Quantitative Chemistry part 2 AQA Triple Chemistry

Name: ____________________

Class: ____________________

Date: ____________________

Time: **51 minutes**

Marks: **48 marks**

Comments:

1. This question is about electrolysis.

Aluminium is produced by electrolysing a molten mixture of aluminium oxide and cryolite.

(a) Explain why a mixture is used as the electrolyte instead of using only aluminium oxide.

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(2)

(b) What happens at the negative electrode during the production of aluminium?

Tick (✓) **one** box.

Aluminium atoms gain electrons. ☐

Aluminium atoms lose electrons. ☐

Aluminium ions gain electrons. ☐

Aluminium ions lose electrons. ☐

(1)

(c) Oxygen is produced at the positive electrode.

Complete the balanced half-equation for the process at the positive electrode.

$$\quad \rightarrow \quad O_2 \quad + \quad$$

(2)

(d) Explain why the positive electrode must be continually replaced.

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(3)

(e) The overall equation for the electrolysis of aluminium oxide is:

$$2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2$$

Calculate the mass of oxygen produced when 2000 kg of aluminium oxide is completely electrolysed.

Relative atomic masses (A_r): O = 16 Al = 27

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Mass of oxygen = ____________________________ kg

(4)

Sodium metal and chlorine gas are produced by the electrolysis of molten sodium chloride.

(f) Explain why sodium chloride solution **cannot** be used as the electrolyte to produce sodium metal.

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(2)

(g) Calculate the volume of 150 kg of chlorine gas at room temperature and pressure.

The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3

Relative formula mass (M_r): Cl_2 = 71

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Volume = ______________________ dm^3

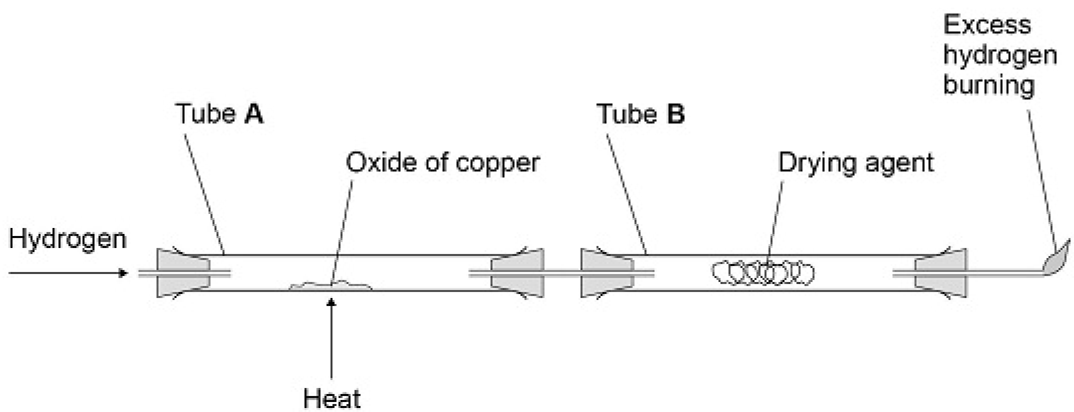
(2)

(Total 16 marks)

2. Copper forms two oxides, Cu_2O and CuO

A teacher investigated an oxide of copper.

The following figure shows the apparatus.



This is the method used.

1. Weigh empty tube **A**.

2. Add some of the oxide of copper to tube **A**.

3. Weigh tube **A** and the oxide of copper.

4. Weigh tube **B** and drying agent.

5. Pass hydrogen through the apparatus and light the flame at the end.

6. Heat tube **A** for 2 minutes.

7. Reweigh tube **A** and contents.

8. Repeat steps 5 to 7 until the mass no longer changes.

9. Reweigh tube **B** and contents.

10. Repeat steps 1 to 9 with different masses of the oxide of copper.

(a) Suggest **one** reason why step 8 is needed.

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(1)

(b) Explain why the excess hydrogen must be burned off.

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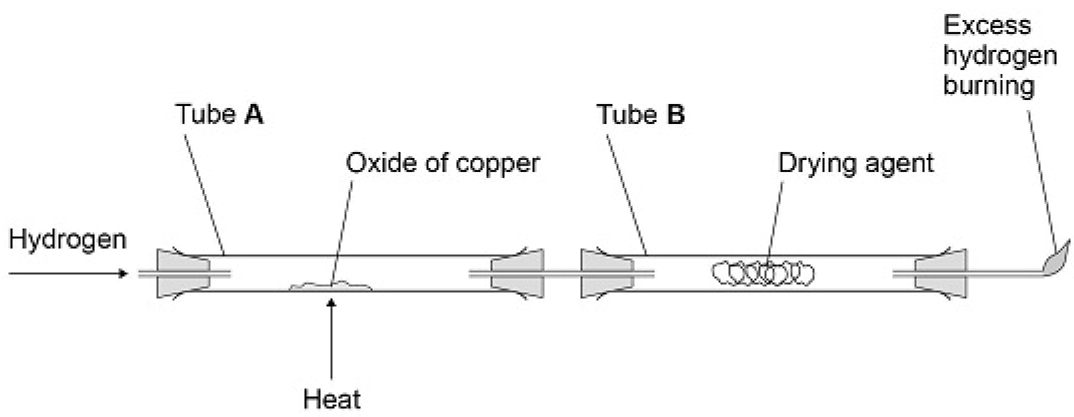
(2)

