S4 Chemistry Practice Paper: Acid-Base and Redox Titration, Electrolysis, Rates of Reaction and Enthalpy Change

S4 Chemistry | Time allowed: 90 minutes | Total: 100 marks | 24 questions

A. Acid-Base Neutralisation and pH (17 marks)

All volumes are in cm³; give answers to 3 significant figures.

1. 25.0 cm³ of 0.100 M NaOH is neutralised by 0.125 M HCl. Find the volume of HCl required. (4 marks)

> **Answer:** Moles NaOH = 0.100 × 0.0250 = 0.00250 mol; moles HCl = 0.00250; volume = 0.00250 / 0.125 = 0.0200 dm³ = 20 cm³.

2. Find the pH of 0.010 M HCl at 25 °C, assuming complete dissociation. (4 marks)

> **Answer:** $[H^+] = 0.010$ mol dm^{-3}; pH = -log 0.010 = 2.

3. Find the pH of 0.0020 M $Ba(OH)_2$ solution, assuming complete dissociation. (5 marks)

> **Answer:** $[OH^-] = 2 \times 0.0020 = 0.0040$ mol dm^{-3}; pOH = -log 0.0040 = 2.4; pH = 14 - 2.4 = 11.6.

4. 20.0 cm³ of 0.100 M H_2SO_4 is mixed with 30.0 cm³ of 0.150 M NaOH. Find the pH of the mixture. (4 marks)

> **Answer:** Moles $H^+ = 2 \times 0.0200 \times 0.100 = 0.00400$ mol; moles $OH^- = 0.0300 \times 0.150 = 0.00450$ mol; excess $OH^- = 0.00050$ mol; total volume 0.0500 dm³; $[OH^-] = 0.0100$ mol dm^{-3}; pOH = 2.00, pH = 12.

B. Redox Titration (17 marks)

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$; $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$.

5. 25.0 cm³ of a solution containing Fe^{2+} needs 18.0 cm³ of 0.0200 M $KMnO_4$ to reach the end point. Find the concentration of Fe^{2+}. (5 marks)

> **Answer:** Moles $MnO_4^- = 0.0200 \times 0.0180 = 3.60 \times 10^{-4}$ mol; ratio MnO_4^- : Fe^{2+} = 1 : 5; $Fe^{2+} = 1.80 \times 10^{-3}$ mol; concentration = $1.80 \times 10^{-3} / 0.0250 = 0.072$ M.

6. Find the oxidation number of manganese in MnO_4^- and of chromium in $Cr_2O_7^{2-}$. (4 marks)

> **Answer:** MnO_4^-: x + 4(-2) = -1, so x = +7; $Cr_2O_7^{2-}$: 2x + 7(-2) = -2, so x = +6.

7. What volume of 0.0200 M $K_2Cr_2O_7$ is needed to oxidise 25.0 cm³ of 0.100 M $FeSO_4$ completely? (4 marks)

> **Answer:** $Fe^{2+} = 0.100 \times 0.0250 = 2.50 \times 10^{-3}$ mol; ratio $Cr_2O_7^{2-}$: Fe^{2+} = 1 : 6; $Cr_2O_7^{2-} = 4.17 \times 10^{-4}$ mol; volume = $4.17 \times 10^{-4} / 0.0200 = 0.021$ dm³ = 20.8 cm³.

8. How many moles of electrons are transferred when 1.00 g of copper is oxidised completely to Cu^{2+}? (Relative atomic mass of Cu = 63.5) (4 marks)

> **Answer:** Moles Cu = 1.00 / 63.5 = 0.0157 mol; each mole of Cu releases 2 mol of electrons; moles of electrons = 0.031 mol.

C. Electrolysis and Electroplating (17 marks)

Take the Faraday constant as 96 500 C mol^{-1}; relative atomic masses: Cu 63.5, Ag 107.9, Ni 58.7.

9. A current of 2.50 A passes through copper(II) sulphate solution for 30.0 minutes. Find the mass of copper deposited at the cathode. (5 marks)

> **Answer:** Charge = 2.50 × 1 800 = 4 500 C; electrons = 4 500 / 96 500 = 0.0466 mol; Cu = 0.0466 / 2 = 0.0233 mol; mass = 0.0233 × 63.5 = 1.481 g.

10. A current of 0.500 A passes through silver nitrate solution for 60.0 minutes. Find the mass of silver deposited at the cathode. (4 marks)

> **Answer:** Charge = 0.500 × 3 600 = 1 800 C; electrons = 1 800 / 96 500 = 0.0187 mol; $Ag^+ + e^- \rightarrow Ag$; mass = 0.0187 × 107.9 = 2.013 g.

11. A current of 1.00 A electrolyses water for 2.00 hours. Find the volume of hydrogen collected at the cathode at room temperature (molar volume 24.0 dm^3 mol^{-1}). (4 marks)

> **Answer:** Charge = 1.00 × 7 200 = 7 200 C; electrons = 7 200 / 96 500 = 0.0746 mol; $2H^+ + 2e^- \rightarrow H_2$, so H_2 = 0.0373 mol; volume = 0.0373 × 24.0 = 0.895 dm^3.

