A LEVEL Cambridge Topical Past Papers

CHEMISTRY

PAPER 2 2020 — 2025

1 - (9701/21_Summer_2020_Q2) ANSWER

(a) The equation shown in **(a)(i)** describes the reaction which occurs when aqueous potassium iodide is added to aqueous copper(II) sulfate. A white precipitate of copper(I) iodide forms in a brown solution of iodine and potassium sulfate.

(i) Balance the equation and include state symbols.

......$CuSO_4$(.....) + ...KI(.....) → ......CuI(.....) + ...I_2(.....) + ...K_2SO_4(.....)

[2]

The table gives the oxidation numbers of iodine in the different species in the equation.

iodine-containing species	oxidation number of iodine
KI	–1
CuI	–1
I_2	0

(ii) Deduce the oxidation number of copper in $CuSO_4$ and CuI.

- oxidation number of copper in $CuSO_4$ ....
- oxidation number of copper in CuI ....

[1]

(iii) Describe the type of reaction shown by the equation in **(a)(i)**. Explain your answer in terms of electron transfer.

....

....

.... [2]

(b) In the reaction described in **(a)(i)**, a student uses 17.43 g of $CuSO_4$•**y**H_2O. By further titration of the reaction products the student concludes that the total amount of $CuSO_4$ in the sample is 0.0982 mol.

Use the *Data Booklet* to complete the table to calculate the value of **y**, where **y** is an integer. Show your working.

mass of 0.0982 mol $CuSO_4$	.... g
amount of H_2O in 17.43 g of $CuSO_4$•**y**H_2O	.... mol H_2O
value of **y**	**y** = ...

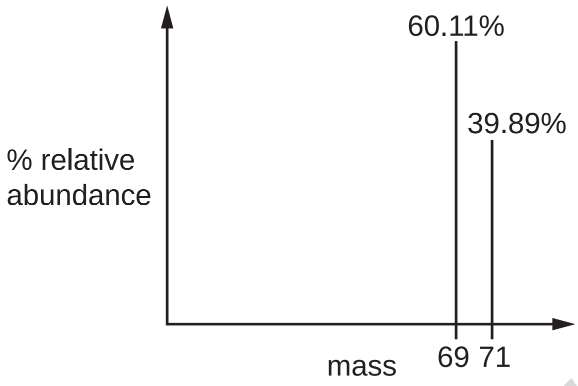
[4]

[Total: 9]

2 - (9701/22_Summer_2020_Q1)

Gallium is an element in Group 13.

A sample of gallium is analysed using a mass spectrometer. The mass spectrum produced is shown.



(a) Explain what is meant by the term *relative atomic mass*.

....

.... [2]

(b) Calculate the relative atomic mass of gallium in this sample. Give your answer to 4 significant figures.

Show your working.

relative atomic mass = ... [2]

(c) Complete the table which describes a gaseous atom of gallium.

isotope	nucleon number	total number of electrons in **lowest** energy level	type of orbital which contains the electron in the **highest** energy level
^{71}Ga			

[3]

(d) When gallium is heated in excess chlorine, gallium trichloride, $GaCl_3$, is made.

Draw the shape of the gallium trichloride molecule and suggest the Cl–Ga–Cl bond angle.

shape of molecule

bond angle ....

[2]

(e) Gallium oxide, Ga_2O_3, and aluminium oxide react in the same way with HCl(aq) and with NaOH(aq).

(i) Suggest the equation for the reaction between Ga_2O_3 and HCl(aq).

.... [1]

(ii) Suggest an equation for the reaction between gallium oxide and NaOH(aq).

.... [2]

[Total: 12]

3 - (9701/23_Summer_2020_Q2) ANSWER

(a) Explain what is meant by the term *relative isotopic mass*.

....

....

.... [2]

(b) A sample of copper contains two isotopes, ^{63}Cu and ^{65}Cu. The relative atomic mass of the copper in this sample is 63.55.

