

A-Level Chemistry Paper 1 (Structured) - Practice Paper

TutorZone original practice paper · 10 questions · 100 marks · 2 hours

Name: _____	Class: _____	Date: _____
Time allowed: 2 hours	Total marks: 100	Questions: 10 (30 parts)

Answer all questions. Show all necessary working; marks are given for clear method. Give non-exact numerical answers correct to 3 significant figures unless a different accuracy is stated. A calculator may be used.

Questions

1. (10 marks) Mole calculations and water of crystallisation

- (a) Calculate the relative molecular mass of hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. (A_r : Cu = 63.5, S = 32.0, O = 16.0, H = 1.0) (3)
- (b) A sample of the hydrated salt has mass 12.475 g. Calculate the amount, in mol, of the hydrated salt and the amount, in mol, of water of crystallisation it contains. (3)
- (c) The sample is heated gently until the mass is constant. Calculate the mass of anhydrous copper(II) sulfate obtained and the mass of water lost, and show that the two masses add up to the original mass. (4)
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2. (10 marks) Acid-base titration and concentration

- (a) In a titration, 25.0 cm³ of sodium hydroxide solution of unknown concentration required 23.60 cm³ of 0.100 mol dm⁻³ hydrochloric acid to reach the end-point. $\text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$. Calculate the amount, in mol, of hydrochloric acid used. (3)
- (b) Calculate the concentration, in mol dm⁻³, of the sodium hydroxide solution. (4)
- (c) Calculate the mass of sodium hydroxide dissolved in 250 cm³ of this solution. ($M = 40.0 \text{ g mol}^{-1}$) (3)
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3. (10 marks) Calorimetry and enthalpy change

- (a) 25.0 cm³ of 0.500 mol dm⁻³ copper(II) sulfate solution was added to excess zinc powder. The temperature rose from 19.0 °C to 22.4 °C. The solution has mass 50.0 g and specific heat capacity 4.18 J g⁻¹ K⁻¹. Calculate the heat energy released, in J. (4)
- (b) Calculate the amount, in mol, of copper(II) sulfate used. (3)
- (c) Calculate the enthalpy change of the reaction, in kJ mol⁻¹, and state whether the reaction is exothermic or endothermic. (3)
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4. (10 marks) Chemical equilibrium and K_c

- (a) 1.00 mol of hydrogen and 1.00 mol of iodine are mixed in a 1.00 dm³ vessel and left to reach equilibrium: $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$. At equilibrium 1.58 mol of hydrogen iodide is present. Calculate the amount of hydrogen and of iodine at equilibrium. (3)
- (b) Calculate the value of K_c for this equilibrium, and state its units. (4)
- (c) The forward reaction is exothermic. State and explain the effect of increasing the temperature on the value of K_c . (3)
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5. (10 marks) Rates of reaction

- (a) In a reaction the concentration of a reactant fell from 0.80 mol dm⁻³ to 0.20 mol dm⁻³ in 120 s. Calculate the average rate of reaction in mol dm⁻³ s⁻¹. (4)
- (b) Explain what is meant by the rate-determining step of a reaction mechanism. (3)
- (c) State and explain the effect of adding a catalyst on the rate of reaction and on the value of the equilibrium constant. (3)
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6. (10 marks) Atomic structure and ionisation energy

- (a) Write the electron configuration of a chromium atom ($Z = 24$) using the 3d and 4s subshells, and explain why it is not what the simple filling order predicts. (3)
- (b) The first ionisation energy of magnesium is 738 kJ mol⁻¹ and that of aluminium is 578 kJ mol⁻¹. Explain why the value for aluminium is lower, even though it has more protons. (4)
- (c) Explain why the first ionisation energy generally increases across Period 3 from sodium to argon. (3)
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7. (10 marks) Bonding and molecular shape

- (a) The ammonium ion, NH_4^+ , has four bonds and no lone pair on the nitrogen. State the shape of the ion and the bond angle, and explain your answer. (4)
- (b) Ammonia, NH_3 , is a polar molecule but carbon dioxide, CO_2 , is not. Explain this difference in terms of shape and bond polarity. (3)
- (c) Hydrogen fluoride boils at 20 °C while hydrogen chloride boils at -85 °C, although HCl has the larger M_r . Explain this difference. (3)
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8. (10 marks) Organic nomenclature and isomerism

- (a) Give the IUPAC name of $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$. (2)
- (b) There are four structural isomers with the molecular formula $\text{C}_4\text{H}_9\text{Br}$. Name or describe all four. (4)
- (c) Explain why 2-bromobutane has optical isomers but 1-bromobutane does not. (4)
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9. (10 marks) Organic reaction mechanisms

