta H_{1} = \frac{\Delta H_{2} - \Delta H_{3}}{2} = \frac{-6004 - (-5756)}{2} \text{ kJ mol}^{-1}$$

= -124 kJ mol⁻¹

[3]



(c) Explain why but-2-ene is able to show *cis-trans* isomerism but ethene is not. But-2-ene is able to show *cis-trans* isomerism because there are two different groups on each of the C=C carbon, namely, a methyl group and a hydrogen atom. Hence, the two methyl groups can be on the same side of the C=C in the *cis* isomer or on opposite side in the *trans* isomer. Ethene is unable to show *cis-trans* isomerism as each of the C=C carbon possesses two identical groups, namely, two hydrogen atoms. Hence there is no spatial differentiation between the relative positions of the groups about the C=C.

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(d) A gaseous organic compound X contains carbon, hydrogen and oxygen only.

X contains 64.9% by mass of carbon and 13.5% by mass of hydrogen.

2.56 g of **X** occupies 830 cm^3 at room temperature and pressure.

(i) Calculate the empirical formula of X.

In 100 g of X	С	Н	0
mass / g	64.9	13.5	21.6
amount / mol	$\frac{64.9}{12.0} = 5.41$	$\frac{13.5}{1.0} = 13.5$	$\frac{21.6}{16.0} = 1.35$
mole ratio	4	10	1

Empirical formula is $\underline{C_4H_{10}O}$.

(ii) Calculate the molecular formula of X.

 $n_{\rm X}$ in 2.56 g of ${\rm X} = \frac{830}{24000} = 0.03458$ mol molar mass of ${\rm X} = \frac{2.56}{0.03458} = 74.0$ g mol⁻¹ Let ${\rm X}$ be ${\rm C}_{4n}{\rm H}_{10n}{\rm O}_n$. $n(12.0 \times 4 + 1.0 \times 10 + 16.0) = 74.0$ n = 1Molecular formula is <u>C₄H₁₀O</u>. [2]

[2]

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- e) Carbon exists in a number of forms including diamond and graphene.
 - (i) Graphene is a nanomaterial.

Define what is meant by the term nanomaterial.

Nanomaterials are materials which have structured components with at least one
dimension in the size range between 1 to 100 nm.

- (ii) Describe the structure, bonding and properties of diamond and graphene.
 - Diamond has a giant molecular structure consisting of network of carbon atoms each tetrahedrally covalently bonded to four other carbon atoms via strong C-C single bonds in a 3-dimensional lattice structure. Diamond is hard, strong and non-malleable as the carbon atoms are held closely together by strong C–C bonds in the giant lattice structure. In addition, as large amount of energy is needed to overcome the network of strong C–C bonds, diamond has high melting and boiling points. Diamond is a non-conductor of electricity as all the electrons are localised in the covalent bonds and are not mobile to conduct electricity. Graphene has a giant molecular structure consisting of a single layer of carbon atoms with each carbon atom bonded to three other carbon atoms by strong covalent bonds to form a network of hexagonal rings. The remaining lone electron from each unhybridised p orbital delocalised over the whole lattice structure, making the C–C bond stronger. As a large amount of energy is required to break the network of strong C–C bonds, graphene will have high tensile strength, as well as high melting and boiling points. Graphene is a good electrical conductivity as there is one lone electron on each carbon atom that is delocalised in the structure. The free mobile electrons move in the presence of an applied electric field. [5]

[Total: 20]



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