S4 Chemistry Practice Paper: Mole Concept and Stoichiometry, Solution Concentration and Dilution, Acid-Base Titration, Redox and Electron Transfer, Electrolysis and Faraday Law, Reaction Rate

Level: S4 | Subject: Chemistry | 75 minutes | 100 marks | 24 questions | answer key

Section A: Mole Concept and Stoichiometry (18 marks)

Show all working. Relative atomic masses: Mg 24.0, Ca 40.0, C 12.0, O 16.0, H 1.0, S 32.1, Zn 65.4, Cu 63.5, Ag 108.0; molar volume at room conditions = 24.0 dm3/mol.

#	Question	Answer	Marks
1	4.8 g of magnesium reacts with excess dilute hydrochloric acid: Mg + 2HCl -> MgCl2 + H2. Find (a) the number of moles of magnesium, (b) the volume of hydrogen at room conditions, (c) the mass of magnesium chloride formed (Mr = 95.0).	n(Mg) = 4.8 / 24.0 = 0.20 mol. The equation gives 1 mol H2 per mol Mg, so V(H2) = 0.20 x 24.0 = 4.8 dm3. n(MgCl2) = 0.20 mol, mass = 0.20 x 95.0 = 19.0 g.	5
2	25.0 g of calcium carbonate is completely decomposed by heating: CaCO3 -> CaO + CO2. Find the number of moles of calcium carbonate and the volume of carbon dioxide released at room conditions.	Mr(CaCO3) = 40 + 12 + 48 = 100, so n = 25.0 / 100 = 0.25 mol. 1 mol CaCO3 gives 1 mol CO2, hence V = 0.25 x 24.0 = 6.0 dm3.	4
3	A compound contains 40.0% carbon, 6.70% hydrogen and 53.3% oxygen by mass, and has a relative molecular mass of 60. Find its empirical and molecular formulae.	Mole ratio C : H : O = 40.0/12 : 6.70/1.0 : 53.3/16 = 3.33 : 6.70 : 3.33, which divides to 1 : 2 : 1, so the empirical formula is CH2O (Mr = 30). 60 / 30 = 2, hence the molecular formula is C2H4O2.	4
4	0.50 mol of zinc is heated with 0.40 mol of sulphur: Zn + S -> ZnS. Find (a) the limiting reagent, (b) the mass of zinc sulphide formed (Mr = 97.5), (c) the mass of the reactant left over.	The ratio is 1 : 1 and sulphur is in shorter supply, so sulphur is limiting. n(ZnS) = 0.40 mol, mass = 0.40 x 97.5 = 39.0 g. Zinc left = 0.50 - 0.40 = 0.10 mol, mass = 0.10 x 65.4 = 6.54 g.	5

Section B: Solution Concentration and Dilution (17 marks)

Concentrations are in mol/dm3; 1 dm3 = 1000 cm3; the number of moles of solute is unchanged on dilution.

#	Question	Answer	Marks
5	5.85 g of sodium chloride (Mr = 58.5) is dissolved in water and made up to 250 cm3 of solution. Find the concentration.	n(NaCl) = 5.85 / 58.5 = 0.10 mol, volume = 250/1000 = 0.250 dm3, so concentration = 0.10 / 0.250 = 0.40 mol/dm3.	4
6	25.0 cm3 of 2.0 mol/dm3 sulphuric acid is diluted to a total volume of 500 cm3. Find the new concentration and state what happens to the number of moles of solute.	Before dilution n = 0.0250 x 2.0 = 0.050 mol. New concentration = 0.050 / 0.500 = 0.10 mol/dm3. Adding water only increases the volume, so the moles of solute stay at 0.050 mol.	5
7	How many grams of anhydrous sodium carbonate (Mr = 106) are needed to prepare	n = 0.250 x 0.20 = 0.050 mol, mass = 0.050 x 106 = 5.3 g. Weigh 5.3 g, dissolve and make up	4

