S5 Chemistry Practice Paper: Reaction Rates and Collision Theory, Chemical Equilibrium and Le Chatelier's Principle, Electrolysis and Redox, Organic Compounds and Polymers, Energetics and Enthalpy (100 marks)

S5 | Chemistry | Time: 75 minutes | Total: 100 marks | 24 questions

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Section A Reaction Rates and Collision Theory

Part A: 4 marks each, 16 marks in total.

1. The initial concentration of a reactant is 0.80 mol dm⁻³ and it falls to 0.32 mol dm⁻³ after 30 s. Calculate the average rate of reaction (mol dm⁻³ s⁻¹) over this period. [4]

Answer: Average rate = (0.80 - 0.32) / 30 = 0.016 mol dm⁻³ s⁻¹.

2. Raising the temperature by 10 K roughly doubles the rate of most reactions. Explain two reasons for this using collision theory. [4]

Answer: (1) The average kinetic energy of particles rises, so the energy distribution shifts right and a much larger fraction of particles has energy at or above the activation energy. (2) Particles move faster, so the collision frequency per unit time rises and there are more effective collisions.

3. How does a catalyst increase the rate of a reaction? Does adding a catalyst change the ΔH of the reaction? [4]

Answer: A catalyst provides an alternative pathway of lower activation energy, so more particles can surmount the energy barrier and the rate increases. It does not change the enthalpy of reactants or products, so ΔH is unchanged.

4. For the reaction 2A + B -> C, A is consumed at 0.024 mol dm⁻³ s⁻¹. Find the rate of consumption of B and the rate of formation of C. [4]

Answer: From the stoichiometric ratio: rate of consumption of B = 0.024 / 2 = 0.012 mol dm⁻³ s⁻¹; rate of formation of C = 0.024 / 2 = 0.012 mol dm⁻³ s⁻¹.

Section B Chemical Equilibrium and Le Chatelier's Principle

Part B: 4 marks each, 16 marks in total.

5. For N2(g) + 3H2(g) <=> 2NH3(g), at equilibrium [N2] = 0.40, [H2] = 0.50 and [NH3] = 0.60 mol dm⁻³. Calculate the equilibrium constant Kc. [4]

Answer: Kc = [NH3]^2 / ([N2][H2]^3) = 0.36 / (0.050) = 7.2 (units mol⁻² dm⁶).

6. At constant temperature the volume of the equilibrium vessel is halved. Explain the direction in which the equilibrium shifts. [4]

Answer: Increasing the pressure raises the concentration of every gas. The left side has 4 mol of gas while the right side has only 2 mol, so the equilibrium shifts to the side with fewer moles of gas (to the right, forming NH3) to oppose the rise in pressure.

7. The forward reaction is exothermic ($\Delta H < 0$). What effect does raising the temperature have on Kc and on the yield of ammonia? [4]

Answer: Raising the temperature shifts the equilibrium in the endothermic direction (to the left, decomposing NH3), so the yield of ammonia falls and Kc decreases.

8. Iron catalyst is added to the equilibrium mixture. What is the effect on the position of equilibrium and on Kc? [4]

Answer: A catalyst speeds up the forward and reverse reactions equally, so the position of equilibrium does not move and Kc is unchanged; equilibrium is simply reached sooner.

Section C Electrolysis and Redox

Part C: 4 marks each, 16 marks in total.

9. A current of 2.0 A is passed through CuSO4(aq) for 965 s (F = 96500 C mol^{-1}, Ar(Cu) = 63.5). Calculate the mass of copper deposited at the cathode. [4]

Answer: Charge = 2.0 x 965 = 1930 C; moles of electrons = 1930 / 96500 = 0.02 mol; $Cu^{2+} + 2e^{-}$ -> Cu, so n(Cu) = 0.02 / 2 = 0.010 mol; mass = 0.010 x 63.5 = 0.635 g.

10. Find the oxidation number of manganese in KMnO4 and of chromium in K2Cr2O7. [4]

Answer: KMnO4: K = +1 and four O give -8 in total, so Mn = +7. K2Cr2O7: 2(+1) + 2x + 7(-2) = 0, so 2x = 12 and x = +6.

11. Write the anode reaction of a hydrogen-oxygen fuel cell with an acidic electrolyte, and explain why it is regarded as a cleaner energy source. [4]

Answer: Anode (oxidation): H2 -> 2H+ + 2e-. The only product is water, so no CO2, SO2 or particulates are emitted.

