Name: _____

Class: _____

Date: _____

Quantitative Chemistry part 1 AQA Triple Chemistry

Time: **85 minutes**

Marks: **80 marks**

Comments:

1. This question is about iron.

(a) Iron is a metal.

Describe how iron conducts thermal energy.

_____

_____

_____

_____

(2)

(b) Pure iron is too soft for many uses.

Explain why mixing iron with other metals makes alloys which are harder than pure iron.

_____

_____

_____

_____

_____

_____

(3)

(c) When iron reacts with chlorine, 0.12 mol of iron reacts with 0.18 mol of chlorine (Cl_2).

Which is the correct equation for the reaction?

Tick (✓) **one** box.

$Fe + Cl_2 \rightarrow FeCl_2$ ☐

$Fe + 3\ Cl_2 \rightarrow FeCl_6$ ☐

$2\ Fe + Cl_2 \rightarrow 2\ FeCl$ ☐

$2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$ ☐

(1)

The most common oxides of iron are Fe_2O_3 and Fe_3O_4

(d) What is the ratio of the numbers of ions in Fe_3O_4?

Tick (✓) **one** box.

$2\ Fe^{2+} : 1\ Fe^{3+} : 4\ O^{2-}$ ☐

$1\ Fe^{2+} : 2\ Fe^{3+} : 4\ O^{2-}$ ☐

$3\ Fe^{2+} : 4\ O^{2-}$ ☐

$3\ Fe^{3+} : 4\ O^{2-}$ ☐

(1)

(e) Calculate the percentage (%) by mass of iron in Fe_3O_4

Relative atomic masses (A_r): O = 16 Fe = 56

Percentage by mass of iron = _____ %

(3)

(f) Fe_2O_3 reacts with carbon to produce carbon dioxide.

The equation for the reaction is:

$$2\ Fe_2O_3(s) + 3\ C(s) \rightarrow 4\ Fe(s) + 3\ CO_2(g)$$

Calculate the volume of carbon dioxide gas at room temperature and pressure that is produced from 40.0 kg of Fe_2O_3 using excess carbon.

Relative formula mass (M_r): $Fe_2O_3 = 160$

The volume of 1 mole of any gas at room temperature and pressure is 24 dm^3.

Volume of carbon dioxide = _____ dm^3

(5)

(Total 15 marks)

2. This question is about titanium dioxide (TiO_2).

(a) Self-cleaning windows are coated with a layer of nanoparticles of titanium dioxide.

Titanium dioxide:

- helps sunlight break down dirt particles
- attracts water, so dirt is washed away by rain.

Nanoparticles of titanium dioxide are used instead of fine particles of titanium dioxide for coating self-cleaning windows.

Suggest **two** reasons why.

1 _____

_____

2 _____

_____

(2)

(b) Titanium is extracted from titanium dioxide in a two-stage process.

The equation for the first stage in the process is:

$$TiO_2 + 2\ Cl_2 + 2\ C \rightarrow TiCl_4 + 2\ CO$$

Calculate the volume of chlorine gas needed to react completely with 100 kg of titanium dioxide.

Relative atomic masses (A_r): O = 16 Ti = 48

The volume of one mole of gas = 24 dm^3

Volume = _____ dm^3

(6)

(Total 8 marks)

3. Zinc reacts with iodine to produce the salt zinc iodide.

The reaction is done in a solution using ethanol as the solvent.

Ethanol is a flammable liquid with a boiling point of 78 °C.

The table below shows the solubility of zinc, iodine and zinc iodide in ethanol.

	Zinc	**Iodine**	**Zinc iodide**
Solubility in ethanol	Insoluble	Soluble	Soluble

(a) Plan a method to obtain crystals of zinc iodide from zinc and iodine.

(6)

(b) A student used 6.35 g of iodine in the reaction.

6.29 g of zinc iodide was produced.

The equation for the reaction is:

$$Zn + I_2 \rightarrow ZnI_2$$

Calculate the percentage yield of zinc iodide.

Give your answer to 3 significant figures.

Relative formula masses (M_r): $I_2 = 254$ $ZnI_2 = 319$

Percentage yield (3 significant figures) = _____ %

(5)

(Total 11 marks)

4. A student investigated the reactions of copper carbonate and copper oxide with dilute hydrochloric acid.

In both reactions one of the products is copper chloride.

