Stage 2

Ratio and proportion

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Introduction

Chemists use mole ratios from balanced equations to calculate the quantities of reactants and products in chemical reactions. Understanding how to read and apply these ratios is essential for quantitative chemistry.

Learning objectives

1. Use ratios from balanced symbol equations to determine quantities of reactants and products.
2. Calculate and use mole ratios from chemical equations.

Reading mole ratios

Activity

Write the mole ratio for each equation and then carry out the calculation.

1. $2H_2 + O_2 \rightarrow 2H_2O$

a) What is the ratio of hydrogen to oxygen?

b) How many moles of H_2O are produced from 3 moles of H_2?

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

a) What is the ratio of nitrogen to ammonia?

b) How many moles of NH_3 are produced from 6 moles of H_2?

3. $4Na + O_2 \rightarrow 2Na_2O$

a) What is the ratio of sodium to sodium oxide?

b) If 0.5 moles of Na_2O are produced, how many moles of Na reacted?

Reading mole ratios – answers

Answers

1.

a) 2:1

b) $H_2 : H_2O = 2 : 2 = 1 : 1$. Therefore 3 moles of water are produced.

2.

a) 1:2

b) $H_2 : NH_3 = 3 : 2.\ 6 \div 3 = 2,\ 2 \times 2 = 4$. Therefore 4 moles of ammonia are produced.

3.

a) 4:2 = 2:1

b) $Na : Na_2O = 2 : 1.\ 2 \times 0.5 = 1$. Therefore 1 mole of sodium reacted.

Calculating masses from equations

Activity

Zinc reacts with hydrochloric acid to form zinc chloride and hydrogen:

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Relative masses: $Zn = 65$; $H_2 = 2$; $ZnCl_2 = 136$

a) Calculate the mass of zinc chloride produced when 13 g of zinc reacts with excess hydrochloric acid.

b) Calculate the mass of hydrogen gas produced when 13 g of zinc reacts with excess hydrochloric acid.

c) Show that the answers are consistent with the conservation of mass.

Calculating masses from equations – part a answer

Answer

a)

Step 1: **identify** the mole ratio from the equation.

$\mathrm{Zn}: \mathrm{ZnCl_2} = 1:1$

Step 2: **calculate** the moles you know.

$\mathrm{Moles\ of\ Zn} = 13 \div 65 = 0.2\ \mathrm{mol}$

Step 3: **use** the ratio to **find** the moles you need.

Ratio is 1:1, so $\mathrm{moles\ of\ ZnCl_2} = 0.2\ \mathrm{mol}$

Step 4: **convert** moles back to mass.

$\mathrm{Mass} = 0.2 \times 136 = 27.2\ \mathrm{g}$

Calculating masses from equations – part b answer

Answer

b)

Step 1: **identify** the mole ratio from the equation.

$\mathrm{Zn}: \mathrm{H_2} = 1:1$

Step 2: **calculate** the moles you know.

$\mathrm{Moles\ of\ Zn} = 0.2\ \mathrm{mol}$ (taken from part a)

Step 3: **use** the ratio to **find** the moles you need.

Ratio is 1:1, so moles of $\mathrm{H_2} = 0.2\ \mathrm{mol}$

Step 4: **convert** moles back to mass.

$\mathrm{Mass} = 0.2 \times 2 = 0.4\ \mathrm{g}$

Calculating masses from equations – part c answer

Answer

c)

Step 1: **identify** the mole ratio from the equation.

$\mathrm{Zn: HCl} \ = \ 1:2$

Step 2: **calculate** the moles you know.

$\mathrm{Moles\ of\ Zn} \ = \ 0.2\ \mathrm{mol}$

Step 3: **use** the ratio to **find** the moles you need.

$\mathrm{Moles\ of\ HCl} \ = \ 0.2 \ \times 2 = 0.4\ \mathrm{mol}$

Step 4: **convert** moles back to mass.

$\mathrm{M}_r \ \mathrm{of\ HCl} = 1 + 35.5 = 36.5. \ \mathrm{Mass} \ = \ 0.4 \ \times \ 36.5 \ = \ 14.6\ \mathrm{g}$

Reactants: $13 \ + \ 14.6 \ = \ 27.6\ \mathrm{g}$

Products: $27.2 \ + \ 0.4 \ = \ 27.6\ \mathrm{g}$

Calculating masses

Activity

Aluminium reacts with iron oxide in a thermite reaction:

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

a) Calculate the mass of iron produced when 5.4 g of aluminium reacts with excess iron oxide.
b) Calculate the mass of iron oxide needed to react completely with 5.4 g of aluminium.

