GCSE · AQA · Chemistry

2 hours 23 questions

Exam Questions

Calculating Mass of Substances

The Mole / Amounts of Substances in Equations / Using Moles to Balance Equations / Limiting Reactants / Concentrations of Solutions

Easy (6 questions)	/44
Medium (10 questions)	/48
Hard (7 questions)	/48
Total Marks	**/140**

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Easy Questions

1 (a) This question is about elements in Group 2.

A teacher burns magnesium in oxygen, O_2.

Complete the word equation for the reaction.

magnesium + oxygen → _____

Answer

The completed word equation for the reaction is:

- magnesium + oxygen → magnesium oxide; [1 mark]

[Total: 1 mark]

- Word equations are considered a basic skill so make sure that you can write them
- This is one of the most common examples used in a classroom but it demonstrates that you may not always be given lots of information in the question

(1 mark)

(b) Balance the equation for the reaction between magnesium and oxygen.

$$\_\_Mg + O_2 \rightarrow \_\_MgO$$

Answer

The balanced equation for the reaction between magnesium and oxygen is:

- $2Mg + O_2 \rightarrow 2MgO$; [1 mark]

[Total: 1 mark]

- **Remember:** A balanced symbol equation must show the Law of Conservation of Mass
- This means that there must be the same number of each atom at the start and the end of the reaction
- At the start of the reaction, the magnesium is balanced with one at the start and one at the end of the reaction
- But there are two oxygens at the start of the reaction and one at the end of the reaction
    - $\_\_Mg + O_2 \rightarrow \_\_MgO$
- You balance the oxygen by putting a 2 in front of the MgO, as this doubles the amount of MgO
    - $\_\_Mg + O_2 \rightarrow 2MgO$
- This balances the oxygen with two at the start and end
- But now the magnesium is unbalanced as there is one magnesium at the start and two at the end
- You balance the magnesium by putting a 2 in front of the Mg, as this doubles the amount of Mg
    - $2Mg + O_2 \rightarrow 2MgO$

(1 mark)

(c) The teacher reacts calcium with water.

$$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$$

How many moles of reactant and product are there in this reaction?

Moles of reactant = _____

Moles of product = _____

Answer

The number of moles in this reaction are:

- Moles of reactant = Three / 3; [1 mark]
- Moles of product = Two / 2; [1 mark]

[Total: 2 marks]

- From the balanced symbol equation
  - Reactants = There is 1 mole of calcium / Ca and 2 moles of water / H_2O
  - Products = There is 1 mole of calcium hydroxide / $Ca(OH)_2$ and 1 mole of hydrogen / H_2

(2 marks)

(d) According to the symbol equation, how many calcium atoms are present at the start of this reaction?

Tick (✓) **one** box.

6.02×10^{-23}	
6.23×10^{-23}	
6.02×10^{23}	

Answer

The number of calcium atoms present at the start of this reaction is:

6.02×10^{-23}	
6.23×10^{-23}	
6.02×10^{23}	✓; [1 mark]

[Total: 1 mark]

- **Remember:** The number of atoms present in one mole of any element is Avogadro's number, 6.02×10^{23}

(1 mark)

(e) According to the symbol equation, how many hydrogen atoms are present in the hydrogen gas produced during this reaction?

Tick (✓) **one** box.

6.02×10^{-23}	
6.02×10^{23}	
1.20×10^{24}	
1.20×10^{-24}	

Answer

The number of hydrogen atoms present in the hydrogen gas produced during this reaction is:

6.02×10^{-23}	
6.02×10^{23}	
1.20×10^{24}	✓; [1 mark]
1.20×10^{-24}	

[Total: 1 mark]

- **Careful:** You are asked for the number of **atoms** of hydrogen that are in the hydrogen gas product
- The hydrogen molecule contains 2 hydrogen atoms
- This means that there are 2 x (6.02×10^{23}) atoms of hydrogen = 1.204×10^{24} atoms
    - The answer options are rounded to 2 decimal places

(1 mark)

2 (a) Ethanol, C_2H_5OH, can be formed by the hydration of ethene, C_2H_4.

Balance the equation for the hydration of ethene.

$$C_2H_4 + \_\_\_\_ \rightarrow C_2H_5OH$$

Answer

The balanced equation for the hydration of ethene is:

- $C_2H_4 + \mathbf{H_2O} \rightarrow C_2H_5OH$; [1 mark]

[Total: 1 mark]

- The question states that this reaction is **hydration** of ethene which suggests the addition of water
- Checking the symbol equation
  - The reactant side has two carbon atoms and four hydrogen atoms
  - The product side has two carbon atoms, six hydrogen atoms and one oxygen atom
  - The products side has gained two hydrogen atoms and one oxygen atom which matches with the missing chemical being water / H_2O

(1 mark)

(b) Calculate the relative formula mass (M_r) of ethanol, C_2H_5OH.

Relative atomic masses (A_r): C = 12; H = 1; O = 16

Answer

To calculate the relative formula mass (Mr) of ethanol, C_2H_5OH:

- (2 x 12) + (6 x 1) + 16; [1 mark]
- 46; [1 mark]

[Total: 2 marks]

- To calculate the relative formula mass of a compound, add up the atomic masses of all the component elements
- **Careful:** It is easy to miss the final hydrogen in the formula because it is separate from the other 5 hydrogens
  - This would give you a final answer of 45
  - If you made this mistake but showed your workings, then you might still gain one mark

(2 marks)

(c) 16.1 g of ethanol is produced in a hydration of ethene reaction.

How many moles of ethanol are in 16.1 g?

Use the equation:

$$\text{Moles} = \frac{\text{mass}}{\text{relative formula mass}}$$

Answer

To calculate the number of moles of ethanol in 16.1 g:

- $\text{Moles} = \frac{\text{mass}}{\text{relative formula mass}} = \frac{16.1}{46}$; [1 mark]
- 0.35 moles; [1 mark]

[Total: 2 marks]

- $\text{Moles} = \frac{\text{mass}}{\text{relative formula mass } (M_r)}$ is one of the most common calculations in Chemistry so it is best to practice using, rearranging and applying it
- Some students are taught a rearranged version of this called Mr Moles:
  - $\text{Relative formula mass } (M_r) \times \text{moles} = \text{mass}$

(2 marks)

(d) Calculate the number of moles of ethene that is required to produce 16.1 g of ethanol.

Answer

The number of moles of ethene that is required to produce 16.1 g of ethanol is:

- 0.35 moles; [1 mark]
  Accept the same value as the answer to part (c)

[Total: 1 mark]

- The incomplete symbol equation given in part (a) shows that there is a 1 : 1 ratio between ethene and ethanol
  - $C_2H_4 + \_\_\_\_\_ \rightarrow C_2H_5OH$
- 16.1 g of ethanol is 0.35 moles as calculated in part (c)
- This means that 0.35 moles of ethanol need 0.35 moles of ethene
- This type of follow on question from a moles calculation is relatively common

(1 mark)

3 (a) This question is about the reactions of metals and metal oxides.

9.6 g of magnesium is burned in oxygen to form magnesium oxide.

$$2Mg + O_2 \rightarrow 2MgO$$

How many moles are in 9.6 g of magnesium?

Relative atomic mass (A_r): Mg = 24

Use the equation:

$$\text{Moles} = \frac{\text{mass}}{M_r}$$

Answer

The number of moles of magnesium is:

- $\text{Moles} = \frac{9.6}{24} = 0.4$; [1 mark]

[Total: 1 mark]

(1 mark)

(b) How many moles of magnesium oxide are produced when 9.6 g of magnesium is burned in oxygen?