Calculate the percentage abundance of each of these isotopes. Show your working.

percentage abundance of ^{63}Cu = ... %

percentage abundance of ^{65}Cu = ... %
[2]

(c) **(i)** Name the type of bonding within a sample of solid copper.

.... [1]

(ii) Draw a labelled diagram to show the bonding within a sample of solid copper.

[2]

(iii) State the electronic configuration of a copper atom.

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

(d) A student is provided with a sample of hydrated copper(II) sulfate, $CuSO_4•xH_2O$, and is asked to determine the value of x.
The student dissolves a sample of the hydrated copper(II) sulfate in water and adds it to an excess of aqueous potassium iodide to make a total volume of 250.0 cm^3 of solution.

$$2CuSO_4 + 4KI \rightarrow 2CuI + I_2 + K_2SO_4$$

The amount of iodine produced during this reaction is found by titrating a sample of this solution with sodium thiosulfate solution.

25.0 cm^3 of the iodine-containing solution requires 20.0 cm^3 of 0.10 mol dm^{-3} sodium thiosulfate solution.

$$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$$

(i) Calculate the amount, in mol, of copper(II) sulfate present in the original sample of hydrated copper(II) sulfate.

Show your working.

amount of copper(II) sulfate = ... mol [2]

(ii) A total of 7.98 g of $CuSO_4$ is present in 10.68 g of $CuSO_4•xH_2O$.

Complete each row of the table to calculate the value of x, where x is an integer.

[M_r: $CuSO_4$,159.6]

amount of $CuSO_4$ in 10.68 g of $CuSO_4•xH_2O$	.... mol
amount of H_2O in 10.68 g of $CuSO_4•xH_2O$	.... mol
value of x	x = ...

[3]

[Total: 13]

4 - (9701/21_Summer_2021_Q1) ANSWER

Ethanedioic acid, HO_2CCO_2H, has a relative molecular mass of 90.0.

(a) **(i)** Explain what is meant by the term *relative molecular mass*.

....

....

.... [2]

(ii) State the empirical formula of ethanedioic acid.

.... [1]

(iii) Calculate how many atoms of carbon are present in 0.18 g of ethanedioic acid, HO_2CCO_2H.

Show your working.

atoms of carbon present = ... [3]

(b) Solid ethanedioic acid reacts with aqueous calcium ions to make a precipitate of calcium ethanedioate, CaC_2O_4.

CaC_2O_4 breaks down when heated to form calcium oxide, carbon dioxide and carbon monoxide.

(i) Construct an equation to represent the reaction of CaC_2O_4 when heated. Include state symbols.

.... [2]

(ii) Identify the type of reaction which occurs when CaC_2O_4 is heated.

.... [1]

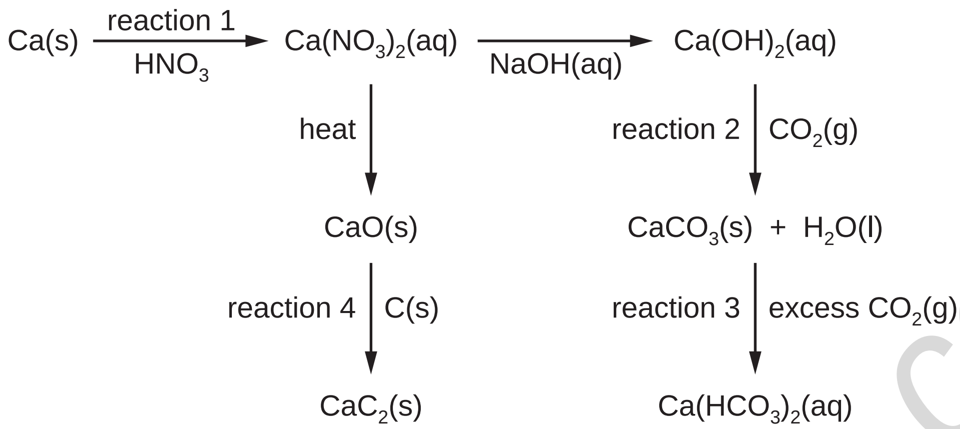
(iii) Identify another compound containing calcium ions which will also produce carbon dioxide and calcium oxide when it is heated.