(a) Describe how a sample of copper chloride crystals could be made from copper carbonate and dilute hydrochloric acid.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) A student wanted to make 11.0 g of copper chloride.

The equation for the reaction is:

$$CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$$

Relative atomic masses, A_r: H = 1; C = 12; O = 16; Cl = 35.5; Cu = 63.5

Calculate the mass of copper carbonate the student should react with dilute hydrochloric acid to make 11.0 g of copper chloride.

_____

_____

_____

_____

Mass of copper carbonate = _____ g

(4)

(c) The percentage yield of copper chloride was 79.1 %.

Calculate the mass of copper chloride the student actually produced.

Actual mass of copper chloride produced = _____ g

(2)

(d) Look at the equations for the two reactions:

Reaction 1 $CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$

Reaction 2 $CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$

Reactive formula masses: CuO = 79.5; HCl = 36.5; $CuCl_2$ = 134.5; H_2O = 18

The percentage atom economy for a reaction is calculated using:

$$\frac{\text{Relative formula mass of desired product from equation}}{\text{Sum of relative formula masses of all reactants from equation}} \times 100$$

Calculate the percentage atom economy for Reaction 2.

Percentage atom economy = _____ %

(3)

(e) The atom economy for Reaction 1 is 68.45 %.
Compare the atom economies of the two reactions for making copper chloride.

Give a reason for the difference.

(1)

(Total 14 marks)

5. This question is about metals and metal oxides.

Tin (Sn) is extracted from tin oxide using carbon.

The equation for the reaction is:

$$SnO_2 + C \rightarrow Sn + CO_2$$

(a) Which substance is reduced in this reaction?

Give **one** reason for your answer.

Answer in terms of oxygen.

Substance reduced _____

Reason _____

_____

(2)

(b) Why can carbon be used to extract tin from tin oxide?

_____

_____

(1)

(c) Cadmium (Cd) can be extracted by the reaction of cadmium oxide with carbon.

The equation for the reaction is:

$$CdO + C \longrightarrow Cd + CO$$

Calculate the percentage atom economy for the production of cadmium in this reaction.

Relative atomic masses (*A*r): C = 12 Cd = 112

Relative formula mass (*M*r): CdO = 128

_____

_____

_____

_____

_____

Percentage atom economy = _____ %

(3)

(d) Tungsten is a transition metal.

Potassium is a Group 1 metal.

Give **two** differences between the properties of tungsten and the properties of potassium.

1 _____

_____

2 _____

_____

(2)

Tungsten oxide reacts with hydrogen to give tungsten (W) and water.

(e) The equation for the reaction is:

$$WO_3 + 3\ H_2 \rightarrow W + 3\ H_2O$$

The law of conservation of mass states:

> 'The mass of the products equals the mass of the reactants during a chemical reaction.'

Show that the equation obeys the law of conservation of mass.

Relative atomic mass (A_r): W = 184

Relative formula masses (M_r): H_2 = 2 WO_3 = 232 H_2O = 18

_____

_____

_____

_____

(2)

(f) The reaction producing tungsten has a high atom economy.

Why is it important to use reactions with a high atom economy in industry?

_____

_____

(1)

(Total 11 marks)

6. This question is about the extraction of metals.

(a) Tungsten is a metal.

The symbol of tungsten is W

Tungsten is produced from tungsten oxide by reaction with hydrogen.

The equation for the reaction is:

$$WO_3 + 3\,H_2 \rightarrow W + 3\,H_2O$$

Calculate the percentage atom economy when tungsten is produced in this reaction.

Use the equation:

$$\text{percentage atom economy} = \frac{184}{(M_r\ WO_3) + (3 \times M_r\ H_2)} \times 100$$

Relative formula masses (M_r): $WO_3 = 232$ $H_2 = 2$

Percentage atom economy = _____%

(2)

Aluminium is extracted from aluminium oxide.

(b) 38% of a rock sample is aluminium oxide.

Calculate the mass of aluminium oxide in 40 kg of the rock sample.

Mass of aluminium oxide = _____ kg

(2)

(c) The formula of aluminium oxide is Al_2O_3

Calculate the relative formula mass (M_r) of aluminium oxide.