Answer

The number of moles of magnesium oxide produced when 9.6 g of magnesium is burned in oxygen is:

- 2 : 2 ratio of magnesium : magnesium oxide
  AND
  Therefore, moles of magnesium oxide = 0.4 moles; [1 mark]

[Total: 1 mark]

- Check the stoichiometry (big numbers at the front) of the two chemicals you are considering in the chemical equation
  - In this case, 2 magnesium : 2 magnesium oxide
  - This means that the moles of magnesium = moles of magnesium oxide

(1 mark)

(c) What mass of magnesium oxide is produced when 9.6 g of magnesium is burned in oxygen?

Use the equation:

$$\text{Mass} = \text{moles} \times M_r$$

Answer

The mass of magnesium oxide produced when 9.6 g of magnesium is burned in oxygen is:

Mass = moles x M_r

- Mass = 0.4 x (24 + 16) = 16 g; [1 mark]

[Total: 1 mark]

(1 mark)

(d) What mass of hydrogen is needed to react with 3.18 g of copper oxide?

$$CuO + H_2 \rightarrow Cu + H_2O$$

Relative formula mass (M_r): CuO = 79.5

Answer

To calculate the mass of hydrogen needed to reduce with 3.18 g of copper oxide:

- Moles of copper oxide = $\frac{\text{mass}}{M_r} = \frac{3.18}{79.5}$ = 0.04 moles; [1 mark]

- 1 : 1 ratio of copper oxide : hydrogen
  AND
  Therefore, moles of hydrogen = 0.04 moles; [1 mark]

- Mass of hydrogen = moles x M_r = 0.04 x 2 = 0.08 g; [1 mark]

[Total: 3 marks]

- When a question contains the phrase "calculate the (maximum/minimum) mass..." you will be using the moles equation
  - $\text{Moles} = \frac{\text{mass}}{M_r}$
- Calculate the moles of the chemical that you are given the mass for (copper oxide)
- Check the stoichiometry (big numbers at the front) of the two chemicals you are considering in the chemical equation
- Apply the number of moles of the target chemical (hydrogen) using the rearranged formula (mass = moles x M_r)

(3 marks)

(e) Potassium is burned in oxygen to form potassium oxide.

$$4K + O_2 \rightarrow 2K_2O$$

What mass of potassium oxide is formed when 1.95 g of potassium is burned in oxygen?

Answer

To calculate the mass of potassium oxide formed when 1.95 g of potassium is burned in oxygen:

- Moles of potassium = $\frac{\text{mass}}{M_r} = \frac{1.95}{39}$ = 0.05 moles; [1 mark]

- 4 : 2 ratio of potassium : potassium oxide
  AND
  Therefore, moles of potassium oxide = 0.025 moles; [1 mark]

- Mass of potassium oxide = moles x M_r = 0.025 x (39 + 39 + 16) = 2.35 g; [1 mark]

[Total: 3 marks]

- When a question contains the phrase "calculate the (maximum/minimum) mass..." you will be using the moles equation
  - $\text{Moles} = \frac{\text{mass}}{M_r}$

- Calculate the moles of the chemical that you are given the mass for (potassium)

- Check the stoichiometry (big numbers at the front) of the two chemicals you are considering in the chemical equation

- Apply the number of moles of the target chemical (potassium oxide) using the rearranged formula (mass = moles x M_r)

(3 marks)

4 (a) 15.9 g of copper oxide reacts with 1.2 g of carbon to form 12.7 g of copper and 4.4 g of carbon dioxide.

The unbalanced equation for the reaction is:

$$CuO + C \rightarrow Cu + CO_2$$

Relative atomic masses (A_r): C = 12; Cu = 63.5; O = 16

Calculate the number of moles of each chemical in the equation.

Use the equation:

$$\text{Moles} = \frac{\text{mass}}{M_r}$$

Answer

To calculate the number of moles of each chemical in the equation:

$$\text{Moles} = \frac{\text{mass}}{M_r}$$

- Moles of copper oxide = $\frac{15.9}{(63.5 + 16)}$ = 0.2 moles; [1 mark]
- Moles of carbon = $\frac{1.2}{12}$ = 0.1 moles; [1 mark]
- Moles of copper = $\frac{12.7}{63.5}$ = 0.2 moles; [1 mark]
- Moles of carbon dioxide = $\frac{4.4}{44}$ = 0.1 moles; [1 mark]

[Total: 4 marks]

(4 marks)

(b) Use your answer to part (a) to balance the equation.

$$\_\_CuO + \_\_C \rightarrow \_\_Cu + \_\_CO_2$$

Answer

The balanced equation is:

$$2CuO + C \rightarrow 2Cu + CO_2$$

- The ratio of CuO : C : Cu : CO_2 is 2 : 1 : 2 : 1; [1 mark]
- Correctly place 2 in front of CuO and Cu; [1 mark]

[Total: 2 marks]

- Once you have determined the number of moles of each chemical, you work out the ratio of each chemical relative to the others
- In this case, there are twice as many moles of copper oxide and copper (compared to carbon and carbon dioxide), therefore, you need 2 moles of copper oxide and copper

(2 marks)

(c) 2.8 g of calcium oxide, CaO, reacts with 2.2 g of carbon dioxide to form 5.0 g of calcium carbonate, $CaCO_3$.

Relative atomic masses (A_r): Ca = 40; C = 12; O = 16

Use the number of moles of each chemical to write the balanced symbol equation for this reaction.

Show your working.

Answer

To write a balanced equation for the reaction:

$$\text{Moles} = \frac{\text{mass}}{M_r}$$

- Moles of calcium oxide = $\frac{2.8}{56}$ = 0.05 moles; [1 mark]

- Moles of carbon dioxide = $\frac{2.2}{44}$ = 0.05 moles; [1 mark]

- Moles of calcium carbonate = $\frac{5.0}{100}$ = 0.05 moles; [1 mark]

All chemicals have the same number of moles, therefore the balanced symbol equation is:

- $CaO + CO_2 \rightarrow CaCO_3$; [1 mark]

[Total: 4 marks]

- Calculate the number of moles of each chemical
- Compare the ratio of the number of moles
- Apply that ratio to the unbalanced equation

(4 marks)

5 (a) This question is about limiting reagents.

Which of the following statements about limiting reagents is **not** correct?

Tick (✓) **one** box.

The limiting reagent is in excess	
The limiting reagent is used up first	
The limiting reagent controls the amount of product formed	
Doubling the amount of limiting reagent doubles the amount of product formed	

Answer

The incorrect statement about limiting reagents:

The limiting reagent is in excess	✓; [1 mark]
The limiting reagent is used up first	
The limiting reagent controls the amount of product formed	
Doubling the amount of limiting reagent doubles the amount of product formed	

[Total: 1 mark]

- By definition, the limiting reagent cannot be in excess
    - It is the chemical that controls or limits the reaction

(1 mark)

(b) Magnesium reacts with sulfur to form magnesium sulfide.

Write the word equation for this reaction.

Answer

The word equation for the reaction of magnesium with sulfur to form magnesium sulfide is:

- Magnesium + sulfur → magnesium sulfide; [1 mark]

[Total: 1 mark]

- There is enough information in the question to completely write the equation
  - "...magnesium with sulfur to form magnesium sulfide."
    - With becomes +
    - To form becomes →
  - Magnesium + sulfur → magnesium sulfide

(1 mark)

(c) The balanced symbol equation for the reaction of magnesium with sulfur is:

$$Mg + S \rightarrow MgS$$

1.8 g of magnesium is reacted with 1.8 g of sulfur.