.... [1]

[Total: 10]

5 - (9701/21_Winter_2021_Q2) ANSWER

The reaction scheme shows some reactions of calcium.



(a) **(i)** Reaction 1 produces $Ca(NO_3)_2$ and one other product.

Identify the other product.

.... [1]

(ii) Construct an equation for the thermal decomposition of $Ca(NO_3)_2(s)$.

.... [1]

(iii) State the trend in the thermal stability of the Group 2 nitrates down the group.

.... [1]

(iv) In reaction 3, excess CO_2 is bubbled through water containing $CaCO_3$. A solution of $Ca(HCO_3)_2(aq)$ forms.

Construct an equation for reaction 3.

.... [1]

(b) Describe how $Ca(OH)_2$ is used in agriculture.

....

.... [1]

(c) In reaction 4, calcium carbide, CaC_2, is formed from CaO.

CaC_2 contains the C_2^{2-} anion. Each carbon in C_2^{2-} is sp hybridised.

(i) Describe how sp hybridised orbitals are formed.

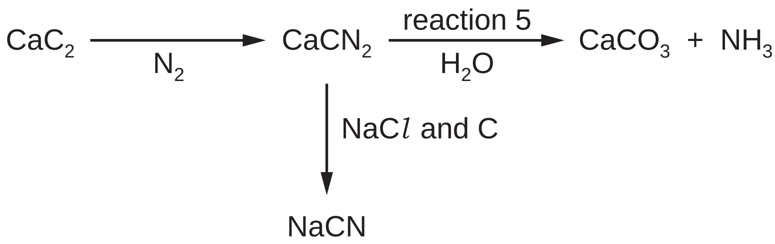
....

.... [1]

(ii) Sketch a diagram to show how two sp hybrid orbitals can form a sigma (σ) bond.

[2]

(d) The flowchart shows some reactions of CaC_2.



(i) Reaction 5 can be used to prepare NH_3.

$$CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$$

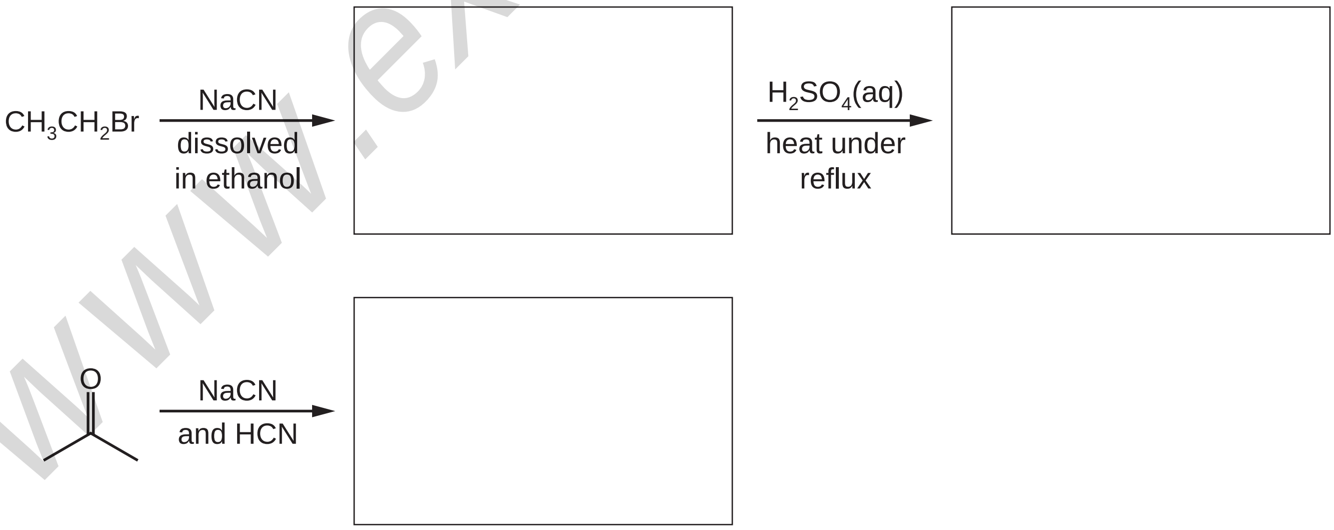
Calculate the minimum mass, in tonnes, of calcium cyanamide, $CaCN_2$, that is required to produce 1.50×10^6 tonnes of NH_3.