Relative masses: $Al = 27$; $Fe_2O_3 = 160$

Calculating masses – part a answer

Answer

a)

Step 1: **identify** the mole ratio from the equation.

$\mathrm{Al:Fe} = 2:2$, which simplifies to 1:1.

Step 2: **calculate** the moles you know.

M_r of $\mathrm{Al} = 27$. Moles of $\mathrm{Al} = 5.4 \div 27 = 0.2\ \mathrm{mol}$.

Step 3: **use** the ratio to **find** the moles you need.

Ratio is 1:1, so moles of $\mathrm{Fe} = 0.2\ \mathrm{mol}$.

Step 4: **convert** moles back to mass.

M_r of $\mathrm{Fe} = 56$. Mass $= 0.2 \times 56 = 11.2\ \mathrm{g}$.

Calculating masses – part b answer

Answer

b)

Step 1: **identify** the mole ratio from the equation.

$\mathrm{Al}: \mathrm{Fe_2O_3} = 2:1.$

Step 2: **calculate** the moles you know.

$\mathrm{Mole\ of\ Al} = 0.2\ \mathrm{mol}$ (taken from part a).

Step 3: **use** the ratio to **find** the moles you need.

For every 2 moles of Al, 1 mole of $\mathrm{Fe_2O_3}$ is needed.

$\mathrm{Moles\ of\ Fe_2O_3} = 0.2 \div 2 = 0.1\ \mathrm{mol}.$

Step 4: **convert** moles back to mass.

$\mathrm{Mass} = 0.1 \times 160 = 16.0\ \mathrm{g}.$

$M_r\ \mathrm{of\ Fe} = 56.\ \mathrm{Mass} = 0.2 \times 56 = 11.2\ \mathrm{g}.$

Working backwards from the product

Activity

In the Haber process, nitrogen and hydrogen react to form ammonia:

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

A chemist wants to produce 3.4 g of ammonia (NH_3).

Calculate the mass of nitrogen (N_2) needed.

Relative masses: $N_2 = 28$; $H_2 = 2$; $NH_3 = 17$

Working backwards from the product – answer

Answer

Step 1: **identify** the mole ratio from the equation.

$N_2 : NH_3 = 1 : 2.$

Step 2: **calculate** the moles you know.

$\text{Moles of } NH_3 = 3.4 \div 17 = 0.2 \text{ mol}.$

Step 3: **use** the ratio to **find** the moles you need.

For every 2 moles of NH_3 produced, 1 mole of N_2 is needed.

$\text{Moles of } N_2 = 0.2 \div 2 = 0.1 \text{ mol}.$

Step 4: **convert** moles back to mass.

$\text{Mass} = 0.1 \times 28 = 2.8 \text{ g}.$

Discussing mole ratios

Activity

Three learners are calculating the mass of carbon dioxide produced when 10 g of calcium carbonate is heated. Which student has the correct answer? A_r: Ca = 40, C = 12, O = 16.

$$CaCO_3 \rightarrow CaO + CO_2$$

Learner A

The ratio is 1:1:1.
M_r of $CaCO_3 = 100$.
$10 \div 100 = 0.1$ mol $CaCO_3$.
So, 0.1 mol CO_2.
M_r of $CO_2 = 44$.
$0.1 \times 44 = 4.4$ g.

Learner B

The ratio is 1:1:1.
So, 10 g of $CaCO_3$ makes 10 g of CO_2 because the ratio is the same.

Learner C

M_r of $CaCO_3 = 100$.
$10 \div 100$
$= 0.1$ mol $CaCO_3$.
M_r of $CO_2 = 16 + 12$
$= 28$.
$0.1 \times 28 = 2.8$ g.

Discussing mole ratios – answer

Answer

Learner A is correct.

Learner B is incorrect. They have assumed that a 1:1 mole ratio means the masses are equal. A 1:1 ratio means equal moles, not equal masses. 0.1 mol $CaCO_3$ has a mass of 10 g, but 0.1 mol of CO_2 has a mass of only 4.4 g because they have different relative formula masses (100 vs 44).

Learner C is incorrect. They have followed the correct method but makes an error calculating the M_r of CO_2. They write $M_r = 12 + 16 = 28$, but CO_2 contains two oxygen atoms, not one. The correct calculation is $M_r = 12 + (2 \times 16) = 12 + 32 = 44$.

Learner A

The ratio is 1:1:1.

M_r of $CaCO_3 = 100$.

$10 \div 100 = 0.1$ mol $CaCO_3$.

So, 0.1 mol CO_2.

M_r of $CO_2 = 44$.

$0.1 \times 44 = 4.4$ g.