Explain which chemical is the limiting reactant. Show your working.

Relative atomic masses (A_r): Mg = 24; S = 32

Answer

To explain which chemical is the limiting reactant:

$$\text{Moles} = \frac{\text{mass}}{M_r}$$

- Moles of magnesium = $\frac{1.8}{24}$ = 0.075 moles; [1 mark]

- Moles of sulfur = $\frac{1.8}{32}$ = 0.056(25) moles; [1 mark]

- (Therefore,) sulfur is the limiting reactant; [1 mark]

- (Because,) there are fewer / lesser moles of sulfur
  OR
  There are more moles of magnesium; [1 mark]

[Total: 4 marks]

- To answer these questions, you should always calculate the number of moles of each chemical
  - The one with the least / lowest number of moles is the limiting reactant
  - The one with the most / highest number of moles is in excess

(4 marks)

6 (a) The concentration of a solution can be measured in different ways.

Which are the correct units for concentration in terms of the mass of a solid dissolved in a known quantity of liquid?

Circle the correct answer.

dm^3 / g	g / dm^3	mol / dm^3

Answer

The correct units for concentration in terms of the mass of a solid dissolved in a known quantity of liquid are:

dm^3 / g	g / dm^3; [1 mark]	mol / dm^3

[Total: 1 mark]

- Mass can be measured in grams
- Quantities of liquid can be measured in dm^3
- Therefore, concentration can be represented as g / dm^3

(1 mark)

(b) A student is asked to make a sodium hydrogen carbonate solution, $NaHCO_3$ (aq).

The student uses 0.25 moles of sodium hydrogen carbonate.

Calculate the mass of sodium hydrogen carbonate that the student uses.

Relative atomic masses (A_r): C = 12; H = 1; Na = 23; O = 16

Answer

To calculate the mass of sodium hydrogen carbonate that the student uses:

- M_r of $NaHCO_3$ = 23 + 1 + 12 + (3 x 16); [1 mark]
- M_r of $NaHCO_3$ = 84 g / mol; [1 mark]
- Mass = moles x M_r = 0.25 x 84 = 21 g; [1 mark]

[Total: 3 marks]

- **Remember:** One mole is the relative atomic mass of an element or the relative molecular / formula of a compound

(3 marks)

(c) What is the concentration of the student's solution in g / dm^3?

Answer

The concentration of the student's solution in g / dm^3 is:

- 21 g / dm^3; [1 mark]
  Accept a concentration that is the answer to part (b)

[Total: 1 mark]

- From part (b) you calculated the 0.25 moles of sodium hydrogen carbonate is 21 g
- Therefore, there will be 21 g in 1 dm^3
- This is written as 21 g / dm^3

(1 mark)

(d) The student takes a 25 cm^3 portion from their 1 dm^3 sodium hydrogen carbonate solution.

There are 1000 cm^3 in 1 dm^3.

Estimate the mass of sodium hydrogen carbonate in the 25 cm^3 portion.

Answer

To estimate the mass of sodium hydrogen carbonate in the 25 cm^3 portion:

- $\frac{1000}{25}$ = 40; [1 mark]
- $\frac{21}{40}$ = 0.525 g; [1 mark]

[Total: 2 marks]

- This question is an example of the ways that concentration questions can continue after you have calculated a concentration

(2 marks)

Medium Questions

1 (a) The amount of substances can be described in different ways.

Complete the sentences.

One mole of a substance is the relative formula mass in _____

The relative atomic mass of an element compares the mass of an atom of an element with the mass of an atom of _____

Answer

The completed sentences are:

- One mole of a substance is the relative formula mass in grams / g; [1 mark]
- The relative atomic mass of an element compares the mass of an atom of an element with the mass of an atom of ^{12}C / carbon-12 / C-12; [1 mark]

[Total: 2 marks]

- All the masses recorded on the Periodic Table are measured in grams and relative to / compared with the mass of a carbon-12 atom being exaclty 12.0 g
    - There are other Periodic Tables where the masses recorded for each element are compared to another element instead of carbon

(2 marks)

(b) Explain the meaning of the term “mole”.

Answer

One mole is:

- The amount of a substance that contains Avogadro's Number / 6.02 x 10^{23} particles (atoms, molecules or formulae units); [1 mark]
- One mole of any substance contains the same number of units as one mole of any other substance; [1 mark]

[Total: 2 marks]

- This is a question that is only occasionally asked but examiners often comment about the poor standard of answers
    - This suggests that it's worth knowing the definition, just in case

(2 marks)

(c) Describe the link between the mole and the relative atomic mass of an element.

Answer

The link between the mole and the relative atomic mass of an element is:

- The numerical value of the relative atomic mass of any element; [1 mark]
- Is equal to the mass of one mole of that element; [1 mark]
- In grams; [1 mark]

[Total: 3 marks]

- This is one of those questions where you might struggle to think of three marks worth of answer because you're not expecting the answer to use one sentence for three specific marks
- **Tip:** Examiner's reports often comment about answers missing the basic detail required
    - This question is an almost perfect example of the need to start your answer with the basics and add more detail if needed
    - One mole of carbon dioxide is 44 g, the combined mass of one mole of carbon atoms and two moles of oxygen atoms all measured in grams. This is the relative atomic mass.
    - You are more used to being asked to calculate the mass of x moles of a substance which applies this principle

(3 marks)

2 (a) Calcium sulfate is used as a coagulant in the production of tofu and to make Plaster of Paris.

The molecular formula of calcium sulfate is $CaSO_4$.

Calculate the relative formula mass (M_r) of $CaSO_4$.

Relative atomic masses: O = 16; S = 32; Ca = 40.

Relative formula mass (M_r) = _____

Answer

The relative formula mass (M_r) of $CaSO_4$ is:

- 40 + 32 + (4 x 16); [1 mark]
- 136; [1 mark]

[Total: 2 marks]

- In some "calulate the relative formula mass" questions, they will be given to you and in others you will have to look them up on the Periodic Table
    - If you have to look them up, make sure that you use the **mass** numbers
        - For example, using the atomic numbers for $CaSO_4$ would give (20 + 16 + (4 x 8)) = 68
        - You would lose marks for not reading the Periodic Table correctly – if in doubt, use the key

(2 marks)

(b) What is the mass of one mole of calcium sulfate?

Answer

The mass of one mole of calcium sulfate is:

- 136 grams / g; [1 mark]

[Total: 1 mark]

- The mass of one mole of any element is the relative atomic mass
- The mass of one mole of any compound is the relative molecular / formula mass

(1 mark)

(c) What mass of calcium sulfate would be needed to provide 18 grams of calcium?

Answer

The mass of calcium sulfate would be needed to provide 18 grams of calcium is:

- $136 \times \frac{18}{40}$ = 61.2 g; [1 mark]

[Total: 1 mark]

- Using the relative formula and atomic masses:
  - 136 g of calcium sulfate will make 40 g of calcium
- The key is converting this to determine how much calcium sulfate will make 18 g of calcium
  - Calculate the number of moles in 18 g of calcium
    - Moles = $= \frac{mass}{A_r} = \frac{18}{40} = 0.45$
  - Calculate the mass of 0.45 moles of calcium sulfate
    - Mass = moles x M_r = 0.45 x 136 = 61.2 g

- There are other ways that you can calculate this answer mathematically

(1 mark)

(d) Calculate the number of moles in 320 g of Fe_2O_3.

You may need to use the periodic table to answer this question.

