Atoms, Amount, Equations & Reactions
AS & A Level

Question Paper 5

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Foundations in Chemistry
Topic	Atoms, Amount, Equations & Reactions
Paper	AS & A Level
Booklet	Question Paper 5

Time allowed: **78 minutes**

Score: **/58**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

Barium combines with oxygen, chlorine and nitrogen to form ionic compounds.

(a) Barium oxide, BaO, has a giant ionic lattice structure.

(i) State what is meant by the term *ionic bond*.

[1]

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in barium oxide.

Show outer electrons only.

[2]

(iii) Calculate the number of barium ions in 1.50 g of barium oxide.

Give your answer in standard form and to **three** significant figures.

[2]

(b) Barium chloride, $BaCl_2$, is soluble in water.

(i) Compare the electrical conductivities of solid and aqueous barium chloride.

Explain your answer in terms of the particles involved.

[2]

(ii) Describe the use of aqueous barium chloride in qualitative analysis.

[2]

(iii) Hydrated barium chloride can be crystallised from solution.

Hydrated barium chloride has the formula $BaCl_2 \cdot xH_2O$ and a molar mass of $244.3\,g\,mol^{-1}$.

Determine the value of ***x*** in the formula of $BaCl_2 \cdot xH_2O$.

Show your working.

[2]

(c) Barium nitride is formed when barium is heated with nitrogen.

(i) Complete the electron configuration of a nitride ion.

[1]

(ii) Solid barium nitride is reacted with water, forming an alkaline solution **A** and an alkaline gas **B**.

Identify **A** and **B**.

Write an equation, including state symbols, for the reaction.

[4]

(Total 16 marks)

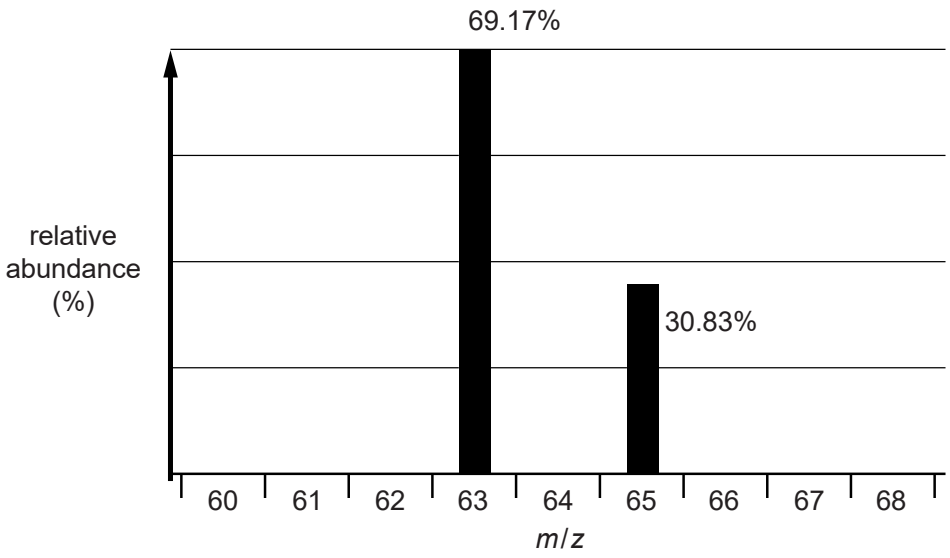
A twenty pence coin contains copper and nickel.

(a) Copper and nickel each exist as a mixture of isotopes.

State the similarities and differences between the atomic structure of isotopes of the **same** element.

[2]

(b) The copper used to make a batch of coins is analysed by mass spectrometry. The mass spectrum is shown below.



(i) Calculate the relative atomic mass of the copper used to make the coins.

Give your answer to **two** decimal places.

[2]

(ii) One coin has a mass of 5.00 g and contains 84.0% of copper, by mass.

Calculate the number of copper atoms in one coin.

Give your answer in standard form and to **three** significant figures.

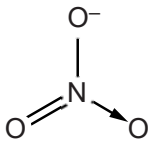
[2]

(c) Nickel(II) nitrate, $Ni(NO_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

(i) Write the equation for this reaction.

[1]

(ii) $Ni(NO_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the '*dot-and-cross*' diagram for the NO_3^- ion, showing outer shell electrons only. Use a different symbol for the extra electron.

[2]

(Total 9 marks)

This question is about several salts.

(a) A hydrated salt, compound **A**, is analysed and has the following percentage composition by mass:

Cr, 19.51%; C*l*, 39.96%; H, 4.51%; O, 36.02%.

