

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.



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.

$$\text{number of moles of SO}_2 = \frac{\text{mass of substance (g)}}{\text{Ar or Mr of substance (g mol}^{-1}\text{)}}$$

$$481 \text{ kg} \times 1000 = 481\,000 \text{ g}$$

$$\text{Mr of SO}_2 = (32.1 \times 1) + (16.0 \times 2) = 64.1$$

$$\frac{481\,000}{64.1} = 7503.900156 \text{ moles SO}_2$$

$$\text{SO}_2 : \text{CaCO}_3 = 1:1$$

$$7503.900156 \text{ moles of CaCO}_3$$

$$\text{mass of CaCO}_3 = \text{number of moles} \times \text{Mr}$$

$$\text{Mr of CaCO}_3 = (40.1 \times 1) + (12.0 \times 1) + (16.0 \times 3) = 100.1$$

$$7503.900156 \times 100.1 = 751\,140.4056 \text{ g}$$

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

$$\text{mass} = \mathbf{751 \text{ kg (3 s.f.)}}$$

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



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

Give your answer to an appropriate number of significant figures.

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

$$10.0 \times 0.671 = 6.71 \text{ moles}$$

NaClO : Cl₂ = 1:1

6.71 moles of Cl₂

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

volume of Cl₂ = number of moles \times 24.0 dm^3

$$6.71 \times 24.0 = 161.04 \text{ dm}^3$$

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

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



75 cm³ 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 m³, of carbon dioxide that was produced at this temperature and a pressure of 100 kPa.

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

Give your answer to an appropriate number of significant figures.

moles of HNO_3 = volume (dm³) × concentration (mol dm⁻³)

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

$$0.075 \times 1.5 = 0.1125 \text{ moles of } \text{HNO}_3$$

stoichiometric ratio $\text{HNO}_3 : \text{CO}_2 = 2 : 1$

$$\text{moles of } \text{CO}_2 = \frac{0.1125}{2} = 0.05625 \text{ moles}$$

$$\text{volume of } \text{CO}_2 = \frac{nRT}{P}$$

$$T = 40^\circ\text{C} + 273 = 313 \text{ K}$$

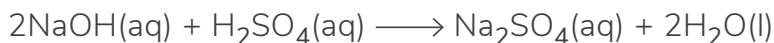
$$p = 100 \text{ kPa} \times 1000 = 100\,000 \text{ Pa}$$

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

$$\text{volume} = \mathbf{0.0015 \text{ m}^3 (2 \text{ s.f.})}$$

4. A student dissolved an unknown mass of sodium hydroxide in water and made the solution up to 200 cm³.

The student then titrated a 20.0 cm³ sample of the sodium hydroxide solution with 0.650 mol dm⁻³ sulfuric acid.



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.

$$\text{mean titre volume of H}_2\text{SO}_4 = \frac{35.70 + 35.75 + 35.80}{3} = 35.75 \text{ cm}^3$$

$$\text{moles of H}_2\text{SO}_4 \text{ in mean titre volume} = \text{volume (dm}^3\text{)} \times \text{concentration (mol dm}^{-3}\text{)}$$

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

$$0.03575 \times 0.650 = 0.0232375 \text{ moles}$$

$$\text{stoichiometric ratio H}_2\text{SO}_4 : \text{NaOH} = 1 : 2$$

$$\text{moles of NaOH in 20.0 cm}^3 \text{ of solution} = 0.0232375 \times 2 = 0.046475 \text{ moles}$$

$$\text{moles of NaOH in 200 cm}^3 \text{ of solution} = 0.046475 \times 10 = 0.46475 \text{ moles}$$

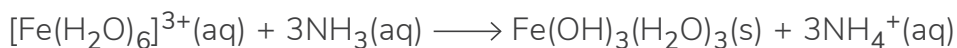
$$\text{concentration of NaOH} = \frac{\text{number of moles}}{\text{volume (cm}^3\text{)}}$$

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

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

$$\text{concentration} = \mathbf{2.32 \text{ mol dm}^{-3} \text{ (3 s.f.)}}$$

5. Calculate the volume, in cm^3 , of $0.500 \text{ mol dm}^{-3}$ ammonia solution that would be needed to produce 804 mg of the brown precipitate $\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3$ in the following reaction.



Give your answer to an appropriate number of significant figures.

$$\text{moles of Fe}(\text{OH})_3(\text{H}_2\text{O})_3 = \frac{\text{mass of substance (g)}}{\text{Ar or Mr of substance (g mol}^{-1}\text{)}}$$

$$\frac{804 \text{ mg}}{1000} = 0.804 \text{ g of Fe}(\text{OH})_3(\text{H}_2\text{O})_3$$

$$\text{Mr of Fe}(\text{OH})_3(\text{H}_2\text{O})_3 = (55.8 \times 1) + (16.0 \times 6) + (1.0 \times 9) = 160.8$$

$$\frac{0.804}{160.8} = 0.005 \text{ moles}$$

$$\text{stoichiometric ratio Fe}(\text{OH})_3(\text{H}_2\text{O})_3 : \text{NH}_3 = 1 : 3$$

$$\text{moles of NH}_3 = 0.005 \times 3 = 0.015 \text{ moles}$$

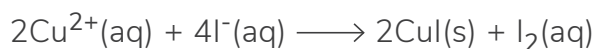
$$\text{volume of NH}_3 = \frac{\text{number of moles}}{\text{concentration (mol dm}^{-3}\text{)}}$$

$$\frac{0.015}{0.500} = 0.03 \text{ dm}^3$$

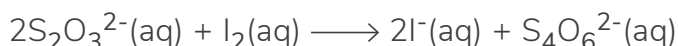
$$0.03 \text{ dm}^3 \times 1000 = 30 \text{ cm}^3$$

$$\text{volume} = \mathbf{30.0 \text{ cm}^3 \text{ (3 s.f.)}}$$

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 cm³ solution containing Cu²⁺ ions. An excess of potassium iodide solution was added to a 25 cm³ sample of the Cu²⁺ solution to produce iodine.



The reaction mixture was filtered to remove the copper iodide precipitate and then titrated with 0.150 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃. 6.50 cm³ of sodium thiosulfate reacted completely with the resulting iodine solution.



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

Give your answer to an appropriate number of significant figures.

moles of S₂O₃²⁻ = volume (dm³) × concentration (mol dm⁻³)

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

$$0.0065 \times 0.150 = 0.000975 \text{ moles}$$

stoichiometric ratio S₂O₃²⁻ : I₂ = 2 : 1

moles of I₂ produced in the reaction between Cu²⁺ solution and potassium iodide =

$$\frac{0.000975}{2} = 0.0004875 \text{ moles I}_2$$

stoichiometric ratio I₂ : Cu²⁺ = 1 : 2

moles of Cu²⁺ in 25 cm³ of solution = 0.0004875 × 2 = 0.000975 moles

moles of Cu²⁺ in 250 cm³ of solution = 0.000975 × 10 = 0.00975 moles

mass of Cu²⁺ = number of moles × *Ar*

***Ar* of Cu = 63.5**

$$0.00975 \times 63.5 = 0.619125 \text{ g}$$

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

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

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