Answer

The number of moles in 320 g of Fe_2O_3 is:

- 2 moles; [1 mark]

[Total: 1 mark]

- The mass / one mole of Fe_2O_3 is (2 x 56) + (3 x 16) = 160 g
- Therefore, there are $\frac{320}{160}$ = 2 moles of Fe_2O_3 in 320 g

(1 mark)

(e) Calculate the number of moles in 14 g of C_2H_4.

Answer

The number of moles in 14 g of C_2H_4 is:

- 0.5 moles; [1 mark]

[Total: 1 mark]

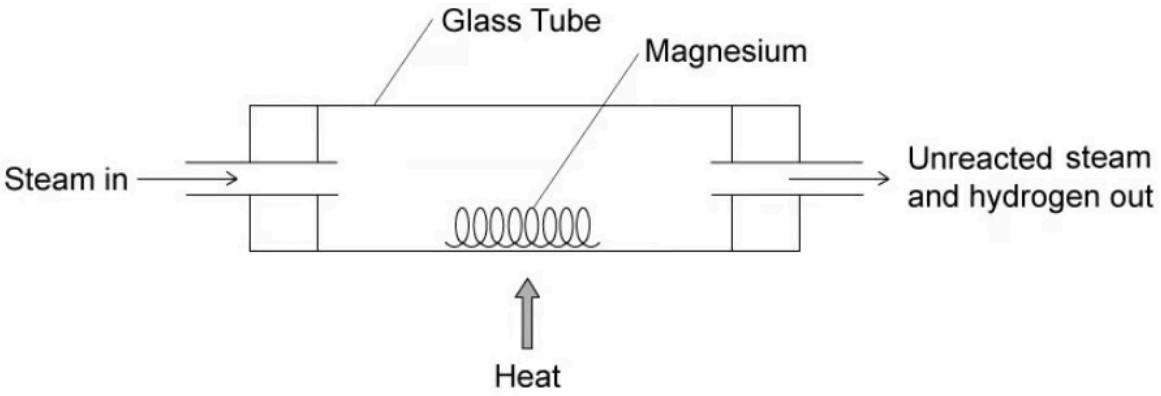
- The mass of C_2H_4 is (12 x 2) + (4 x 1) = 28 g
- Therefore, there are $\frac{14}{28}$ = 0.5 moles of C_2H_4 in 14 g

(1 mark)

3 (a) Magnesium and steam react to produce magnesium oxide and hydrogen gas.

A student carried out the reaction using the apparatus shown in **Figure 1** below.

Figure 1



The balanced equation for the reaction is:

$$Mg\ (s) + H_2O\ (g) \rightarrow MgO\ (s) + H_2\ (g)$$

The student used 2.00 g of Mg.

Using the equation, calculate the maximum mass of magnesium oxide produced.

Give your answer to three significant figures.

Relative atomic masses (A_r): O = 16; Mg = 24

Maximum mass MgO = _____ g

Answer

To calculate the maximum mass of magnesium oxide produced:

- 3.33 (g); **[3 marks]**
  All 3 marks can be awarded for the correct answer to 3 significant figures with or without workings

If the answer is incorrect:
Option 1:

- 24 → 40; [1 mark]

- 2.00 → $\frac{40}{24}$ x 2; [1 mark]

Option 2:

- Moles magnesium = $\frac{2}{24}$ = 0.08(3); [1 mark]
- $\frac{2}{24} \times 40$
  OR
  0.08(3) x 40; [1 mark]

[Total: 3 marks]

- The best way to approach this question is using option 2 to calculate the number of moles of magnesium and then apply it to the magnesium oxide
  - This is the correct chemical way to answer this question and will be expected of you should you progress on to A-level Chemistry

(3 marks)

(b) A student uses 75 cm^3 of a copper (II) sulfate solution of 90 g / dm^3 in an experiment.

What mass of copper (II) sulfate is dissolved in 75 cm^3 of this solution?

Mass = _____ g

Answer

The mass of copper(II) sulfate is dissolved in 75 cm^3 of this solution is:

- 6.75 g; [2 marks] Two marks can be awarded for a correct answer including units
- $\frac{90\ (g/dm^3)}{1000}$ = 0.09 g / cm^3; [1 mark]
- 0.09 x 75 = 6.75 g; [1 mark]
  The units of grams must be included in your answer for the second mark

[Total: 2 marks]

- First, convert the 90 g / dm^3 to g / cm^3 by dividing by 1000

- Then, multiply this answer by the 75 cm^3 to get the mass required

(2 marks)

(c) Another student uses a 0.20 mol / dm^3 solution of sodium hydroxide in an acid - base reaction.

Calculate the mass of sodium hydroxide in 250 cm^3 of a 0.20 mol / dm^3 solution.

Relative formula mass (M_r): NaOH = 40

Mass of sodium hydroxide = _____ g

Answer

To calculate the mass of sodium hydroxide in 250 cm^3 of a 0.20 mol / dm^3 solution:

- Moles NaOH in 1 dm^3 = 0.20; [1 mark]
- Moles NaOH in 1 cm^3 = $\frac{0.20}{1000}$ = 0.00020; [1 mark]
- Moles NaOH in 250 cm^3 = 0.00020 x 250 = 0.05; [1 mark]
- Mass NaOH in 250 cm^3 = 0.05 x 40 = 2.0 g; [1 mark]

[Total: 4 marks]

(4 marks)

4 How many moles are present in 9 kg of glucose, $C_6H_{12}O_6$?

Relative formula mass (M_r): $C_6H_{12}O_6$ = 180

A. 0.02 mol

B. 0.05 mol

C. 20 mol

D. 50 mol

Answer

The correct answer is D because:

- **Step 1:** To find the number of moles of a substance use the formula

$$\text{moles} = \frac{\text{mass in g}}{\text{molar mass}}$$

- **Step 2:** Make sure the units of mass are in g (1 kg = 1 000 g)

$$9 \text{ kg} = 9\,000 \text{ g}$$

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{9\,000}{180} = 50 \text{ mol}$$

(1 mark)

5 What is the mass of 0.25 moles of hydrated copper(II) sulfate, $CuSO_4.5H_2O$?

Relative formula mass (M_r): $H_2O = 18$ $CuSO_4 = 160$

A. 40.0 g

B. 44.5 g

C. 62.5 g

D. 1000 g

Answer

The correct answer is C because:

- **Step 1:** Calculate the molar mass of $CuSO_4.5H_2O$

molar mass of $CuSO_4.5H_2O = 160 + (5 \times 18) = 250$ g/mol

- **Step 2:** To find the mass use the formula

$$\text{mass} = \text{moles} \times \text{molar mass}$$

$$\text{mass of } CuSO_4.5H_2O = 0.25 \times 250 = 62.5 \text{ g}$$

(1 mark)

6 (a) This question is about Avogadro's constant.

How many grams are there in one mole of carbon?

Answer

The number of grams in one mole of carbon is:

- 12(.011); [1 mark]

[Total: 1 mark]

- **Remember:** The mass of one mole of an element is its relative atomic mass on the Periodic Table

(1 mark)

(b) How many atoms are present in one mole of chlorine atoms?

Tick (✔) **one** box.

6.02×10^{23}	
6.02×10^{24}	
7.02×10^{23}	
8.02×10^{26}	

Answer

The correct answer is:

6.02×10^{23}	✔; [1 mark]
6.02×10^{24}	
7.02×10^{23}	
8.02×10^{26}	

[Total: 1 mark]

- The number of atoms present in one mole of any individual set of atoms is Avogadro's number, which is 6.02×10^{23}

(1 mark)

(c) How many atoms are present in one mole of oxygen molecules?

Tick (✔) **one** box.