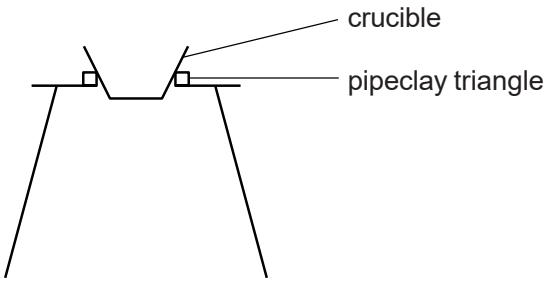
Calculate the formula of compound **A**, showing clearly the water of crystallisation.

Show your working.

[3]

(b) A student carries out an experiment to determine the amount of water of crystallisation in the formula of another hydrated salt. The student intends to remove the water by heating the hydrated salt.

A diagram of the apparatus used by the student is shown below.



- The student adds the hydrated salt to the crucible and weighs the crucible and contents.
- The student heats the crucible and contents and allows them to cool.
- The student weighs the crucible and residue.

The student's results are shown below.

Mass of crucible + hydrated salt / g	16.84
Mass of crucible + residue after heating / g	16.26

(i) The maximum error in each mass measurement using the balance is ±0.005 g.

Calculate the percentage error in the mass of water removed.

[1]

(ii) Suggest **one** modification that the student could make to their method to reduce the percentage error in the mass of water removed.

[1]

(iii) The student is not sure that all the water of crystallisation has been removed.

How could the student modify the experiment to be confident that all the water of crystallisation has been removed?

[1]

(c) A student prepares a solution of sodium sulfate, Na_2SO_4, by adding 6.25×10^{-2} mol dm^{-3} sulfuric acid, H_2SO_4, from a burette to 25.0 cm^3 of 0.124 moldm^{-3} NaOH in a conical flask.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

Calculate the minimum volume of the H_2SO_4 that the student would need to completely react with the NaOH present.

[3]

(d) Salts can also be prepared in redox reactions of metals with acids.

A student prepares a solution of aluminium sulfate by reacting aluminium with dilute sulfuric acid.

$$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$$

Using oxidation numbers, show which element has been oxidised and which has been reduced in this reaction. State the changes in oxidation numbers, including all signs.

element oxidised.....

oxidation number change: from ..... to .....

element reduced .....

oxidation number change: from ..... to.....

[2]

(Total 11 marks)

Chromium shows typical properties of a transition element. The element's name comes from the Greek word 'Chroma' meaning colour because of its many colourful compounds.

(a) Write down the electron configuration of

(i) a Cr atom, [1]

(ii) a Cr^{3+} ion. [1]

(b) An acidified solution containing orange $Cr_2O_7^{2-}$ ions reacts with zinc in a redox reaction to form a solution containing Zn^{2+} ions and blue Cr^{2+} ions.

The unbalanced half-equations are shown below.

$$Zn \longrightarrow Zn^{2+} + e^-$$

$$Cr_2O_7^{2-} + H^+ + e^- \longrightarrow Cr^{2+} + H_2O$$

Balance these equations and construct an overall equation for this reaction. [3]

(c) Aqueous solutions of Cr^{3+} ions contain ruby-coloured $[Cr(H_2O)_6]^{3+}$ complex ions. If an excess of concentrated ammonia solution is added, the solution changes to a violet colour as the hexaammine chromium(III) complex ion forms.

(i) What type of reaction has taken place? [1]

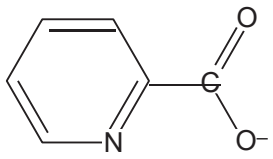
(ii) Suggest an equation for this reaction. [2]

(d) Chromium picolinate, $Cr(C_6H_4NO_2)_3$, is a bright red complex, used as a nutritional supplement to prevent or treat chromium deficiency in the human body.

In this complex,

- chromium has the +3 oxidation state,
- picolinate ions, $C_6H_4NO_2^-$, act as bidentate ligands.

The structure of the picolinate ion is shown below.



$Cr(C_6H_4NO_2)_3$ exists as a mixture of stereoisomers.

(i) What is meant by the term *ligand*? [1]

(ii) How is the picolinate ion able to act as a **bidentate** ligand? [2]

(iii) Why does $Cr(C_6H_4NO_2)_3$ exist as a mixture of stereoisomers?
Draw diagrams of the stereoisomers as part of your answer. [3]

(e) Compound **A** is an orange ionic compound of chromium with the percentage composition by mass N, 11.11%; H, 3.17%; Cr, 41.27%; O, 44.45%. Compound **A** does **not** have water of crystallisation.

On gentle heating, compound **A** decomposes to form three products, **B**, **C** and water.
B is a green oxide of chromium with a molar mass of 152.0 $g mol^{-1}$.
C is a gas. At RTP, each cubic decimetre of **C** has a mass of 1.17 g.

In the steps below, show all your working.

- Calculate the empirical formula of compound **A**.
- Deduce the ions that make up the ionic compound **A**.
- Identify substances **B** and **C**. [8]
- Write an equation for the decomposition of compound **A** by heat.

[Total: 22 Marks]