# S4 Chemistry Practice Paper 2 | Mole, titration, enthalpy, equilibrium and electrolysis calculations (with answers and marking scheme)

S4 chemistry paper: moles and gas volume, titration, enthalpy, equilibrium and Kc, electrolysis with Faraday calculations and rate graphs; full answers and marks included.

## 1. Mole and molar gas volume (16 marks)

*A student obtains a bottle of carbon dioxide in the laboratory. Relative atomic masses: C = 12.0, O = 16.0; Avogadro constant = 6.02 x 10^23 mol^-1; molar volume at room temperature and pressure = 24.0 dm3 mol^-1; at standard conditions = 22.4 dm3 mol^-1. The mass of the sample is 8.8 g.*

| # | Question |
|---|---|
| **1** | (a) Calculate the number of moles of carbon dioxide in the sample. |
| **2** | (b) Calculate the number of carbon dioxide molecules in the sample. |
| **3** | (c) Calculate the volume of the sample at room temperature and pressure. |
| **4** | (d) If measured at standard conditions instead, what is the volume of the same number of moles? |
| **5** | (e) Calculate the number of moles of oxygen atoms and their total mass in 8.8 g of carbon dioxide. |

## 2. Dilution and acid-base titration (18 marks)

*25.0 cm3 of sodium hydroxide solution is titrated with 0.100 M hydrochloric acid; the indicator changes from pink to colourless and the mean titre of three runs is 22.40 cm3. The reaction is HCl + NaOH -> NaCl + H2O.*

| # | Question |
|---|---|
| **6** | (a) Calculate the number of moles of hydrochloric acid used. |
| **7** | (b) Deduce the number of moles of sodium hydroxide from the equation. |
| **8** | (c) Calculate the concentration of the sodium hydroxide solution in mol dm^-3. |
| **9** | (d) If 25.0 cm3 of the sodium hydroxide solution is diluted with water to 250.0 cm3, find the new concentration. |
| **10** | (e) 25.0 cm3 of the diluted solution is titrated with the same acid; find the volume of acid required. |

## 3. Enthalpy of combustion and heat calculation (16 marks)

*Burning 0.500 g of ethanol (C2H5OH, molar mass 46.0 g mol^-1) raises the temperature of 100 g of water from 22.0 C to 40.0 C. Specific heat capacity of water = 4.2 J g^-1 K^-1; assume all heat is transferred to the water.*

| # | Question |
|---|---|
| **11** | (a) Calculate the number of moles of ethanol burnt. |
| **12** | (b) Calculate the heat absorbed by the water in kJ. |
| **13** | (c) Hence estimate the enthalpy of combustion of ethanol in kJ mol^-1. |

| # | Question |
|---|---|
| **14** | (d) The literature value is -1367 kJ mol^-1. Give two reasons why the calculated value is much smaller. |
| **15** | (e) Using the value in (c), what mass of ethanol must be burnt to heat 500 g of water from 20 C to 50 C? |

## 4. Chemical equilibrium and the equilibrium constant (16 marks)

*At a fixed temperature, 0.100 mol each of hydrogen and iodine vapour are sealed in a 1.00 dm3 vessel: H2(g) + I2(g) in a reversible reaction giving 2HI(g). At equilibrium the concentration of hydrogen iodide is 0.120 M.*

| # | Question |
|---|---|
| **16** | (a) Find the change in concentration of hydrogen. |
| **17** | (b) Find the equilibrium concentrations of hydrogen and iodine vapour. |
| **18** | (c) Calculate the equilibrium constant Kc at this temperature. |
| **19** | (d) If a further 0.020 mol of hydrogen is added at constant volume, how do the position of equilibrium and Kc change? |
| **20** | (e) If the vessel is compressed to 0.50 dm3 at constant temperature, does Kc change? Explain. |

## 5. Electrolysis and Faraday calculations (18 marks)

*Copper(II) sulphate solution is electrolysed with a steady current of 2.00 A for 30.0 minutes using copper electrodes. Faraday constant = 96 500 C mol^-1; relative atomic mass of Cu = 64.0.*

| # | Question |
|---|---|
| **21** | (a) Calculate the quantity of charge passed. |
| **22** | (b) Calculate the number of moles of electrons passed. |
| **23** | (c) From the half equation Cu^2+ + 2e^- -> Cu, find the moles of copper deposited at the cathode. |
| **24** | (d) Calculate the increase in mass of the cathode. |
| **25** | (e) If the current efficiency is only 90%, what mass is actually deposited, and what happens at the anode? |

## 6. Reaction rate and gas volume graph (16 marks)

*A strip of magnesium is added to excess 1.0 M hydrochloric acid and the volume of hydrogen is measured with a gas syringe: time s / volume cm3 = 0 / 0, 20 / 28, 40 / 46, 60 / 58, 80 / 64; the volume no longer changes after 80 s.*

| # | Question |
|---|---|
| **26** | (a) Calculate the average rate over the first 20 s in cm3 s^-1. |
| **27** | (b) Calculate the average rate between 20 s and 40 s. |
| **28** | (c) Explain why the rate decreases with time. |
| **29** | (d) Calculate the percentage of the reaction completed at 40 s. |

| # | Question |
|---|---|
| **30** | (e) If 0.50 M acid is used instead with magnesium still in excess, how do the initial slope and final volume differ? |
| **31** | (f) If the same mass of magnesium is used as a powder instead of a strip, how does the curve change? Explain. |