1.24×10^{24}	
1.204×10^{24}	
12.04×10^{22}	
6.02×10^{46}	

Answer

The correct number of atoms in one mole of oxygen molecules is:

1.24×10^{24}	
1.204×10^{24}	✔; [1 mark]
12.04×10^{22}	
6.02×10^{46}	

[Total: 1 mark]

- There are two atoms of oxygen in every one molecule
- Therefore, there are 2 x (6.02×10^{23}) = 1.204×10^{24} atoms in one mole of oxygen molecules

(1 mark)

(d) Methanol is produced on an industrial scale by reacting carbon monoxide with hydrogen.

The equation for the reaction is:

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g)$$

How many moles of CO react completely with 6.0×10^3 moles of H_2?

Tick (✔) **one** box

3.0×10^3	
2.0×10^3	
2.5×10^3	
9.0×10^3	

Answer

The number of moles of CO that react completely with 6.0×10^3 moles of H_2 is:

3.0×10^3	✔; [1 mark]
2.0×10^3	
2.5×10^3	
9.0×10^3	

[Total: 1 mark]

- This question does not use Avogadro's number
- This question uses the ratio of $1CO : 2H_2$
    - Therefore, the number of moles of CO must be half the number of moles of H_2

(1 mark)

7 (a) A chemist prepares some zinc iodide (ZnI_2) to use as a catalyst in the production of some organic compounds.

The equation for the reaction is:

$$Zn + I_2 \longrightarrow ZnI_2$$

Calculate the minimum mass of zinc that should be added to 0.600 g of iodine so that the iodine fully reacts.

Relative atomic masses (A_r): Zn = 65; I = 127

Minimum mass of Zn = _____ g

Answer

To calculate the minimum mass of zinc that should be added to 0.600 g of iodine so that the iodine fully reacts:

- Moles of I_2 = $\frac{0.600}{254}$ = 0.00236; [1 mark]
- Mass of Zn = 0.00236 x 65; [1 mark]
- Mass of Zn = 0.1534 g; [1 mark]
  A correct answer of 0.1534 g with or without workings gain 3 marks

[Total: 3 marks]

- This question used the $\text{moles} = \frac{\text{mass}}{M_r}$ equation
- Use this equation to determine the number of moles of iodine as this is the chemical that you have the mass and M_r information for
- From the chemical equation, you can see that the ratio is $1Zn : 1I_2$
- Therefore, the number of moles of iodine will be the same as the number of moles of zinc
- Now use the rearranged equation mass = moles x M_r to calculate the mass / final answer

(3 marks)

(b) Titanium is extracted from titanium dioxide in a two step industrial process:

Step 1 $TiO_2 + 2C + 2Cl_2 \longrightarrow TiCl_4 + 2CO$

Step 2 $TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$

In step 2, 40 kg of $TiCl_4$ is added to 20 kg of Na.

The equation for the reaction is:

$$TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$$

Relative atomic masses (A_r): Na = 23; Cl = 35.5; Ti = 48

Explain why titanium chloride is the limiting reactant.

You **must** show your working.

Answer

To explain why titanium chloride is the limiting reactant:

- Moles Na = $\frac{20000}{23}$ = 870 mol; [1 mark]
- Moles $TiCl_4$ = $\frac{40000}{190}$ = 211 mol; [1 mark]
- Molar ratio from balanced equation is 1$TiCl_4$: 4Na; [1 mark]
- So 211 x 4 = 844 moles of Na are required but there are 870; [1 mark]
- Therefore, Na is in excess
  AND
  $TiCl_4$ is the limiting reagent; [1 mark]

[Total: 5 marks]

- For limiting reagent questions, always calculate the moles of each reagent to determine which one is in excess and, therefore, which one is the limiting reagent

(5 marks)

8 A solution of $CuSO_4$ has a concentration of 35 g/dm^3.

What mass of $CuSO_4$ would there be in 250 cm^3 of the solution?

A. 140 g

B. 8.75 g

C. 7.14 g

D. 1.40 g

Answer

The correct answer is B because:

- To find the mass of a solution we need two pieces of information, volume and concentration:

$$\text{concentration in g/dm}^3 = \text{mass / volume in dm}^3$$

$$\text{mass} = \text{concentration x volume in dm}^3$$

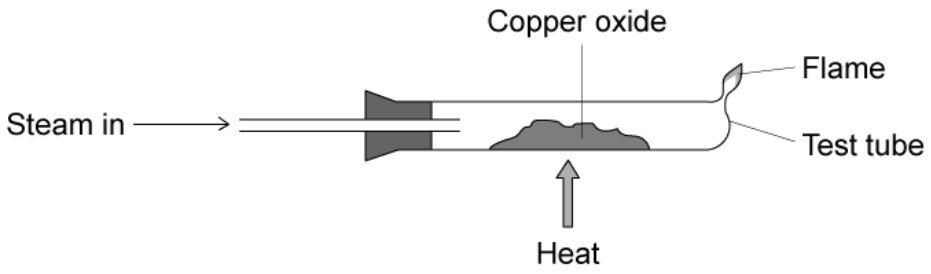
- The volume and concentration must have consistent units; since 1000 cm^3 = 1 dm^3 you must divide the volume by 1000 to convert from cm^3 to dm^3

$$\text{mass of copper(II) sulfate} = \frac{35 \times 250}{1000} = 8.75 \text{ g}$$

(1 mark)

9 (a) Copper oxide (CuO) was reacted with methane (CH_4) in the apparatus shown below in **Figure 1.**

Figure 1



Balance the equation for the reaction:

$$\_\_CuO\ (s) + \_\_CH_4\ (g) \rightarrow \_\_Cu\ (s) + \_\_H_2O\ (g) + \_\_CO_2\ (g)$$

Answer

The balanced equation is:

- **4**$CuO\ (s) + CH_4\ (g) \rightarrow 4Cu(s) + 2H_2O\ (g) + CO_2\ (g)$; [1 mark]

[Total: 1 mark]

(1 mark)

(b) Use the equation to calculate the mass of copper that could be made from 6.0 g of copper oxide.

Mass of copper = _____ g

Answer

To calculate the mass of copper that could be made from 6.0 g of copper oxide:

- M_r of CuO = 63.5 + 16 = 79.5; [1 mark]
- Moles of CuO: $\frac{6.0}{79.5}$ = 0.075; [1 mark]
- Mass of copper: 0.075 x 63.5 = 4.76 g; [1 mark]
  An answer of 4.76g without or without working scores 3 marks

[Total: 3 marks]

- This question uses the $\text{moles} = \frac{\text{mass}}{M_r}$ equation so make sure that you know this equation and how to rearrange it

(3 marks)

10 (a) Iron (III) chloride is used in industrial waste treatment, in water purification and in the production of electronic circuit boards.

One method of producing iron (III) chloride is reacting iron with chlorine:

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

Calculate the maximum mass of $FeCl_3$ that can be produced from 14.0 g of iron.

Relative atomic masses (A_r): Cl = 35.5; Fe = 56

Maximum mass of $FeCl_3$ = _____ g

Answer

To calculate the maximum mass of $FeCl_3$ that can be produced from 14.0 g of iron:

- M_r of $FeCl_3$ = (56) + (3 x 35.5) = 162.5 **[1 mark]**
- Moles of Fe = $\frac{14.0}{56}$ = 0.25 **[1 mark]**
- Mass of $FeCl_3$ = 0.25 x 162.5 = 40.63 g **[1 mark]** *An answer of 40.63 g with or without working gains 3 marks*

[Total: 3 marks]

(3 marks)

(b) A student wanted to make 12.0 g of copper chloride by reacting copper carbonate with hydrochloric acid. The equation for the reaction is as follows:

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

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

Calculate the mass of $CuCO_3$ the student needs to react with dilute hydrochloric acid to make 12.0 g of copper chloride.