12. 0.243 g of magnesium reacts completely with excess dilute hydrochloric acid (Ar(Mg) = 24.3, molar volume = 24 dm^3 mol^{-1}). Calculate the volume of hydrogen formed at room conditions. [4]

Answer: n(Mg) = 0.243 / 24.3 = 0.010 mol; Mg + 2HCl -> MgCl2 + H2, so n(H2) = 0.010 mol; volume = 0.010 x 24 = 0.24 dm^3 = 240.0 cm^3.

Section D Organic Compounds

Part D: 4 marks each, 16 marks in total.

13. State the general formulae of alkanes and alkenes, and hence give the molecular formula of the alkane with 5 carbon atoms and the alkene with 4 carbon atoms. [4]

Answer: Alkanes: CnH2n+2, so n = 5 gives C5H12. Alkenes: CnH2n, so n = 4 gives C4H8.

14. State the conditions, the type of reaction and the equation for the dehydration of ethanol to ethene. [4]

Answer: Conditions: concentrated sulphuric acid catalyst, heated to about 170 °C. Type: dehydration (elimination). Equation: C2H5OH -> C2H4 + H2O.

15. Ethanol and ethanoic acid are warmed with concentrated sulphuric acid. Name the compound formed and give its molecular formula and functional group. [4]

Answer: Ethyl ethanoate is formed; its molecular formula is C4H8O2 and its functional group is the ester group, -COO-.

16. Ethene is bubbled through bromine water. Does the orange-yellow colour decolourise? Write the equation and state the mole ratio of the reactants. [4]

Answer: Yes, it decolourises. CH2=CH2 + Br2 -> CH2BrCH2Br; 1 mol of ethene adds 1 mol of Br2.

Section E Polymers and Materials

Part E: 4 marks each, 16 marks in total.

17. Poly(ethene) is made by addition polymerisation of ethene; the repeating unit C2H4 has relative mass 28. If the average degree of polymerisation is 2000, find the relative molecular mass. [4]

Answer: Relative molecular mass = 28 x 2000 = 56,000.

18. Nylon-6,6 is made from hexane-1,6-diamine and hexanedioic acid. State the type of reaction, the small molecule released for each bond formed, and the characteristic bond in the repeating unit. [4]

Answer: Type: condensation polymerisation; one water molecule is released per bond formed; the characteristic bond in the repeating unit is the amide link, -CONH-.

19. Give the name and the structure (in words if preferred) of the monomer of poly(chloroethene), PVC. [4]

Answer: The monomer is chloroethene (vinyl chloride), CH2=CHCl.

20. Describe how thermosoftening and thermosetting plastics behave when heated, giving one example of each. [4]

Answer: Thermosoftening plastics soften on heating and can be remoulded repeatedly (e.g. poly(ethene)); thermosetting plastics do not soften, they decompose and cannot be remoulded (e.g. phenol-formaldehyde).

Section F Energetics and Enthalpy Change

Part F: 5 marks each, 20 marks in total.

21. Complete combustion of 0.50 mol of methanol releases 363 kJ of energy. Find the enthalpy change of combustion of methanol. [5]

Answer: $\Delta H_c = -363 / 0.50 = -726$ kJ mol^{-1}.

22. 50 cm^3 of 1.0 M hydrochloric acid is mixed with 50 cm^3 of 1.0 M sodium hydroxide solution and the temperature rises by 6.7 °C. Taking the density as 1.0 g cm^{-3} and the specific heat capacity as 4.2 J g^{-1} K^{-1}, find the enthalpy change of neutralisation. [5]

Answer: Mass of solution = 100 g; heat released = 100 x 4.2 x 6.7 = 2814 J = 2.814 kJ; water formed = 1.0 x 0.050 = 0.050 mol; per mole = 2.814 / 0.050 = 56.28, i.e. about 56.3 kJ mol^{-1}, so $\Delta H = -56.3$ kJ mol^{-1}.

23. For a reaction, ΔH of the forward reaction is -92 kJ mol^{-1} and the activation energy of the reverse reaction is 200 kJ mol^{-1}. Find the activation energy of the forward reaction. [5]

Answer: Ea(forward) = Ea(reverse) + ΔH = 200 + (-92) = 108 kJ mol^{-1}.

24. Given bond enthalpies H-H = 436, Cl-Cl = 243 and H-Cl = 431 kJ mol⁻¹, calculate ΔH for H2(g) + Cl2(g) -> 2HCl(g). [5]

Answer: Energy absorbed breaking bonds = 436 + 243 = 679 kJ mol⁻¹; energy released forming bonds = 2 x 431 = 862 kJ mol⁻¹; ΔH = 679 - 862 = -183 kJ mol⁻¹.