	0.250 dm3 of 0.20 mol/dm3 solution?	to the 250 cm3 mark.	
8	200 cm3 of 0.50 mol/dm3 solution is mixed with 300 cm3 of 0.20 mol/dm3 of the same solute (assume volumes are additive). Find the final concentration.	n1 = 0.200 x 0.50 = 0.100 mol, n2 = 0.300 x 0.20 = 0.060 mol, total n = 0.160 mol; total volume = 0.500 dm3, so concentration = 0.160 / 0.500 = 0.32 mol/dm3.	4

Section C: Acid-Base Neutralisation and Titration (17 marks)

Acid-base reactions follow the stoichiometric ratio; pH + pOH = 14 at 25 C; take the specific heat capacity of water as 4.2 J g-1 K-1 and its density as 1.0 g/cm3.

#	Question	Answer	Marks
9	25.0 cm3 of sodium hydroxide solution needs 20.0 cm3 of 0.10 mol/dm3 hydrochloric acid to reach the end point. Find the concentration of the sodium hydroxide solution.	NaOH + HCl -> NaCl + H2O, a 1 : 1 ratio. n(HCl) = 0.0200 x 0.10 = 0.0020 mol, so n(NaOH) = 0.0020 mol and concentration = 0.0020 / 0.0250 = 0.080 mol/dm3.	5
10	Find (a) the pH of 0.010 mol/dm3 hydrochloric acid; (b) the pH of 0.0010 mol/dm3 sodium hydroxide solution at 25 C.	(a) The strong acid is fully ionised, so [H+] = 0.010 mol/dm3 and pH = -log 0.010 = 2.00. (b) [OH-] = 0.0010, pOH = 3.00, so pH = 14 - 3.00 = 11.00.	4
11	25.0 cm3 of sulphuric acid needs 30.0 cm3 of 0.20 mol/dm3 sodium hydroxide for neutralisation: H2SO4 + 2NaOH -> Na2SO4 + 2H2O. Find the acid concentration.	n(NaOH) = 0.0300 x 0.20 = 0.0060 mol. From the 1 : 2 ratio, n(H2SO4) = 0.0060 / 2 = 0.0030 mol, so concentration = 0.0030 / 0.0250 = 0.12 mol/dm3.	4
12	50 cm3 of 1.0 mol/dm3 hydrochloric acid is mixed with 50 cm3 of 1.0 mol/dm3 sodium hydroxide and the temperature rises by 6.7 C. Find the enthalpy change of neutralisation in kJ/mol and state the sign of dH.	Heat released q = mcDT = 100 x 4.2 x 6.7 = 2814 J. Water formed n = 0.050 mol, so per mole 2814 / 0.050 = 56280 J = 56.28 kJ. Heat is released, so dH = -56.3 kJ/mol.	4

Section D: Redox and Electron Transfer (16 marks)

Use changes in oxidation number to identify redox; the reduction half-equation of permanganate in acid is MnO4- + 8H+ + 5e- -> Mn2+ + 4H2O.

#	Question	Answer	Marks
13	In acidic solution MnO4- is reduced to Mn2+. Find (a) the number of electrons gained per MnO4- ion, (b) the number of moles of Fe2+ oxidised by 1 mol of MnO4-.	Mn falls from +7 to +2, so 5 electrons are gained. Fe2+ -> Fe3+ + e- loses one electron per mole, so 1 mol MnO4- oxidises 5 mol Fe2+.	4
14	25.0 cm3 of iron(II) sulphate solution needs 20.0 cm3 of 0.020 mol/dm3 potassium permanganate to reach the end point. Find the concentration of Fe2+.	n(MnO4-) = 0.0200 x 0.020 = 4.0 x 10-4 mol. By electron balance n(Fe2+) = 5 x 4.0 x 10-4 = 2.0 x 10-3 mol, so concentration = 2.0 x 10-3 / 0.0250 = 0.080 mol/dm3.	4
15	Find the oxidation number of the stated element: (a) Cr in K2Cr2O7, (b) Mn in MnO2, (c) N in NO3-.	(a) 2x + 7(-2) = -2 gives x = +6. (b) x + 2(-2) = 0 gives x = +4. (c) x + 3(-2) = -1 gives x = +5.	4
16	1.3 g of zinc is placed in copper(II) sulphate solution: Zn + Cu2+ -> Zn2+ + Cu. Find (a) the oxidising and reducing agents, (b) the moles of electrons transferred, (c) the mass of copper deposited.	Zn rises from 0 to +2 and is oxidised, so it is the reducing agent; Cu2+ falls from +2 to 0 and is the oxidising agent. n(Zn) = 1.3 / 65 = 0.020 mol, so 0.040 mol of electrons move. n(Cu) = 0.020 mol, mass = 0.020 x 63.5 = 1.27 g.	4