Mass of copper carbonate = _____ g

Answer

To calculate the mass of $CuCO_3$ the student needs to react with dilute hydrochloric acid to make 12.0 g of copper chloride:

- M_r of $CuCl_2$ = (2 x 35.5) + 63.5 = 134.5; **[1 mark]**
- Moles of $CuCl_2$ = $\frac{12.0}{134.5}$ = 0.089; **[1 mark]**
- M_r $CuCO_3$ = 63.5 + 12 + (3 x 16) = 123.5; **[1 mark]**
- Mass of $CuCO_3$ = 0.089 x 123.5 = 10.9(9) **[1 mark]**
  An answer of 10.9(9) g with or without working gains 4 marks

[Total: 4 marks]

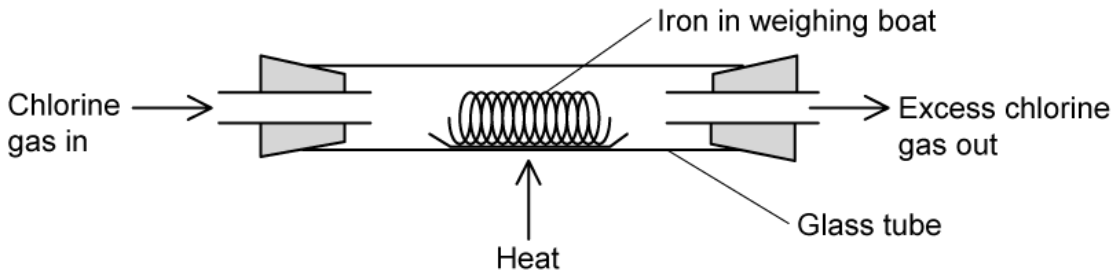
(4 marks)

Hard Questions

1 (a) This question is about the reaction of iron and chlorine.

A teacher uses the apparatus shown in **Figure 1** to react iron with chlorine.

Figure 1



This is the teacher's method.

- Record the mass of the weighing boat
- Add iron and record the mass again
- Heat the weighing boat and iron strongly for two minutes and then allow to cool
- Record the mass of the weighing boat and its contents

Give an addition to the method to check that the iron has fully reacted with the chlorine.

Answer

An addition to the method to check that the iron has fully reacted with the chlorine is:

- Heat again to a constant mass; [1 mark]

[Total: 1 mark]

- Any reaction where the results are being measured by changes in mass should be allowed to run until there is no further change in mass, including:
    - Reactions involving heat such as this one or thermal decomposition reactions

- Reactions that produce a gas such as carbonates with acid

(1 mark)

(b) The iron is the limiting reagent in the reaction.

Explain **one** resulting safety precaution for this reaction.

Answer

One resulting safety precaution for this reaction is:

- The reaction should be performed in a fume cupboard; [1 mark]
- (Because) chlorine is toxic/poisonous
  OR
  To prevent inhalation of chlorine; [1 mark]

[Total: 2 marks]

- **Careful:** Since this question opens by stating that iron is the limiting reagent, it is easy to focus on this point
- If iron is the limiting reagent, then an excess of toxic chlorine gas is being used
- This requires the use of a fume cupboard

(2 marks)

(c) **Table 1** shows the teacher's results.

Table 1

	Mass in g
empty weighing boat	11.76
weighing boat and iron	16.24
weighing boat and iron chloride	24.76

Use the teacher's results to show that the empirical formula of iron chloride is $FeCl_3$.

Relative atomic masses (A_r): Fe = 56, Cl = 35.5

Answer

To show that the empirical formula of iron chloride is $FeCl_3$:

- Mass of iron = 16.24 - 11.76 = 4.48 g
  AND
  Mass of chlorine = 24.76 - 16.24 = 8.52 g; [1 mark]

- Moles of iron = $\frac{4.48}{56}$ = 0.08 moles
  AND
  Moles of chlorine = $\frac{8.52}{35.5}$ = 0.24 moles; [1 mark]

- $\frac{0.08}{0.08}$ = 1 **AND** $\frac{0.24}{0.08}$ = 3 (therefore the formula is $FeCl_3$)
  OR
  Ratio of iron : chlorine is 1 : 3 (therefore the formula is $FeCl_3$)
  OR
  One iron requires 3 chlorine (therefore the formula is $FeCl_3$); [1 mark]

[Total: 3 marks]

- As soon as the phrase empirical formula is mentioned you should be:
  - Finding the mass of each element
  - Dividing the mass of each element by its atomic mass to calculate moles
  - Finding the ratio of each element to the other(s) by dividing by your smallest answer
  - Stating the overall formula that you have calculated

(3 marks)

(d) Write the balanced symbol equation, including state symbols, for this reaction of iron and chlorine.

Answer

The balanced symbol equation, including state symbols, for this reaction of iron and chlorine is:

$2Fe\ (s) + 3Cl_2\ (g) \rightarrow 2FeCl_3\ (s)$

- All chemical formula correct
  AND
  Correctly balanced; [1 mark]

- All state symbols correct; [1 mark]

[Total: 2 marks]

- There are two aspects to this question
- Balancing the equation
  - You know that the reactants are Fe and Cl_2 and that the product is $FeCl_3$
    - ___Fe + ___Cl_2 → ___$FeCl_3$
  - There are two chlorines on the reactant side and three chlorines on the product side
  - Therefore, you need six chlorines on each side of the equation to balance it
    - ___Fe + **3**Cl_2 → **2**$FeCl_3$
  - This now means that you have one iron on the reactant side and two irons on the product side
  - Therefore, you need to balance the iron on the reactant side
    - **2**Fe + 3Cl_2 → 2$FeCl_3$
- State symbols
  - From **Figure 1** you know that iron is solid and chlorine is a gas

- $2Fe$ **(s)** + $3Cl_2$ **(g)** → $2FeCl_3$

- From the last bullet point in the method, the iron chloride must be a solid

- $2Fe$ (s) + $3Cl_2$ (g) → $2FeCl_3$ **(s)**

(2 marks)

2 A teacher carried out an experiment to determine the balanced equation for the reaction of tungsten oxide with hydrogen.

The word equation for this reaction is:

tungsten oxide + hydrogen → tungsten + water

The teacher weighed:

- the glass tube
- the glass tube and tungsten oxide before the reaction
- the glass tube and tungsten after the reaction.

Table 1 shows the teacher's results.

Table 1

	Mass in g
empty weighing boat	12.22
weighing boat and tungsten oxide	14.54
weighing boat and tungsten	14.06

Calculate the simplest whole number ratio of:

moles of tungsten atoms : moles of oxygen atoms

Determine the balanced equation for the reaction.

Relative atomic masses (A_r): W = 184, O = 16

Answer

To calculate the simplest whole number ratio of moles of tungsten atoms : moles of oxygen atoms:

- Mass of tungsten = 14.06 - 12.22 = 1.84 g
  AND
  Mass of oxygen = 14.54 - 14.06 = 0.48 g; [1 mark]
- Moles of tungsten = $\frac{1.84}{184}$ = 0.01 moles; [1 mark]
- Moles of oxygen = $\frac{0.48}{16}$ = 0.03 moles; [1 mark]
- Moles of tungsten atoms : moles of oxygen atoms = 1 **:** 3; [1 mark]

To determine the balanced equation for the reaction:

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

- Correct formulae for all chemicals; [1 mark]
- Correct balancing; [1 mark]

[Total: 6 marks]

- Part (a) gave the word equation
- You have to use the information in the question to determine the formula of tungsten oxide as WO_3
- Then you should be able to deduce the unbalanced symbol equation
- $WO_3 + H_2 \rightarrow W + H_2O$
- You then have to balance this equation

(6 marks)

3 (a) This question is about the reaction of zinc with sulfuric acid.

