Using Balanced Equations **Answers**

Use a calculator and a periodic table to answer the following questions.

1. Sulfur dioxide is produced as a by-product of the combustion of fossil fuels. Many manufacturing businesses use calcium carbonate to remove sulfur dioxide from flue gases.

$$CaCO_3(s) + SO_2(g) \longrightarrow CaSO_3(s) + CO_2(g)$$

One factory reports its annual emissions of sulfur dioxide to be 481 kg.

Calculate the mass of calcium carbonate, in kg, that would be required to prevent the emission of this amount of sulfur dioxide.

Give your answer to an appropriate number of significant figures.

$$\textbf{number of moles of } SO_2 = \frac{\textbf{mass of substance (g)}}{Ar \textbf{ or } Mr \textbf{ of substance (g mol}^{-1}\textbf{)}}$$

481 kg × 1000 = 481 000 g

Mr of SO_2 = (32.1 × 1) + (16.0 × 2) = 64.1

$$\frac{481\ 000}{64.1} = 7503.900156 \textbf{ moles } SO_2$$

SO_2 : $CaCO_3$ = 1:1

7503.900156 moles of $CaCO_3$

mass of $CaCO_3$ = number of moles × Mr

Mr of $CaCO_3$ = (40.1 × 1) + (12.0 × 1) + (16.0 × 3) = 100.1

7503.900156 × 100.1 = 751 140.4056 g

$$\frac{751\ 140.4056 \text{ g}}{1000} = 751.1404056 \text{ kg}$$

mass = **751** kg **(3 s.f.)**

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2. Sodium chlorate(I), NaClO, is a component of bleach and can be made in the reaction between sodium hydroxide and chlorine at room temperature and pressure.

$$2NaOH(aq) + Cl_2(g) \longrightarrow NaClO(aq) + NaCl(aq) + H_2O(l)$$

Calculate the volume, in dm^3, of chlorine that is required to produce 10.0 dm^3 of 0.671 mol dm^{-3} sodium chlorate(I) solution.

Give your answer to an appropriate number of significant figures.

moles of NaClO = volume (dm^3) × concentration (mol dm^{-3})

10.0 × 0.671 = 6.71 moles

NaClO : Cl_2 = 1:1

6.71 moles of Cl_2

at 298 K and 101 kPa the volume of 1 mole of gas = 24.0 dm^3

volume of Cl_2 = number of moles × 24.0 dm^3

6.71 × 24.0 = 161.04 dm^3

volume = **161** dm^3 **(3 s.f.)**

3. Magnesium carbonate reacts with nitric acid to produce magnesium nitrate solution, carbon dioxide and water.

$$MgCO_3(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

75 cm^3 of 1.5 mol dm^{-3} nitric acid was heated to a temperature of 40 °C.

Magnesium carbonate powder was added to the warm acid until it no longer dissolved, and the excess was then removed by filtration.

Calculate the maximum volume, in m^3, of carbon dioxide that was produced at this temperature and a pressure of 100 kPa.

The gas constant, R = 8.31 J K^{-1} mol^{-1}.

Give your answer to an appropriate number of significant figures.

moles of HNO_3 = volume (dm^3) × concentration $(mol\ dm^{-3})$

$$\frac{75\ cm^3}{1000} = 0.075\ dm^3$$

0.075 × 1.5 = 0.1125 moles of HNO_3

stoichiometric ratio $HNO_3 : CO_2 = 2 : 1$

moles of CO_2 = $\frac{0.1125}{2}$ = 0.05625 moles

volume of CO_2 = $\frac{nRT}{P}$

T = 40°C + 273 = 313 K

p = 100 kPa × 1000 = 100 000 Pa

$$\frac{0.05625 \times 8.31 \times 313}{100\ 000} = 0.001463079375\ m^3$$

volume = **0.0015** m^3 **(2 s.f.)**

4. A student dissolved an unknown mass of sodium hydroxide in water and made the solution up to 200 cm^3.

The student then titrated a 20.0 cm^3 sample of the sodium hydroxide solution with 0.650 mol dm^{-3} sulfuric acid.

$$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

The student's results are shown in the table below.

	Rough	**Titre 1**	**Titre 2**	**Titre 3**
Volume of Sulfuric Acid (cm^3)	36.05	35.70	35.75	35.80

Calculate the concentration of the sodium hydroxide solution.