Section E: Electrolysis and Faraday Law (16 marks)

Charge Q = It with the Faraday constant taken as 96500 C/mol; electrolysis of copper(II) sulphate deposits copper at the cathode and gives oxygen at the anode.

#	Question	Answer	Marks
17	A current of 2.0 A passes through copper(II) sulphate solution for 30 minutes. Find the charge passed and the mass of copper deposited at the cathode (Ar Cu = 63.5).	t = 30 x 60 = 1800 s, Q = 2.0 x 1800 = 3600 C. n(e-) = 3600 / 96500 = 0.0373 mol and Cu2+ + 2e- -> Cu, so n(Cu) = 0.0187 mol and mass = 0.0187 x 63.5 = 1.18 g.	5
18	On electrolysing water, hydrogen forms at the cathode and oxygen at the anode: 2H2O -> 2H2 + O2. If 0.50 mol of hydrogen is collected at the cathode, find the moles of oxygen and the volume ratio.	From the 2 : 1 ratio, n(O2) = 0.50 / 2 = 0.25 mol. At the same temperature and pressure the volume ratio equals the mole ratio, so V(H2) : V(O2) = 2 : 1.	4
19	In a zinc-copper cell, state (a) the metal at the negative electrode, (b) the direction of electron flow, (c) the type of reaction at the cathode.	Zinc is more reactive, so it is the negative electrode and is oxidised: Zn -> Zn2+ + 2e-. Electrons flow through the external circuit from zinc to copper, where Cu2+ gains electrons and is reduced.	3
20	Silver is electroplated with a current of 1.0 A. Find the charge and the time in minutes needed to deposit 1.08 g of silver (Ar Ag = 108).	n(Ag) = 1.08 / 108 = 0.010 mol. Ag+ + e- -> Ag needs 0.010 mol of electrons, so Q = 0.010 x 96500 = 965 C. t = Q / I = 965 / 1.0 = 965 s, about 16.1 minutes.	4

Section F: Reaction Rate (16 marks)

Rate is expressed as the amount of reactant used or product formed per unit time; change only one variable in a comparison experiment.

#	Question	Answer	Marks
21	Zinc reacts with dilute sulphuric acid and the volume of hydrogen is read every 30 s by water displacement; 48 cm3 is collected in the first 60 s. Find the average rate over the first 60 s in cm3/s.	Average rate = volume change / time = 48 / 60 = 0.80 cm3/s. The slope falls with time because the acid concentration drops and the zinc surface shrinks.	4
22	A reaction has the rate equation rate = k[A]. At constant temperature [A] is doubled. State the change in rate and whether the rate constant k changes.	The rate is proportional to [A], so doubling [A] doubles the rate. Since the temperature is unchanged, k stays the same; k depends only on temperature and catalysts.	4
23	A catalyst lowers the activation energy of a reaction from 80 kJ/mol to 60 kJ/mol. Explain why the rate increases and state whether dH changes.	Lowering the activation energy by 20 kJ/mol greatly increases the fraction of molecules with enough energy, so there are more effective collisions and the rate rises. The catalyst does not change the enthalpies of reactants and products, so dH is unchanged.	4
24	The temperature of a reaction is raised from 20 C to 50 C. If the rate roughly doubles for every 10 C rise, find the approximate rate factor and explain why.	The rise is 30 C, i.e. three 10 C intervals, so the rate becomes about 2^3 = 8 times larger. More molecules now have kinetic energy above the activation energy, so effective collisions are far more frequent.	4

TutorZone - original practice paper. Time allowed: 75 minutes. Total: 100 marks.