3.75 g of zinc oxide, ZnO (s), was added to 150 cm^3 of 1.00 mol dm^{-3} of sulfuric acid (aq) producing a salt.

Write a balanced symbol equation for this reaction.

Answer

The balanced symbol equation for the reaction between zinc oxide and sulfuric acid is:

$ZnO\ (s) + H_2SO_4\ (aq) \rightarrow ZnSO_4\ (aq) + H_2O\ (l)$

- Correct reactants and products; [1 mark]
  Ignore state symbols

[Total: 1 mark]

- **Remember:** Metal oxide + acid → salt + water
  - Since the acid used is sulfuric acid, the salt formed is zinc sulfate
- When a balancing equations question is only worth one mark, it means that there will be no balancing or it will be very simple to balance

(1 mark)

(b) Using the equation in part (a), calculate the limiting reactant in the reaction.

Give your answer to 2 significant figures.

Relative atomic masses (A_r): Zn = 65, O = 16, H = 1, S = 32

Answer

To calculate the limiting reactant in the reaction:

- Mass of zinc oxide = 65 + 16 = 81
  AND
  Moles of zinc oxide = $\frac{\text{mass}}{M_r} = \frac{3.75}{81}$ = 0.046 moles; [1 mark]
- Moles of sulfuric acid = volume (dm^3) x concentration = 0.15 x 1.00 = 0.15 moles; [1 mark]

- Therefore, the limiting reagent is ZnO; [1 mark]

[Total: 3 marks]

- In order to determine the limiting reactant, you need to calculate the number of moles of each reactant
    - The limiting reagent will have the fewest number of moles if the ratio is 1 : 1
    - The reactant in excess will have the most number of moles

(3 marks)

(c) Use your answer to part (b), to calculate the amount, in grams, of the salt produced.

Give your answer to 3 significant figures.

Answer

The mass of salt produced is:

- M_r of $ZnSO_4$ = 65 + 32 + (4 x 16) = 161; [1 mark]
- Mass of $ZnSO_4$ = moles x M_r = 0.046 x 161 = 7.41 (g); [1 mark] *Answer **must** be to three significant figures for the second mark*

[Total: 2 marks]

- You should use the moles of the limiting reactant to calculate the mass of salt / $ZnSO_4$ produced
- You should be especially aware that the question says "three significant figures"
    - Often this will be a mark of its own
    - However, there may be times that it is incorporated into the mark for the final answer value of the question

(2 marks)

(d) Calculate the amount, in moles, of sulfuric acid at the end of the reaction.

Give your answer to 3 significant figures.

Answer

The amount, in moles, of sulfuric acid at the end of the reaction is:

- Excess moles of sulfuric acid = 0.15 - 0.046 = 0.104 moles; [1 mark]

[Total: 1 mark]

- As the acid is in excess, there will be unreacted acid left over.
- We can calculate this by finding the difference between the amount, in moles, between the reactant in excess and the limiting reactant

(1 mark)

4 (a) This question is about aluminium.

Aluminium can be extracted from aluminium oxide by electrolysis.

The overall equation for the electrolysis of aluminium oxide is:

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

Write the balanced half-equation, including state symbols, for the process at the negative electrode.

Answer

The balanced half-equation for the process at the negative electrode is:

Al^{3+} (l) + 3e($^-$) → Al (l)

- All chemical formulae correct; [1 mark]
  Allow multiples or fractions
- All state symbols correct; [1 mark]

[Total: 2 marks]

- Aluminium oxide is composed of the Al^{3+} and O^{2-} ions
- The aluminium ion will be attracted to the negative electrode
- **Remember:** The electrolysis of aluminium oxide is done in the molten / liquid state and produces molten / liquid aluminium which is tapped off

(2 marks)

(b) Calculate the mass of oxygen, in kg, produced when 5000 kg of aluminium oxide is completely electrolysed.

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

Answer

To calculate the mass of oxygen produced when 5000 kg of aluminium oxide is completely electrolysed:

Option 1

- M_r of aluminium oxide = (2 x 27) + (3 x 16) = 102; [1 mark]
- Moles of aluminium oxide = $\frac{5000000}{102}$ = 49020 moles; [1 mark] *Allow an un-rounded value of 49019.60784 Allow correct calculation using incorrectly calculated value of M_r of Al_2O_3*
- Moles of oxygen = 49020 x $\frac{3}{2}$ = 73530 moles; [1 mark] *Allow a value of 73529.41176 using the un-rounded value Allow correct calculation using incorrectly calculated value of moles of Al_2O_3*
- Mass of oxygen, in kg = $\frac{73530 \times 32}{1000}$ = 2353 kg; [1 mark]

  Allow correct answer using incorrectly calculated value of moles of O_2

Option 2

- 2 x M_r of aluminium oxide = 204; [1 mark]
- 204 kg of aluminium oxide gives 96 kg of oxygen; [1 mark]
- 5000 kg of aluminium oxide gives $\frac{5000}{204} \times 96$ kg of oxygen; [1 mark]
- 2353 kg; [1 mark]

[Total: 4 marks]

- Calculate the moles of aluminium oxide
- **Careful:** The mass given is in kg and the mole calculation uses g, so x 1000
- Use this to calculate the moles of oxygen produced
- **Careful:** There is a 2 : 3 ratio of aluminium oxide to oxygen, so x 3 ÷ 2
- **Remember:** Give your answer in kg because the question asks for this

(4 marks)

(c) The thermite reaction of aluminium and iron oxide is used to weld train tracks together.

The equation for this reaction is:

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

A 5.00 kg thermite mixture contains 20% aluminium and 80% iron oxide.

Show that aluminium is the limiting reactant.

Relative atomic masses (A_r): O = 16, Al = 27, Fe = 56

Answer

To show that aluminium is the limiting reactant:

Option 1

- Mass of iron oxide in the mixture = = 4.0 kg
  AND
  Mass of aluminium in the mixture = = 1.0 kg; [1 mark]
- M_r of iron oxide = (2 x 56) + (3 x 16) = 160; [1 mark]
- Moles of iron oxide = $\frac{4000}{160}$ = 25 moles; [1 mark]
- Moles of aluminium required = 25 x 2 = 50 moles; [1 mark]
- Mass of aluminium required = 50 x 27 = 1350 g; [1 mark]
- So, 1.0 kg of aluminium is not enough; [1 mark]

Option 2

- Mass of iron oxide in the mixture = $5.00 \times \frac{80}{100}$ = 4.0 kg
  AND
  Mass of aluminium in the mixture = $5.00 \times \frac{20}{100}$ = 1.0 kg; [1 mark]
- Moles of aluminium = $\frac{1000}{27}$ = 37.0 moles; [1 mark]

- Moles of iron oxide required = $\frac{37.0}{2}$ = 18.5 moles; [1 mark]
- M_r of iron oxide = (2 x 56) + (3 x 16) = 160; [1 mark]
- Mass of iron oxide required = 18.5 x 160 = 2960 g; [1 mark]
- So, 4.0 kg of iron oxide is an excess; [1 mark]

[Total: 6 marks]

- You can either:
  - Work out that aluminium is the limiting reactant which requires working with the iron oxide to start
  - Or work out that iron oxide is in excess which requires you to work with the aluminium to start

(6 marks)

(d) Explain why having aluminium as the limiting reactant in the thermite reaction is better for industrial applications.