Give your answer to an appropriate number of significant figures.

mean titre volume of H_2SO_4 = $\frac{35.70 + 35.75 + 35.80}{3}$ = 35.75 cm^3

moles of H_2SO_4 in mean titre volume = volume (dm^3) × concentration (mol dm^{-3})

$\frac{35.75\ cm^3}{1000}$ = 0.03575 dm^3

0.03575 × 0.650 = 0.0232375 moles

stoichiometric ratio H_2SO_4 : NaOH = 1 : 2

moles of NaOH in 20.0 cm^3 of solution = 0.0232375 × 2 = 0.046475 moles

moles of NaOH in 200 cm^3 of solution = 0.046475 × 10 = 0.46475 moles

concentration of NaOH = $\frac{\text{number of moles}}{\text{volume } (cm^3)}$

volume of NaOH = $\frac{200\ cm^3}{1000}$ = 0.200 dm^3

$\frac{0.46475}{0.200}$ = 2.32375 mol dm^{-3}

concentration = **2.32** mol dm^{-3} **(3 s.f.)**

5. Calculate the volume, in cm^3, of 0.500 mol dm^{-3} ammonia solution that would be needed to produce 804 mg of the brown precipitate $Fe(OH)_3(H_2O)_3$ in the following reaction.

$$[Fe(H_2O)_6]^{3+}(aq) + 3NH_3(aq) \longrightarrow Fe(OH)_3(H_2O)_3(s) + 3NH_4^+(aq)$$

Give your answer to an appropriate number of significant figures.

moles of $Fe(OH)_3(H_2O)_3$ = $\dfrac{\text{mass of substance (g)}}{Ar \text{ or } Mr \text{ of substance (g mol}^{-1})}$

$\dfrac{804 \text{ mg}}{1000}$ = 0.804 g of $Fe(OH)_3(H_2O)_3$

Mr of $Fe(OH)_3(H_2O)_3$ = (55.8 × 1) + (16.0 × 6) + (1.0 × 9) = 160.8

$\dfrac{0.804}{160.8}$ = 0.005 moles

stoichiometric ratio $Fe(OH)_3(H_2O)_3$: NH_3 = 1 : 3

moles of NH_3 = 0.005 × 3 = 0.015 moles

volume of NH_3 = $\dfrac{\text{number of moles}}{\text{concentation (mol dm}^{-1})}$

$\dfrac{0.015}{0.500}$ = 0.03 dm^3

0.03 dm^3 × 1000 = 30 cm^3

volume = **30.0** cm^3 **(3 s.f.)**

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6. A tool, believed to date from the bronze age, was analysed to determine its percentage by mass of copper. A 0.850 g sample of the tool was dissolved in a small amount of concentrated nitric acid and made up to a 250 cm^3 solution containing Cu^{2+} ions. An excess of potassium iodide solution was added to a 25 cm^3 sample of the Cu^{2+} solution to produce iodine.

$$2Cu^{2+}(aq) + 4I^-(aq) \longrightarrow 2CuI(s) + I_2(aq)$$

The reaction mixture was filtered to remove the copper iodide precipitate and then titrated with 0.150 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$. 6.50 cm^3 of sodium thiosulfate reacted completely with the resulting iodine solution.

$$2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

Calculate the percentage by mass of copper in the bronze tool.

Give your answer to an appropriate number of significant figures.

moles of $S_2O_3^{2-}$ = volume (dm^3) × concentration (mol dm^{-3})

$$\frac{6.50\ cm^3}{1000} = 0.00650\ dm^3$$

0.0065 × 0.150 = 0.000975 moles

stoichiometric ratio $S_2O_3^{2-} : I_2 = 2 : 1$

moles of I_2 produced in the reaction between Cu^{2+} solution and potassium iodide =

$$\frac{0.000975}{2} = 0.0004875 \text{ moles } I_2$$

stoichiometric ratio $I_2 : Cu^{2+} = 1 : 2$

moles of Cu^{2+} in 25 cm^3 of solution = 0.0004875 × 2 = 0.000975 moles

moles of Cu^{2+} in 250 cm^3 of solution = 0.000975 × 10 = 0.00975 moles

mass of Cu^{2+} = number of moles × *Ar*

***Ar* of Cu = 63.5**

0.00975 × 63.5 = 0.619125 g

percentage by mass of cooper = $\dfrac{\text{mass of Cu}}{\text{total mass of bronze sample}} \times 100$

$$\frac{0.619125}{0.850} \times 100 = 72.83823529$$

percentage by mass of copper = **73 % (2 s.f.)**