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

Relative formula mass (M_r) = _____

(2)

(d) 60.0 kg of aluminium oxide produces a maximum of 31.8 kg of aluminium.

In an extraction process only 28.4 kg of aluminium is produced from 60.0 kg of aluminium oxide.

Calculate the percentage yield.

Give your answer to 3 significant figures.

Use the equation:

$$\text{percentage yield} = \frac{\text{mass of product actually made}}{\text{maximum theoretical mass of product}} \times 100$$

Percentage yield = _____%

(3)

(e) Extracting metals by electrolysis is a very expensive process.

Explain why aluminium is extracted using electrolysis and not by reduction with carbon.

_____

_____

_____

_____

(2)

(Total 11 marks)

7. This question is about silver iodide.

Silver iodide is produced in the reaction between silver nitrate solution and sodium iodide solution.

The equation for the reaction is:

$$AgNO_3(aq) + NaI(aq) \rightarrow AgI(s) + NaNO_3(aq)$$

(a) A student investigated the law of conservation of mass.

This is the method used.

1. Pour silver nitrate solution into a beaker labelled **A**.
2. Pour sodium iodide solution into a beaker labelled **B**.
3. Measure the masses of both beakers and their contents.
4. Pour the solution from beaker **B** into beaker **A**.
5. Measure the masses of both beakers and their contents again.

The table below shows the student's results.

	Mass before mixing in g	**Mass after mixing in g**
Beaker **A** and contents	78.26	108.22
Beaker **B** and contents	78.50	48.54

Explain how the results demonstrate the law of conservation of mass.

You should use data from table above in your answer.

(2)

(b) Suggest how the student could separate the insoluble silver iodide from the mixture at the end of the reaction.

(1)

The student purified the separated silver iodide.

This is the method used.

1. Rinse the silver iodide with distilled water.
2. Warm the silver iodide.

(c) Suggest **one** impurity that was removed by rinsing with water.

(1)

(d) Suggest why the student warmed the silver iodide.

(1)

(e) Calculate the percentage atom economy for the production of silver iodide in this reaction.

The equation for the reaction is:

$$AgNO_3(aq) + NaI(aq) \rightarrow AgI(s) + NaNO_3(aq)$$

Give your answer to 3 significant figures.

Relative formula masses:

(M_r): $AgNO_3 = 170$ NaI = 150 AgI = 235 $NaNO_3 = 85$

Percentage atom economy (3 significant figures) = _____ %

(4)

(f) Give **one** reason why reactions with a high atom economy are used in industry.

(1)

(Total 10 marks)

1.

(a) (thermal) energy is transferred

allow heat is transferred

1

by delocalised electrons

1

(b) (the alloy / mixture has) different sized atoms

1

(so the) layers are distorted

1

(so the) layers cannot easily slide

allow (positive / metal) ions for atoms throughout

allow (so the) atoms cannot slide over each other

1

(c) $2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$

1

(d) $1\ Fe^{2+} : 2\ Fe^{3+} : 4\ O^{2-}$

1

(e) ($M_r\ Fe_3O_4$ =) 232

1

$$(\%\ Fe =)\ \frac{3 \times 56}{232} \times 100$$

allow $\frac{168}{232} \times 100$

allow correct use of an incorrectly determined M_r using the values of A_r given in the question

1

= 72.4 (%)

allow 72.41379 correctly rounded to at least 2 significant figures

1

(f) (40.0 kg =) 40 000 (g)

*a maximum of **4** marks can be awarded for a method which determines and uses the volume of iron oxide as a gas*

1

(moles $Fe_2O_3 = \frac{40\,000}{160}$ =) 250

allow correct use of an incorrectly converted or unconverted mass

1

(moles $CO_2 = 250 \times \frac{3}{2}$ =) 375

allow correct use of an incorrectly determined number of moles of Fe_2O_3

1

(volume of CO_2 =) 375 × 24

allow correct use of an incorrectly determined number of moles of CO_2

1

= 9000 (dm^3)

1

[15]

2. (a) (nanoparticles)

any **two** from:

- have a higher surface area to volume ratio
- less (material) needed (for the same effect)

  allow a thinner coating is needed
- more light gets through

2

allow converse arguments for fine particles

(b) (M_r TiO_2 =) 80

1

(conversion 100 kg =) 100 000 (g)