- (a) Bromoethane reacts with hydroxide ions in aqueous ethanol. Describe the mechanism, naming the type of substitution, the role of the hydroxide ion and the species formed. (5)
- (b) Iodoethane reacts faster than bromoethane with hydroxide ions. Explain this using bond enthalpies. (3)
- (c) Ethanoic acid reacts with ethanol to form ethyl ethanoate. State the equation, the catalyst and one condition needed. (2)
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10. (10 marks) Gas volume, yield and limiting reactant

- (a) 0.486 g of magnesium reacts completely with excess dilute hydrochloric acid. Calculate the amount of magnesium used and the volume of hydrogen produced, in cm^3 , at room temperature and pressure (molar volume = $24.0 \text{ dm}^3 \text{ mol}^{-1}$). (A_r : $\text{Mg} = 24.3$) (4)
- (b) In a repeat experiment only 0.0175 mol of hydrogen was collected. Calculate the percentage yield. (3)
- (c) In another experiment 0.0200 mol of magnesium is added to hydrochloric acid containing 0.050 mol of HCl . Show by calculation which reactant is in excess. (3)
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Answers and mark scheme

Question 1 (10 marks)

(a) $M_r = 63.5 + 32.0 + (4 \times 16.0) + 5 \times 18.0 = 249.5$ (3)

B1 correct A_r sum for CuSO_4 (159.5); B1 $5 \times 18.0 = 90.0$ for the water; B1 total 249.5.

(b) 0.0500 mol of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and 0.250 mol of H_2O (3)

M1 $n = m / M_r$; A1 0.0500 mol; M1 multiplies by 5; A1 0.250 mol (allow ecf).

(c) anhydrous $\text{CuSO}_4 = 7.97$ g; water lost = 4.50 g; $7.97 + 4.50 = 12.475$ g (4)

M1 0.0500×159.5 ; A1 7.98 g; M1 0.250×18.0 ; A1 4.50 g and the check $7.975 + 4.5 = 12.475$.

Question 2 (10 marks)

(a) 0.00236 mol (3)

M1 $n = cV$ with V in dm^3 (0.02360); A1 0.00236 mol.

(b) $0.0944 \text{ mol dm}^{-3}$ (4)

M1 1:1 mole ratio; M1 $c = n / 0.0250$; A1 $0.0944 \text{ mol dm}^{-3}$ (allow 0.094).

(c) 0.944 g (3)

M1 $n = 0.0944 \times 0.250 = 0.0236 \text{ mol}$; A1 0.0236×40.0 ; A1 0.944 g.

Question 3 (10 marks)

(a) $q = 50.0 \times 4.18 \times 3.4 = 711 \text{ J}$ (4)

M1 $q = mc\Delta T$ with $\Delta T = 3.4 \text{ K}$; A1 50.0×4.18 ; A1 209; A1 711 J (allow 710-711).

(b) 0.0125 mol (3)

M1 $n = cV = 0.500 \times 0.0250$; A1 0.0125 mol.

(c) $-56.8 \text{ kJ mol}^{-1}$; exothermic (3)

M1 divides 711 J by 0.0125 mol; A1 56.8 kJ mol^{-1} ; B1 negative sign with exothermic.

Question 4 (10 marks)

(a) 0.21 mol H_2 and 0.21 mol I_2 (3)

M1 $1.58 / 2 = 0.79 \text{ mol reacted}$; A1 0.21 mol of each remaining; B1 states both are equal by symmetry.

(b) $K_c = 56.6$; no units (4)

M1 $K_c = [\text{HI}]^2 / ([\text{H}_2][\text{I}_2])$; M1 substitutes $1.58^2 / (0.21 \times 0.21)$; A1 56.6; B1 no units because the powers cancel.

(c) K_c decreases (3)

B1 K_c decreases; M1 equilibrium shifts in the endothermic (reverse) direction; A1 explained as Le Chatelier opposing the rise in temperature.

Question 5 (10 marks)

(a) $0.0050 \text{ mol dm}^{-3} \text{ s}^{-1}$ (4)

M1 $\Delta[\text{reactant}] = 0.60$; M1 divides by 120 s; A1 $5.0 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$.

(b) the slowest step of the mechanism, which limits the overall rate (3)

B1 slowest step; B1 it controls the overall rate; B1 only species up to and including this step appear in the rate equation.