The figure above is repeated here.



The table below shows the teacher's results.

	Mass in g
Tube **A** empty	105.72
Tube **A** and oxide of copper before heating	115.47
Tube **A** and contents after 2 minutes	114.62
Tube **A** and contents after 4 minutes	114.38
Tube **A** and contents after 6 minutes	114.38
Tube **B** and contents at start	120.93
Tube **B** and contents at end	123.38

When an oxide of copper is heated in a stream of hydrogen, the word equation for the reaction is:

copper oxide + hydrogen → copper + water

(c) Determine the mass of copper and the mass of water produced in this experiment.

Use the table.

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Mass of copper = ___________________________ g

Mass of water = ___________________________ g

(2)

(d) The teacher repeated the experiment with a different sample of the oxide of copper.

The teacher found that the oxide of copper produced 2.54 g of copper and 0.72 g of water.

Two possible equations for the reaction are:

Equation 1: $Cu_2O + H_2 \rightarrow 2\ Cu + H_2O$

Equation 2: $CuO + H_2 \rightarrow Cu + H_2O$

Determine which is the correct equation for the reaction in the teacher's experiment.

Relative atomic masses (A_r): H = 1 O = 16 Cu = 63.5

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(3)
(Total 8 marks)

3. This question is about acids and alkalis.

(a) Ethanoic acid is a weak acid.

What is meant by 'weak acid'?

Answer in terms of ionisation.

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(1)

(b) The concentration of an acid can be measured in mol/dm^3.

Which combination of changes **increases** the concentration of an acid?

Tick (✓) **one** box.

The mass of acid dissolved is halved and the volume of the solution is halved.	☐
The mass of acid dissolved is halved and the volume of the solution is doubled.	☐
The mass of acid dissolved is doubled and the volume of the solution is halved.	☐
The mass of acid dissolved is doubled and the volume of the solution is doubled.	☐

(1)

(c) The concentration of an acid can be determined by titration.

An indicator is added to an alkali in a flask.

Name an indicator that can be used in this titration.

Give the colour change of the indicator when acid from a burette is added to the alkali in the flask.

Name of indicator ____

Colour change from ______________________ to ______________________

(2)

(d) Sodium carbonate dissolves in water to produce an alkaline solution.

Give the formula of the ion that makes a solution alkaline.

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(1)

(e) A student does a titration using sodium carbonate solution and nitric acid.

The equation for the reaction is:

$$Na_2CO_3 + 2\ HNO_3 \rightarrow 2\ NaNO_3 + CO_2 + H_2O$$

25.0 cm^3 of 0.124 mol/dm^3 sodium carbonate solution is neutralised by 23.6 cm^3 of nitric acid.

Calculate the concentration of the nitric acid.

Give your answer to 3 significant figures.

You should calculate:

- the number of moles of sodium carbonate in 25.0 cm^3 of the solution
- the number of moles of nitric acid in 23.6 cm^3 of the nitric acid
- the concentration of the nitric acid in mol/dm^3.

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Concentration (3 significant figures) = ____________ mol/dm^3

(5)

When hydrochloric acid dissolves in water, hydrogen ions (H^+) and chloride ions (Cl^-) are produced.

(f) A solution of hydrochloric acid with pH 4.5 has a concentration of H^+ ions of 3.16×10^{-5} mol/dm^3.

What is the concentration of H^+ ions in a solution of hydrochloric acid with pH 2.5?

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Concentration of H^+ ions = ________________ mol/dm^3

(1)

(g) Which element has atoms that have the same electronic structure as the chloride ion?

Use the periodic table.

____

(1)

(Total 12 marks)

4. This question is about acids and alkalis.

(a) Dilute hydrochloric acid is a strong acid.

Explain why an acid can be described as both strong and dilute.

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(2)

(b) A 1.0×10^{-3} mol/dm^3 solution of hydrochloric acid has a pH of 3.0

What is the pH of a 1.0×10^{-5} mol/dm^3 solution of hydrochloric acid?

pH = ____________________

(1)

A student titrated 25.0 cm^3 portions of dilute sulfuric acid with a 0.105 mol/dm^3 sodium hydroxide solution.

