Mixed moles and stoichiometry

AQA 7404 and 7405 · AS and A level

Show your working. Use the worked answers after you finish.

Name _____ Date _____

1. Mass from a balanced equation

$2Al + 3Cl_2 \rightarrow 2AlCl_3$. A sample of 5.40 g of aluminium reacts with excess chlorine. Calculate the mass of aluminium chloride formed.

A_r: Al = 27.0, Cl = 35.5. Give your answer to three significant figures.

2. Ammonia in a closed vessel

$N_2 + 3H_2 \rightarrow 2NH_3$. A vessel initially contains 0.420 mol of N_2 and 0.900 mol of H_2.

For this calculation assume the reaction goes to completion. Identify the limiting reactant and calculate the amounts of NH_3 and unreacted gas at the end.

3. Empirical and molecular formula

A compound contains 54.5% carbon, 9.1% hydrogen and 36.4% oxygen by mass. Its M_r is 88.0.

Find its empirical and molecular formulae. A_r: C = 12.0, H = 1.00, O = 16.0.

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4. Dilution and a measured portion

A student dilutes 15.0 cm^3 of 0.400 mol dm^{-3} KCl solution to 250.0 cm^3. Calculate the new concentration and the amount of KCl in a 25.0 cm^3 portion of the diluted solution.

5. Percentage yield

$CaCO_3 \rightarrow CaO + CO_2$. Heating 12.5 g of pure $CaCO_3$ gives 5.32 g of pure CaO. Calculate the percentage yield.

M_r: $CaCO_3$ = 100.0, CaO = 56.0.

6. Mass from a precipitate

A 0.850 g solid contains Na_2SO_4 and a soluble inert impurity. Its solution gives 1.165 g of dry $BaSO_4$ with excess barium ions.

$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$. Calculate the mass percentage of Na_2SO_4. M_r: $BaSO_4$ = 233.0, Na_2SO_4 = 142.0.

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7. Oxygen from decomposition

$2KClO_3 \rightarrow 2KCl + 3O_2$. A learner collects 1.28 g of oxygen from a 3.00 g sample of pure potassium chlorate.

Could the reaction have produced this much oxygen from that sample? Use a calculation to justify your decision. M_r: $KClO_3$ = 122.6, O_2 = 32.0.

8. Analysis of a powder

A 0.900 g powder contains Na_2CO_3 and a soluble inert impurity. It is dissolved and made up to 250.0 cm^3. A 25.0 cm^3 portion contains 6.40×10^{-4} mol of Na_2CO_3.

Calculate the mass percentage of Na_2CO_3 in the powder. $M_r(Na_2CO_3)$ = 106.0.

9. Extra challenge · Find both components of a powder

A 1.900 g mixture contains only sodium carbonate, Na_2CO_3, and sodium hydrogencarbonate, $NaHCO_3$. It reacts with exactly 0.0300 mol of HCl. Their M_r values are 106.0 and 84.0 respectively. Both give CO_2, water and sodium chloride.

Write the balanced equations and calculate the mass percentage of Na_2CO_3. Calculate the total volume of CO_2 at room conditions, using a molar gas volume of 24.0 dm^3 mol^{-1}.

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Worked answers

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1. Mass from a balanced equation

n(Al) = 5.40 ÷ 27.0 = 0.200 mol. The 2:2 ratio gives 0.200 mol of $AlCl_3$.

$M_r(AlCl_3)$ = 27.0 + 3 × 35.5 = 133.5. Mass = 0.200 × 133.5 = 26.7 g.

2. Ammonia in a closed vessel

0.900 mol H_2 can react with 0.900 ÷ 3 = 0.300 mol N_2. There is more N_2 than this, so H_2 is limiting and none remains.

NH_3 formed = 2 × 0.300 = 0.600 mol. Unreacted N_2 = 0.420 − 0.300 = 0.120 mol.

3. Empirical and molecular formula

In 100 g, the mole ratio is 54.5 ÷ 12.0 : 9.1 ÷ 1.00 : 36.4 ÷ 16.0, or 4.54 : 9.1 : 2.275.

Divide by 2.275 to get approximately 2:4:1, so the empirical formula is C_2H_4O.

The empirical formula mass is 44.0. The multiplier is 88.0 ÷ 44.0 = 2, so the molecular formula is $C_4H_8O_2$.

4. Dilution and a measured portion

Dilution preserves n(KCl) = 0.400 × 0.0150 = 0.00600 mol in the whole flask.

c = 0.00600 ÷ 0.2500 = 0.0240 mol dm^{-3}. A 25.0 cm^3 portion contains 0.0240 × 0.0250 = 6.00×10^{-4} mol.

5. Percentage yield

n($CaCO_3$) = 12.5 ÷ 100.0 = 0.125 mol. The 1:1 ratio gives 0.125 mol of CaO at full conversion.

Theoretical mass = 0.125 × 56.0 = 7.00 g. Yield = (5.32 ÷ 7.00) × 100 = 76.0%.

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6. Mass from a precipitate

$n(BaSO_4) = 1.165 \div 233.0 = 0.005000$ mol. Each mole of Na_2SO_4 supplies one mole of sulfate, which gives one mole of $BaSO_4$.

Mass of $Na_2SO_4 = 0.005000 \times 142.0 = 0.7100$ g. Percentage = $(0.7100 \div 0.850) \times 100 = 83.5\%$ to three significant figures.

7. Oxygen from decomposition

$n(KClO_3) = 3.00 \div 122.6 = 0.02447\ldots$ mol. At complete decomposition, $n(O_2) = (3 \div 2) \times 0.02447\ldots = 0.03670\ldots$ mol.

The maximum mass of O_2 is $0.03670\ldots \times 32.0 = 1.17$ g. The reported mass is above this maximum, so the sample alone could not have produced that much oxygen.

8. Analysis of a powder

The flask contains ten measured portions, so total $n(Na_2CO_3) = 6.40 \times 10^{-3}$ mol.

Mass of $Na_2CO_3 = 6.40 \times 10^{-3} \times 106.0 = 0.6784$ g. Divide by the original mass of the powder, then multiply by 100 to give 75.4%.

9. Extra challenge · Find both components of a powder

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$. $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$.

If x and y are their respective amounts, $2x + y = 0.0300$ and $106.0x + 84.0y = 1.900$. Substitute $y = 0.0300 - 2x$. This gives $x = y = 0.0100$ mol.

The Na_2CO_3 mass percentage is $(0.0100 \times 106.0) \div 1.900 \times 100 = 55.8\%$. Both equations give one CO_2 per formula unit, so $V(CO_2) = 0.0200 \times 24.0 = 0.480\ dm^3$.

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