

Name: _____

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A-Level Chemistry — Practice Exam

Instructions: A calculator is permitted. Show all working. Data: $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$; $K_w = 1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K. Relative atomic masses are given in the questions where needed.

Time Limit: 60 minutes

Multiple Choice (10 questions)

- [1 point] 1. The mass spectrum of a sample of gallium shows two peaks, at $m/z = 69$ and $m/z = 71$, with relative abundances in the ratio 3 : 2. The relative atomic mass of this sample of gallium is
- 69.4
 - 69.8
 - 70.0
 - 70.2
- [1 point] 2. Xenon has eight electrons in its outer shell. What are the shape of the XeF_4 molecule and the F–Xe–F bond angle?
- Tetrahedral, 109.5°
 - Square planar, 90°
 - Octahedral, 90°
 - See-saw (distorted tetrahedral), 90° and 120°
- [1 point] 3. Mean bond enthalpies: $\text{N} \equiv \text{N}$ 945 kJ mol^{-1} , $\text{H}-\text{H}$ 436 kJ mol^{-1} , $\text{N}-\text{H}$ 391 kJ mol^{-1} . The enthalpy change for the reaction $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$ is
- -93 kJ mol^{-1}
 - $+93 \text{ kJ mol}^{-1}$
 - -965 kJ mol^{-1}
 - $+1080 \text{ kJ mol}^{-1}$
- [1 point] 4. In the Born–Haber cycle for magnesium oxide, which of the following enthalpy changes is exothermic?
- The second ionisation energy of magnesium
 - The second electron affinity of oxygen
 - The first electron affinity of oxygen
 - The enthalpy of atomisation of magnesium

- [1 point]** 5. In a series of experiments, doubling the concentration of reactant A (with B unchanged) doubles the initial rate, and doubling the concentration of B (with A unchanged) quadruples the initial rate. With concentrations in mol dm^{-3} and time in seconds, the units of the rate constant k are
- $\text{mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$
 - $\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$
 - s^{-1}
 - $\text{mol}^2 \text{ dm}^{-6} \text{ s}^{-1}$
- [1 point]** 6. The Arrhenius equation is $k = Ae^{-E_a/RT}$. A student plots $\ln k$ on the vertical axis against $\frac{1}{T}$ on the horizontal axis. The gradient of the straight line obtained is
- $-E_a$
 - $-\frac{E_a}{R}$
 - $\frac{E_a}{R}$
 - $\ln A$
- [1 point]** 7. Dinitrogen tetroxide dissociates in a closed container: $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, $\Delta H = +57 \text{ kJ mol}^{-1}$. Which change increases both the equilibrium yield of NO_2 and the value of K_p ?
- Increasing the temperature at constant pressure
 - Increasing the pressure at constant temperature
 - Decreasing the temperature at constant pressure
 - Adding a catalyst
- [1 point]** 8. Barium hydroxide, $\text{Ba}(\text{OH})_2$, is a strong base. The pH of a $0.050 \text{ mol dm}^{-3}$ solution of barium hydroxide at 298 K ($K_w = 1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$) is
- 1.0
 - 12.7
 - 13.0
 - 13.3
- [1 point]** 9. Standard electrode potentials: $\text{Zn}^{2+}/\text{Zn} -0.76 \text{ V}$; $\text{Fe}^{2+}/\text{Fe} -0.44 \text{ V}$; $\text{Cu}^{2+}/\text{Cu} +0.34 \text{ V}$; $\text{Ag}^{+}/\text{Ag} +0.80 \text{ V}$. Which statement is correct?
- Copper metal can reduce silver ions to silver
 - Fe^{2+} ions are a stronger oxidising agent than Cu^{2+} ions
 - A cell made from the Zn^{2+}/Zn and Cu^{2+}/Cu half-cells has an EMF of 0.42 V
 - Silver is the strongest reducing agent of the four metals
- [1 point]** 10. Which statement about trends in group 2 or group 7 is correct?
- The solubility of the group 2 sulfates increases down the group
 - Bromine displaces iodine from aqueous potassium iodide
 - The reducing power of the halide ions decreases from fluoride to iodide
 - Magnesium reacts vigorously with cold water

Calculations (2 questions)

[10 points] 11. A student standardises a solution of hydrochloric acid using anhydrous sodium carbonate. She dissolves 2.65 g of Na_2CO_3 ($M_r = 106.0$) in water and makes the solution up to 250 cm^3 in a volumetric flask. She titrates 25.0 cm^3 portions of this solution with the hydrochloric acid using methyl orange indicator; the mean titre is 23.50 cm^3 . Equation: $\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$.

[2 points] (a) Calculate the concentration, in mol dm^{-3} , of the sodium carbonate solution.

[3 points] (b) Calculate the concentration, in mol dm^{-3} , of the hydrochloric acid.

[2 points] (c) Calculate the volume of carbon dioxide, in cm^3 , produced during one titration at 298 K and 100 kPa. ($R = 8.31\text{ J K}^{-1}\text{ mol}^{-1}$.)

[1 point] (d) Each burette reading has an uncertainty of $\pm 0.05\text{ cm}^3$. Calculate the percentage uncertainty in the mean titre.

- [2 points] (e) Sodium carbonate is manufactured by a process whose overall equation is $\text{CaCO}_3 + 2\text{NaCl} \rightarrow \text{Na}_2\text{CO}_3 + \text{CaCl}_2$. Calculate the percentage atom economy for the production of sodium carbonate. (A_r : Na 23.0, Cl 35.5, Ca 40.1, C 12.0, O 16.0.)

- [10 points] 12. Ethanoic acid is a weak acid with $K_a = 1.74 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K. In the presence of an acid catalyst it reacts reversibly with ethanol to form ethyl ethanoate: $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$.

- [3 points] (a) 1.00 mol of ethanoic acid and 1.00 mol of ethanol are mixed with a trace of acid catalyst and left to reach equilibrium at 298 K. At equilibrium 0.333 mol of ethanoic acid remains. Write the expression for K_c and calculate its value.

- [2 points] (b) More ethanol is added to the equilibrium mixture at the same temperature. State and explain the effect on the amount of ester at equilibrium and on the value of K_c .

[3 points] (c) Calculate the pH of a $0.100 \text{ mol dm}^{-3}$ solution of ethanoic acid at 298 K.

[2 points] (d) A buffer solution is made by mixing 500 cm^3 of $0.100 \text{ mol dm}^{-3}$ ethanoic acid with 500 cm^3 of $0.200 \text{ mol dm}^{-3}$ sodium ethanoate. Calculate the pH of the buffer.

Short Answer (1 question)

[10 points] 13. 2-Bromobutane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, can be made by reacting hydrogen bromide with but-2-ene. 2-Bromobutane reacts with warm aqueous sodium hydroxide to form compound K, and with hot ethanolic potassium hydroxide to form a mixture of two alkenes.

[3 points] (a) Name the mechanism of the reaction between hydrogen bromide and but-2-ene, and describe in words how the mechanism proceeds.

[3 points] (b) Name the mechanism of the reaction between 2-bromobutane and warm aqueous sodium hydroxide, and describe in words how the mechanism proceeds.

[2 points] (c) Name compound K and the two alkenes formed with ethanolic potassium hydroxide. State which of the two alkenes shows E/Z isomerism and explain why the other does not.

[2 points] (d) The infrared spectrum of K shows a broad absorption at about 3300 cm^{-1} that is absent from the spectrum of 2-bromobutane. Identify the bond responsible, and state the number of peaks in the carbon-13 NMR spectrum of K.