Show your working.

1 tonne = 1.00×10^6 g

minimum mass of $CaCN_2$ = ... tonnes
[2]

(ii) Draw the structure of the organic products formed in the following reactions.



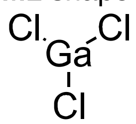
[3]

[Total: 13]

1 - (9701/21_Summer_2020_Q2) QUESTION

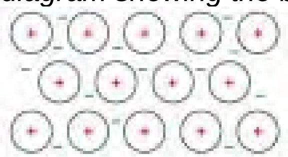
(a)(i)	$2CuSO_4(aq) + 4KI(aq) \rightarrow 2CuI(s) + (1)I_2(aq) + 2K_2SO_4(aq)$ **M1** correct balancing **M2** correct state symbols	**2**
(a)(ii)	Oxidation state of copper in $CuSO_4$ (+)2 AND Oxidation state of copper in CuI (+)1	**1**
(a)(iii)	**M1** redox	**1**
	M2 iodide ions – lost electron(s) AND copper ions – gained electron(s)	**1**
(b)	Mass of 0.0982mol $CuSO_4$ in 17.43g $CuSO_4$.**y**H_2O — **M1** *calculate M_r $CuSO_4$ using Ar from data booklet* 63.5 + 32.1 + 64.0 = 159.6 **M2** *use Mr to calculate mass of $CuSO_4$* (0.0982 × M1) =15.67272g	**4**
	number of water in 17.43g of $CuSO_4$ **y**H_2O — **M3** *calculate the mass amount of water in sample AND use this value to calculate the amount of water present* (17.43-15.67)/18 = 0.097778 mol	
	value of **y** — **M4** *use the ratio of M2: 0.0982 to find y* (mol H_2O ÷ mol $CuSO_4$) = 1	

2 - (9701/22_Summer_2020_Q1) QUESTION

<table>
<tr><td>(a)</td><td>EITHER
M1 (weighted) average/mean mass of the isotope(s)/an atom(s)
M2 relative to 1/12 of the mass (of an atom) of ^{12}C (where an atom of ^{12}C is exactly12).
OR
M1 mass of one mol of atoms
M2 relative / compared to 1/12 (the mass) of 1 mol of C-12 OR
in which one mol C-12 (atom) has a mass of (exactly) 12 g</td><td>2</td></tr>
<tr><td>(b)</td><td>M1 60.11/100 x 69 + 39.89/100x71
M2 69.80</td><td>2</td></tr>
<tr><td>(c)</td><td><table>
<tr><td>isotope</td><td>nucleon number</td><td>total number of electrons in lowest energy level</td><td>type of orbital contains the electron in the highest energy level</td></tr>
<tr><td>^{71}Ga</td><td>M1 71</td><td>M2 2</td><td>M3 p (-orbital)</td></tr>
</table></td><td>3</td></tr>
<tr><td>(d)</td><td>M1 shape

M2 bond angle 120(°)</td><td>2</td></tr>
<tr><td>(e)(i)</td><td>$Ga_2O_3 + 6HCl \rightarrow 2GaCl_3 + 3H_2O$</td><td>1</td></tr>
<tr><td>(e)(ii)</td><td>M1 Identity of correct gallium containing product
$NaGa(OH)_4$ OR $NaGaO_2$