(c) The table below shows the student's results.

	Titration 1	**Titration 2**	**Titration 3**	**Titration 4**	**Titration 5**
Volume of sodium hydroxide solution in cm^3	23.50	21.10	22.10	22.15	22.15

The equation for the reaction is:

$$2\ NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2\ H_2O$$

Calculate the concentration of the sulfuric acid in mol/dm^3

Use only the student's concordant results.

Concordant results are those within 0.10 cm^3 of each other.

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Concentration of sulfuric acid = ____________________ mol/dm^3

(5)

(d) Explain why the student should use a pipette to measure the dilute sulfuric acid and a burette to measure the sodium hydroxide solution.

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(2)

(e) Calculate the mass of sodium hydroxide in 30.0 cm^3 of a 0.105 mol/dm^3 solution.

Relative formula mass (M_r): NaOH = 40

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___

Mass of sodium hydroxide = ____________________ g

(2)

(Total 12 marks)

Mark schemes

1. (a) mixture has a lower melting point (than aluminium oxide)

allow cryolite lowers melting point (of aluminium oxide)

ignore boiling point

*do **not** accept cryolite is a catalyst*

1

(so) less energy needed

ignore cost

1

(b) aluminium ions gain electrons

1

(c) $2\ O^{2-} \rightarrow O_2 + 4\ e^-$

allow multiples

*allow **1** mark for an unbalanced equation containing correct species*

2

(d) the electrode reacts with oxygen

1

the electrode is carbon / graphite

1

(so) carbon dioxide is produced

allow (so) the electrode / carbon / graphite is used up

allow (so) the electrode / carbon / graphite is burned away

ignore (so) the electrode / carbon / graphite is worn away ignore (so) the electrode / carbon / graphite is corroded

1

(e)

*an answer of 941 (kg) scores **4** marks*

(M_r of Al_2O_3 =) 102

$\left(\frac{2\,000\,000}{102}=\right)$ 19 608 (mol Al_2O_3)

allow correct calculation using incorrectly calculated value of M_r of Al_2O_3

1

$\left(19\,608 \times \frac{3}{2}=\right)$ 29412 (mol O_2)

allow correct calculation using incorrectly calculated value of moles of Al_2O_3

1

$\left(\frac{29\,412 \times 32}{1000}=\right)$ 941 (kg)

allow 941.1764706 (kg) correctly rounded to at least 2 significant figures

allow correct answer using incorrectly calculated value of moles of O_2

1

alternative approach:

(2 M_r of Al_2O_3 =) 204 (1)

204 (kg of Al_2O_3) gives 96 (kg of O_2) (1)

(2000 kg of Al_2O_3 gives)

$\frac{2000}{204}$ x 96 (kg of O_2)

or

$\frac{2000000}{204}$ x 96 (g of O_2) (1)

= 941 (kg) (1)

(f) hydrogen (gas) would be produced (instead of sodium)

1

(because) sodium is more reactive than hydrogen

1

(g)

*an answer of 50700 (dm^3) scores **2** marks*
*an answer of 50.7 (dm^3) scores **1** mark*

$\left(\frac{150\ 000}{71} =\right)$ 2113 (mol of Cl_2)

1

or

(volume of 1 g of Cl_2 = $\frac{24}{71}$ =) 0.34 (dm^3)

$(\frac{150\ 000}{71}$ x 24) = 50700 (dm^3)

allow 50704.22535 (dm^3) correctly rounded to at least 2 significant figures

allow correct calculation using their calculated number of moles and/or calculated volume of 1 g

1

[16]

2. (a) to make sure all of the oxide (of copper) has reacted

or

to make sure all water (produced) is removed

ignore to ensure complete reaction unqualified
ignore to make sure all of the hydrogen has reacted

1

(b) to prevent hydrogen escaping (into the air)

1

(because) hydrogen is explosive

ignore hydrogen is flammable

1

(c) (mass of copper) 8.66 (g)

1

(mass of water) 2.45 (g)

1

(d) moles Cu = 0.04
or
$\frac{2.54}{63.5} = 0.04$

1

moles H_2O = 0.04
or
$\frac{0.72}{18} = 0.04$

1

ratio = 1:1 so equation 2 is correct

1

alternative approach A
(calculating mass of water from copper)

moles Cu= 0.04 **or** $\frac{2.54}{63.5} = 0.04$(1)

0.02 x 18 = 0.36 (g of water for equation 1) (1)