1

$\left(\text{moles } TiO_2 = \frac{100\,000}{80} =\right)$

1250

allow correct use of an incorrectly determined M_r

allow correct use of an incorrect / no conversion of mass

1

(moles Cl_2 = 1250 × 2 =) 2500

allow correct use of an incorrectly determined number of moles of TiO_2

1

(volume Cl_2 =) 2500 x 24

allow correct use of an incorrectly determined number of moles of Cl_2

1

= 60 000 (dm^3)

1

[8]

3. (a) **Level 3:** The method would lead to the production of a valid outcome. The key steps are identified and logically sequenced.

5-6

Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the method is not fully logically sequenced.

3-4

Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.

1-2

No relevant content

0

Indicative content

dissolve iodine in ethanol
- in a beaker

add zinc to iodine solution
- stir

continue adding until zinc is in excess
- shown by solid remaining

filter (the reaction mixture)
- to remove the excess zinc

heat the solution
- using a water bath
  or
  using an electric heater
- to evaporate off some of the ethanol
- cool / leave remaining solution to crystallise

(b)

$\left(\text{moles } I_2 = \frac{6.35}{254} =\right)\ 0.025$

1

(moles ZnI_2 = 0.025 theoretical mass ZnI_2 = 0.025 × 319 =)
7.975 (g)

allow (moles Zn = 0.025 mass of Zn = 0.025 × 65 = 1.625 g theoretical mass ZnI_2 = 1.625 + 6.35 =) 7.975 (g)

allow correct use of an incorrectly determined number of moles of I_2

1

$\text{(\% yield =)}\ \frac{6.29}{7.975} \times 100$

allow correct use of an incorrectly determined theoretical mass of ZnI_2

1

= 78.871 (%)

1

= 78.9 (%)

allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses both mass values in the question

alternative approach 1:

$\left(\text{moles } I_2 = \frac{6.35}{254} =\right)\ 0.025$ (1)

$\left(\text{moles } ZnI_2 = \frac{6.29}{319} =\right)\ 0.019717868$ (1)

$\text{(\% yield =)}\ \frac{0.019717868}{0.025} \times 100$ (1)

allow correct use of an incorrectly determined number of moles of I_2 and/or ZnI_2

= 78.871 (%) (1)

= 78.9 (%) (1)

allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses both mass values in the question

alternative approach 2:

$\left(\text{moles } ZnI_2 = \frac{6.29}{319} =\right) 0.019717868$ (1)

(moles I_2 reacted = 0.019717868
mass I_2 reacted = 0.019717868 × 254 =)
5.0083(g) (1)

(% yield =) $\frac{5.0083}{6.35} \times 100$ (1)

allow correct use of an incorrectly determined number of moles of ZnI_2

= 78.871 (%) (1)

= 78.9 (%) (1)

allow correct use of an incorrectly determined mass of I_2 reacted
allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses both mass values in the question

1

[11]

4. (a) add excess copper carbonate (to dilute hydrochloric acid)

accept alternatives to excess, such as 'until no more reacts'

1

filter (to remove excess copper carbonate)

reject heat until dry

1

heat filtrate to evaporate some water **or** heat to point of crystallisation

accept leave to evaporate or leave in evaporating basin

1

leave to cool (so crystals form)

until crystals form

1

*must be in correct order to gain **4** marks*

(b) M_r $CuCl_2$ = 134.5

*correct answer scores **4** marks*

1

moles copper chloride = (mass / M_r = 11 / 134.5) = 0.0817843866

1

M_r $CuCO_3$= 123.5

1

Mass $CuCO_3$ (=moles × M_2= 0.08178 × 123.5) = 10.1(00)

1

*accept 10.1 with no working shown for **4** marks*

(c) $\frac{79.1}{100} \times 11.0$

or

11.0 × 0.791

1

8.70 (g)

1

*accept 8.70(g) with no working shown for **2** marks*

(d) Total mass of reactants = 152.5

1

<u>134.5</u>

152.5

allow ecf from step 1

1

88.20 (%)

1

*allow 88.20 with no working shown for **3** marks*

(e) atom economy using carbonate lower because an additional product is made **or** carbon dioxide is made as well

allow ecf

1

[14]