M2 correctly balanced equation for reaction of Ga_2O_3 with NaOH(aq)
EITHER
$Ga_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaGa(OH)_4$
OR
$Ga_2O_3 + 2NaOH \rightarrow 2NaGaO_2 + H_2O$</td><td>2</td></tr>
</table>

3 - (9701/23_Summer_2020_Q2)

(a)	**EITHER** **M1** mass of an atom / isotope **M2** relative / compared to 1/12 (the mass) of (an atom of) C-12 OR on a scale in which a C-12 (atom / isotope) has (a mass of exactly) 12 (units) **OR** **M1** mass of one mol (of atoms) of an isotope **M2** relative / compared to 1/12 (the mass) of 1 mol of C-12 OR in which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	**2**
(b)	% abundance of ^{63}Cu = 72.5% % abundance of ^{65}Cu = 27.5% **M1** *correct algebraic expression AND correct calculation of x for one isotope* % ab of ^{63}Cu = x (x/100 × 63) + ((1- x)/100 × 65) = 63.55 so x =72.5 OR % ab of ^{65}Cu = x (1- x)/100 × 63) + x/100 × 65) = 63.55 so x = *27.5* **M2** *calculation of abundance of other isotope by 100- x*	**2**
(c)(i)	metallic	**1**
(c)(ii)	*diagram showing the bonding in a sample of copper*  **M1** diagram shows regular arrangement of spheres labelled as positively charged ions / +2 or +1 / cations **M2** diagram shows surrounded by electrons and clearly labelled as ‘delocalised electrons’	**3**
(c)(iii)	$(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$ **OR** $(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$	**1**

(d)(i)	**M1** *calculate the number mol $S_2O_3{}^{2-}$ added* 20/1000 x 0.10 = $2x10^{-3}$ = 0.002 (mol $S_2O_3{}^{2-}$) **M2** *calculate number mol $CuSO_4$ in $250cm^3$* (1mol $S_2O_3{}^{2-}$: 1 mol $CuSO_4$) = 0.002 mol $CuSO_4$ in $25cm^3$ so 0.02 mol $CuSO_4$ in $250cm^3$	**2**
(d)(ii)	**M1** amount of $CuSO_4$ in 10.68 g of $CuSO_4 \cdot xH_2O$: 7.98 / (159.6) = <u>0.05</u> (mol) **M2** amount of H_2O in 10.68 g of $CuSO_4 \cdot xH_2O$: (10.68 – 7.98) / 18 = 2.7 / 18 =) <u>0.15</u> (mol) **M3** value of **x**: (mol H_2O ÷ mol $CuSO_4$ =) 3	**3**

4 - (9701/21_Summer_2021_Q1)

(a)(i)	**option 1** **M1** the mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecule(s)	**1**
	option 1 and **M2** relative / compared to 1 / 12 (the mass) of **an atom** of carbon–12	**1**
	OR on a scale in which a carbon–12 atom / isotope has a mass of (exactly) 12 (units) **option 2** **M1** mass of one mol of molecules	
	option 2 **M2** relative / compared to 1 / 12 (the mass) of 1 mol of C-12 OR which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	
(a)(ii)	CO_2H	**1**
(a)(iii)	$0.18/90 \times 2 \times 6.02 \times 10^{23} = 2.408 \times 10^{21}$ (atoms) OR $\mathbf{2.4(1) \times 10^{21}}$ (atoms) **M1** no mole ethanedioic acid 0.18 / 90 = 0.0020	**1**
	M2 no mole ethanedioic acid × 2 0.0020 × 2 = 0.0040	**1**
	M3 no mole ethanedioic acid × 6.02×10^{23} 2.4×10^{21}	**1**
(b)(i)	$CaC_2O_4(s) \rightarrow CaO(s) + CO_2(g) + CO(g)$ **M1** correct formulae	**1**
	M2 balancing equation AND state symbols.	**1**
(b)(ii)	(thermal) decomposition OR disproportionation	**1**
(b)(iii)	calcium carbonate / $CaCO_3$	**1**