(c) rate increases; K_c is unchanged (3)

B1 rate increases (alternative route of lower activation energy); B1 K_c unchanged; B1 forward and reverse rates are increased equally.

Question 6 (10 marks)

(a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$, i.e. $[\text{Ar}] 3d^5 4s^1$ (3)

B1 $[\text{Ar}] 3d^5 4s^1$ (24 electrons in total); B1 one electron occupies 4s and five occupy 3d; B1 a half-filled 3d subshell has extra stability from exchange.

(b) the outer electron of Al is in a 3p orbital, which is higher in energy and better shielded (4)

M1 states the electron removed from Al is in 3p and from Mg in 3s; M1 3p is at a higher energy level (further from the nucleus); A1 more shielding by the 3s electrons; A1 the shielding and distance effect outweighs the extra proton.

(c) nuclear charge increases while shielding stays similar, so the outer electrons are held more strongly (3)

B1 the number of protons increases; B1 the outer electrons are in the same shell so shielding is similar; B1 the atomic radius decreases, so attraction increases.

Question 7 (10 marks)

(a) tetrahedral; 109.5° (4)

B1 tetrahedral; B1 109.5° (allow $109-110^\circ$); M1 four bonding pairs; A1 they repel equally and arrange as far apart as possible.

(b) NH_3 is trigonal pyramidal so the bond dipoles do not cancel; CO_2 is linear so the two $\text{C}=\text{O}$ dipoles cancel (3)

B1 NH_3 has a lone pair giving a pyramidal shape; B1 the dipoles add up; B1 CO_2 is linear and the equal and opposite dipoles cancel.

(c) HF molecules form hydrogen bonds; HCl has only permanent dipole-dipole forces and van der Waals forces (3)

B1 HF forms hydrogen bonds (H bonded to F); B1 hydrogen bonds are much stronger than dipole-dipole forces; B1 more energy is needed to separate HF molecules.

Question 8 (10 marks)

(a) 2-methylpropan-1-ol (2)

B1 correct stem (propan-1-ol); B1 correct methyl position (2-).

(b) 1-bromobutane; 2-bromobutane; 1-bromo-2-methylpropane; 2-bromo-2-methylpropane (4)

B1 two isomers with a straight butane chain; B1 the two positions on that chain distinguished; B1 two isomers with a branched (2-methylpropane) skeleton; B1 all four correctly named.

(c) C2 of 2-bromobutane carries four different groups, so it is chiral; C1 of 1-bromobutane carries two identical hydrogen atoms (4)

B1 2-bromobutane has a carbon with four different groups; B1 the two enantiomers are non-superimposable mirror images; B1 1-bromobutane has two H atoms on C1; B1 so no chiral centre exists.

Question 9 (10 marks)

(a) nucleophilic substitution; OH^- attacks the δ^+ carbon of $\text{C}-\text{Br}$ and Br^- leaves; ethanol and bromide ions are formed (5)

B1 nucleophilic substitution; M1 curly arrow from the lone pair on OH^- to the carbon; M1 curly arrow from the $\text{C}-\text{Br}$ bond to Br; A1 the transition state with a partial $\text{C}-\text{O}$ and partial $\text{C}-\text{Br}$ bond; A1 products ethanol + Br^- and the name $\text{S}_\text{N}2$.

(b) the $\text{C}-\text{I}$ bond is weaker (lower bond enthalpy) than the $\text{C}-\text{Br}$ bond, so it breaks more easily (3)

B1 $\text{C}-\text{I}$ bond enthalpy is lower than $\text{C}-\text{Br}$; B1 less energy needed to break the bond; B1 so the activation energy is lower.

(c) $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$; concentrated H_2SO_4 ; heat under reflux (2)

B1 correct equation; B1 concentrated sulfuric acid and warming (reflux).

Question 10 (10 marks)

(a) 0.0200 mol Mg; 480 cm³ H₂ (0.48 dm³) (4)

M1 $n = 0.486 / 24.3$; A1 0.0200 mol; M1 $V = n \times 24.0$; A1 $0.480 \text{ dm}^3 = 480 \text{ cm}^3$.

(b) 87.5 % (3)

M1 percentage yield = actual / theoretical $\times 100$ with 0.0200 mol theoretical; A1 87.5 %; B1 the answer is quoted to 3 significant figures.

(c) $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$; 0.0200 mol Mg needs 0.0400 mol HCl, so HCl (0.050 mol) is in excess and magnesium is the limiting reactant (3)

M1 states the 1:2 ratio; M1 calculates 0.0400 mol HCl needed; A1 correct conclusion that HCl is in excess.

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