5. (a) (substance reduced)
SnO_2

allow tin oxide

1

(reason)
(SnO_2) loses oxygen

allow (tin oxide) loses oxygen

MP2 is dependent upon MP1 being awarded

1

(b) carbon is more reactive than tin

allow tin is less reactive than carbon

1

(c) (total M_r = 128 + 12 =) 140

allow (total M_r = 112 + 12 + 16 =) 140

1

(% atom economy =)

$$\frac{112}{140} \times 100$$

allow correct use of an incorrectly determined total M_r

1

= 80 (%)

1

allow the converse for potassium

allow the transition metal for tungsten

allow the Group 1 metal for potassium

ignore references to atomic structure

(d) any **two** from:

tungsten

- has a higher melting / boiling point
- is denser
- is harder

  allow is less malleable / ductile
- is stronger
- is less reactive

  allow specific reactions showing difference in reactivity
- has ions with different charges
- forms coloured compounds
- can be a catalyst

2

(e) (sum of relative formula masses on left hand side =)
232 + (3 × 2) = 238

allow (sum of relative formula masses on left hand side =)

232 + 6 = 238

1

(is equal to sum of relative formula masses on right hand side =)
184 + (3 × 18) = 238

allow (is equal to sum of relative formula masses on right hand side =) 184 + 54 = 238

*if no other mark awarded, allow **1** mark for*

232 + 6 = 184 + 54

or

*allow **1** mark for both sides = 238*

1

(f) for sustainable development

allow to minimise use of limited resources

allow to minimise use of energy

allow to minimise waste

or

for economic reasons

ignore references to yield

1

[11]

6. (a)

*an answer of 77 (%) scores **2** marks*
*an answer of 78.63247863 (%) correctly rounded to at least 2 significant figures scores **1** mark*

$$\frac{184}{(232 + 6)} \times 100$$

1

= 77 (%)

allow 77.31092437 (%) correctly rounded to at least 2 significant figures

1

(b)

*an answer of 15 (kg) scores **2** marks*

$$\frac{38}{100} \times 40$$

1

= 15 (kg)

allow 15.2 (kg)

1

(c)

*an answer of 102 scores **2** marks*

(2 x 27) + (3 x 16)

1

= 102

ignore units

1

(d)

*an answer of 89.3 (%) scores **3** marks*

$$\frac{28.4}{31.8} \times 100$$

1

= 89.3081761 (%)

allow 89.3081761(%) correctly rounded to at least 2 significant figures

1

= 89.3 (%)

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

1

(e) aluminium is more reactive than carbon

allow aluminium is above carbon in the reactivity series

1

(so) carbon cannot displace aluminium

allow (so) carbon cannot replace aluminium

or

(so) carbon cannot reduce aluminium oxide

allow (so) carbon cannot remove oxygen from aluminium oxide

allow (so) carbon will not react with aluminium oxide

1

[11]

7.

(total) mass before = 156.76 (g)
and
(total) mass after = 156.76 (g)

allow 78.26 + 78.50 = 156.76
and
108.22 + 48.54 = 156.76

or

increase in mass of beaker **A** and contents = 29.96 (g)
and
decrease in mass of beaker **B** and contents = 29.96 (g)

allow 108.22 – 78.26 = 29.96
and
48.54 – 78.50 = – 29.96

1

(so) the mass of products equals the mass of the reactants
or
(so) there is no change in mass during the reaction

allow (so) no atoms were lost or made during the reaction

1

(b) filter / filtration

allow a description of filtration

1

(c) sodium nitrate (solution)
or
silver nitrate (solution)
or
sodium iodide (solution)

allow correct formulae

allow sodium / nitrate / silver / iodide ions

1

(d) to remove / evaporate the water

allow to dry (the solid)

1

(e) (total M_r = 170 + 150) = 320

allow (235 + 85) = 320

1

(% atom economy =) 235

$$\frac{235}{320} \times 100$$

allow correct use of incorrectly calculated total M_r

1

= 73.4375 (%)

1

= 73.4 (%)

allow an answer correctly calculated to 3 significant figures from an incorrect percentage calculation which uses the values in the question

1

(f) any **one** from:

- for sustainable development
- for economic reasons
- to produce a high(er) percentage of useful product

allow to reduce waste

1

[10]