0.04 x 18 = 0.72 (g of water) so equation 2 is correct (1)

alternative approach B
calculating mass of copper from water)

moles H_2O=0.04 **or** $\frac{0.72}{18}$=0.04 (1)

0.08 x 63.5 = 5.08 (g of copper for equation 1) (1)

0.04 x 63.5 = 2.54 (g of copper) so equation 2 is correct (1)

alternative approach C
(mass ratio)
(copper : water for equation 1)
127 : 18 = 7.06 : 1 (1)
(copper : water for equation 2)
63.5 : 18 = 3.53 : 1 (1)
2.54 : 0.72 = 3.53 : 1 = 63.5 : 18
so equation 2 is correct (1)

[8]

3. (a) (the acid is only) partially ionised (in aqueous solution)

1

(b) the mass of acid dissolved is doubled and the volume of the solution is halved

1

(c) methyl orange

1

from yellow to red / orange / pink

1

OR

phenolphthalein (1)

from pink to colourless (1)

OR

litmus (1)

from blue to red (1)

MP2 is dependent on the award of MP1

*if no other marks awarded, allow **1** mark for universal indicator turns from purple / blue to green / yellow / orange / red*

(d) OH^-

1

(e) (moles $Na_2CO_3 = \frac{25.0}{1000} \times 0.124$)

= 0.0031(0)

1

(moles $HNO_3 = 2 \times 0.0031(0)$) = 0.0062(0)

allow correct use of an incorrectly determined number of moles of Na_2CO_3

1

(concentration =) $\frac{0.0062(0)}{23.6} \times 1000$

allow correct use of an incorrectly determined number of moles of HNO_3

1

= 0.262711864

1

= 0.263 (mol/dm^3)

allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses all the data in the question

1

alternative approach:

$\left(\text{ratio } \frac{\text{moles } HNO_3}{\text{moles } Na_2CO_3} = \right)$

allow inverted expression

$\frac{2}{1} = \frac{23.6 \times \text{concentration}}{25.0 \times 0.124}$ (2)

*allow **1** mark for the expression with an incorrect mole ratio*

(concentration =)

$\frac{2 \times 25.0 \times 0.124}{23.6}$ (1)

allow correct use of the expression with an incorrect mole ratio

= 0.262711864 (1)

= 0.263 (mol/dm^3) (1)

allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses all the data in the question

(f) 3.16×10^{-3} (mol/dm^3)

1

(g) argon / Ar

1

[12]

4. (a) (strong because) completely ionised (in aqueous solution)

ignore pH

allow dissociated for ionised

*do **not** accept hydrogen is ionising*

*do **not** accept H^+ are ionised*

1

(dilute because) small amount of acid per unit volume

ignore low concentration

1

(b) 5.0

allow 5

1

(c) (titre):

chooses titrations 3, 4, 5

1

average titre = 22.13 (cm^3)

allow average titre = 22.13(3…) (cm^3)

allow a correctly calculated average from an incorrect choice of titrations

1

(calculation):

(moles NaOH =

$\frac{22.13}{1000} \times 0.105 = 0.002324$)

allow use of incorrect average titre from step 2

1

(moles H_2SO_4 =

½ × 0.002324 =) 0.001162

allow use of incorrect number of moles from step 3

1

(concentration =

$\frac{0.001162}{25} \times 1000$)

= 0.0465 (mol/dm^3)

allow use of incorrect number of moles from step 4

1

alternative approach for step 3, step 4 and step 5

$\frac{2}{1} = \frac{22.13 \times 0.105}{25.0 \times conc.\ H_2SO_4}$ *(1)*

(concentration H_2SO_4 =)

$\frac{22.13 \times 0.105}{25.0 \times 2}$

= 0.0465 (mol/dm^3) (1)

an answer of 0.046473 ***or*** *0.04648 correctly rounded to at least 2 sig figs scores marking points 3, 4 and 5*

an answer of 0.092946 ***or*** *0.09296* ***or*** *0.185892* ***or*** *0.18592 correctly rounded to at least 2 sig figs scores marking points 3 and 5*

an incorrect answer for one step does ***not*** *prevent allocation of marks for subsequent steps*

(d) pipette measures a fixed volume (accurately)

1

(but) burette measures variable volume

allow can measure drop by drop

1

(e) $(\text{moles} =) \frac{30}{1000} \times 0.105$

or 0.00315 (mol)

or

(mass per dm^3 =) 0.105 × 40

or 4.2 (g)

1

$(\text{mass} = \frac{30}{1000} \times 0.105 \times 40)$

= 0.126 (g)

1

*an answer of 0.126 (g) scores **2** marks*

*an answer of 126(g) scores **1** mark*

*an incorrect answer for one step does **not** prevent allocation of marks for subsequent steps*

[12]