12. Nickel is electroplated with a current of 0.800 A for 45.0 minutes at 90% current efficiency. Find the mass of nickel deposited. (4 marks)

> **Answer:** Charge = 0.800 × 2 700 = 2 160 C; electrons = 2 160 / 96 500 = 0.0224 mol; $Ni^{2+} + 2e^- \rightarrow Ni$; Ni = 0.0112 mol; theoretical mass = 0.0112 × 58.7 = 0.657 g; actual = 0.657 × 0.90 = 0.591 g.

D. Rates of Reaction (17 marks)

Rates are in mol dm^{-3} s^{-1} or cm^3 s^{-1}; give answers to 3 significant figures.

13. For the reaction 2A + B → C, the concentration of A falls from 0.800 M to 0.200 M in 60 s. Find the average rate of disappearance of A and the average rate of formation of C. (5 marks)

> **Answer:** Rate of disappearance of A = (0.800 - 0.200) / 60 = 0.01 mol dm^{-3} s^{-1}; ratio A : C = 2 : 1; rate of formation of C = 0.005 mol dm^{-3} s^{-1}.

14. A first order reaction has a half-life of 20 minutes and an initial concentration of 0.400 M. Find the concentration after 60 minutes. (4 marks)

> **Answer:** 60 minutes is 3 half-lives; concentration = 0.400 × $(1/2)^3$ = 0.05 M.

15. The rate of a reaction doubles for every 10 °C rise in temperature. By what factor does the rate increase when the temperature rises from 20 °C to 60 °C? (4 marks)

> **Answer:** A 40 °C rise is 4 intervals of 10 °C; factor = 2^4 = 16.

16. Zinc reacts with dilute hydrochloric acid: 24.0 cm^3 of hydrogen is collected in the first 30 s and the theoretical total is 96.0 cm^3. Find the average rate of production and the time needed to complete the reaction. (4 marks)

Answer: Rate = 24.0 / 30 = 0.8 $cm^3\ s^{-1}$; time = 96.0 / 0.8 = 120 s.

E. Enthalpy Change and Energy (16 marks)

Take the specific heat capacity of water as 4.18 J g^{-1} K^{-1} and the density of the solutions as 1.00 g cm^{-3}.

17. 50.0 cm^3 of 1.00 M HCl is mixed with 50.0 cm^3 of 1.00 M NaOH and the temperature rises by 6.8 °C. Find the enthalpy change of neutralisation in kJ mol^{-1}. (5 marks)

Answer: Mass of solution = 100 g; q = 100 × 4.18 × 6.8 = 2 842 J; water formed = 1.00 × 0.0500 = 0.0500 mol; ΔH = -2 842 / 0.0500 = -56.8 kJ mol^{-1} (exothermic).

18. 0.320 g of methanol (Mr 32.0) burns completely and raises the temperature of 150 g of water by 11.6 °C. Find the enthalpy change of combustion in kJ mol^{-1}. (4 marks)

Answer: Moles methanol = 0.320 / 32.0 = 0.0100 mol; q = 150 × 4.18 × 11.6 = 7 273 J; ΔH = -7 273 / 0.0100 = -727.3 kJ mol^{-1} (exothermic).

19. Given standard enthalpies of formation: $CH_4(g)$ -74.8, $CO_2(g)$ -393.5, $H_2O(l)$ -285.8 kJ mol^{-1}, find the standard enthalpy change of $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$. (4 marks)

Answer: ΔH = [-393.5 + 2(-285.8)] - (-74.8) = -965.1 + 74.8 = -890.3 kJ mol^{-1}.

20. Given bond energies: H—H 436, Cl—Cl 243, H—Cl 431 kJ mol^{-1}, find the enthalpy change of $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$. (3 marks)

Answer: ΔH = (436 + 243) - 2 × 431 = 679 - 862 = -183 kJ mol^{-1}.

F. Molar Volume and Solution Preparation (16 marks)

Take the molar volume as 24.0 dm^3 mol^{-1} at room temperature and 22.4 dm^3 mol^{-1} at s.t.p.

21. 25.0 g of calcium carbonate (Mr 100) reacts completely with excess dilute hydrochloric acid. Find the volume of carbon dioxide produced at room temperature. (4 marks)

Answer: Moles $CaCO_3$ = 25.0 / 100 = 0.250 mol; CO_2 = 0.250 mol; volume = 0.250 × 24.0 = 6 dm^3.

22. Find the mass of 4.48 dm^3 of carbon dioxide at s.t.p. (Mr 44.0) (4 marks)

Answer: Moles = 4.48 / 22.4 = 0.200 mol; mass = 0.200 × 44.0 = 8.8 g.

23. What mass of $Na_2CO_3 \cdot 10H_2O$ (Mr 286) is needed to prepare 250.0 cm^3 of 0.200 M sodium carbonate solution? (4 marks)

Answer: Moles = 0.200 × 0.2500 = 0.0500 mol; mass = 0.0500 × 286 = 14.3 g.

24. 100 cm^3 of 2.00 M solution is diluted to 500 cm^3, then 25.0 cm^3 of it is diluted to 100 cm^3. Find the concentration after each dilution. (4 marks)

Answer: First dilution: 2.00 × 100 / 500 = 0.4 M; second dilution: 0.4 × 25.0 / 100 = 0.1 M.