Answer

Having aluminium as the limiting reactant in the thermite reaction is better for industrial applications because:

- It / aluminium is more expensive **AND** due to the high energy costs to produce it by electrolysis
  OR
  Iron oxide is less expensive **AND** because it does not need to be refined; [1 mark]

[Total: 1 mark]

(1 mark)

5 (a) Zinc-bromine batteries are rechargeable batteries that are being developed as an alternative to lithium-ion batteries.

They are less likely to overheat and catch fire compared to lithium-ion batteries.

The zinc-bromine battery has a zinc electrode and a carbon electrode with a solution of zinc bromide as the electrolyte.

Write the balanced symbol equation for the formation of zinc bromide, $ZnBr_2$, using hydrobromic acid.

Answer

The balanced symbol equation for the formation of zinc bromide using hydrobromic acid is:

$Zn + 2HBr \rightarrow ZnBr_2 + H_2$

- All chemical formulae correct; [1 mark]
- Correctly balanced equation; [1 mark]

[Total: 2 marks]

- **Remember:** M.A.S.H. – Metal + acid → salt + hydrogen
  - $Zn + HBr \rightarrow ZnBr_2 + H_2$
  - The equation then needs balancing for hydrogen and bromine
  - $Zn + 2HBr \rightarrow ZnBr_2 + H_2$

(2 marks)

(b) Calculate the minimum mass of zinc that needs to be added to 5.00 cm^3 of hydrobromic acid so that the hydrobromic acid fully reacts.

The density of hydrobromic acid is 1.49 g / cm^3.

Relative atomic masses (A_r): Zn = 65, H = 1, Br = 80

Answer

To calculate the minimum mass of zinc that needs to be added to 5.00 cm^3 of hydrobromic acid so that the hydrobromic acid fully reacts:

- Mass of hydrobromic acid = 5.00 x 1.49 = 7.45 g; [1 mark]
- Moles of hydrobromic acid = $\frac{7.45}{81}$ = 0.092 moles; [1 mark]
- Moles of zinc = $\frac{0.092}{2}$ = 0.046 moles; [1 mark]
- Mass of zinc = 0.046 x 65 = 2.99 g; [1 mark]

[Total: 4 marks]

- **Careful:** This question uses the moles, mass, M_r equation but also has two extra points to consider:
  - The density of hydrobromic acid
  - The 1 : 2 ratio of zinc : hydrobromic acid

(4 marks)

(c) In a second experiment, 5.00 g of zinc powder was reacted with hydrobromic acid.

Calculate the number of atoms of hydrogen produced.

Answer

To calculate the number of atoms of hydrogen produced:

- Moles of zinc = $\frac{5.00}{65}$ = 0.0769 moles
  AND
  Moles of hydrogen = 0.0769 moles; [1 mark]
- Number of molecules of hydrogen = 0.0769 x (6.02×10^{23}) = 4.63×10^{22}; [1 mark]
- Number of atoms of hydrogen = 2 x (4.63×10^{22}) = 9.26×10^{22}; [1 mark]

[Total: 3 marks]

- The ratio of zinc : hydrogen is 1 : 1 which means that the number of moles of zinc is the number of moles of hydrogen
- **Careful:** This question asks for the number of **atoms** of hydrogen
  - There are 6.02×10^{23} particles in one mole – this could be atoms or molecules
  - Hydrogen is a diatomic molecule which means that there are twice as many atoms

(3 marks)

6 Nitrogen and hydrogen react together to make ammonia.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

If 2.0 g of hydrogen is added to 12.0 g of nitrogen which substance is the limiting reactant and how much of the excess reactant remains?

Relative atomic masses (A_r): H = 1 N = 14

	Limiting Reactant	Mass of excess reactant
A	nitrogen	2.0 g
B	nitrogen	10.0 g
C	hydrogen	2.7 g
D	hydrogen	9.3 g

Answer

The correct answer is C because:

- **Step 1**: Calculate the relative formula masses (Mr) of the reactants:

M_r of N_2 = (2 x 14) = 28

M_r of H_2 = (2 x 1) = 2

- **Step 2:** Use the numbers from the balanced equation to calculate the sum of the M_r for each substance:

Sum of for M_r of N_2 = (1 x 28) = 28

Sum of for M_r of H_2 = (3 x 2) = 6

- **Step 3:** Scale down for the amounts in the question:

28 g N_2 reacts with 6 g of H_2

28/3 g of N_2 reacts with 2 g of H_2

9.3 g of N_2 reacts with 2 g of H_2

Since 12 g of N_2 are present, the N_2 is in excess and **H_2 is the limiting reactant**

The amount of excess reactant is 12.0 - 9.3 = **2.7 g**

(1 mark)

7 (a) 2.7 g aluminium reacts with 38.1 g of iodine, I_2, to make 40.8 g aluminium iodide, AlI_3.

Relative atomic masses (A_r): Al = 27 I = 127

Relative formula mass (M_r): AlI_3 = 408

What coefficients would balance the equation for the reaction?

A. 1 : 3 : 2

B. 2 : 1 : 2

C. 2 : 3 : 2

D. 3 : 2 : 3

Answer

The correct answer is C because:

- **Step 1**: Calculate the moles of each substance:

moles of Al = $\frac{2.7}{27} = 0.1$ mol

moles of I_2 = $\frac{38.1}{254*} = 0.15$ mol

moles of AlI_3 = $\frac{40.8}{408} = 0.1$ mol

- **Step 2**: Divide by the lowest number of moles to obtain a whole number ratio

$$Al : I_2 : AlI_3$$

$$\frac{0.1}{0.1} : \frac{0.15}{0.1} : \frac{0.1}{0.1}$$

$$1 : 1.5 : 1$$

- **Step 3**: Multiply by 2 to remove the decimal from the ratio

$$2 : 3 : 2$$

$$2Al : 3I_2 : 2AlI_3$$

This is the mole ratio and is the same as the coefficients in the balanced equation

$$2Al + 3I_2 \rightarrow 2AlI_3$$

*don't forget the reaction is with iodine molecules, I_2, not iodine atoms, so the A_r is multiplied by 2

(1 mark)

(b) This question is about the redox reaction of tungsten oxide.

The word equation for the reaction is:

tungsten oxide + hydrogen → tungsten + water

Explain, in terms of redox, the type of reaction that the tungsten oxide is undergoing.

Answer

In terms of redox, the type of reaction that the tungsten oxide is undergoing is:

- Reduction
  AND
  It / tungsten oxide is losing oxygen; [1 mark]

[Total: 1 mark]

- **Remember:** Reduction is the loss of oxygen and oxidation is the gain of oxygen

(1 mark)

(c) A teacher uses this apparatus in **Figure 1** to for the reaction of tungsten oxide with hydrogen.

Figure 1

The teacher wears appropriate eye protection and a lab coat during the demonstration.

Explain **one** other safety precaution the teacher should take.

Answer

One other safety precaution the teacher should take is:

Any **one** from:

- Use a safety screen; [1 mark]
- Do the experiment in a fume cupboard; [1 mark]
- Ensure the class / students are a safe distance away (from the equipment); [1 mark]

Reason:

- There is a risk of explosion; [1 mark]

[Total: 2 marks]

- You need to recognise that hydrogen gas is produced which is flammable, explain the hazard associated with it and how you will limit the risk of harm

(2 marks)