

Name: _____

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AP Chemistry — Practice Exam

Instructions: Section I (multiple choice): no calculator. Section II (free response): a calculator is permitted. Show all working and include units. Constants and molar masses are given in the questions.

Time Limit: 60 minutes

Multiple Choice (15 questions)

- [1 point] 1. The first four ionization energies of an element, in kJ/mol, are 738, 1451, 7733 and 10 540. The element is most likely:
- A. Na
 - B. Mg
 - C. Al
 - D. Si
- [1 point] 2. Standard reduction potentials: $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$, $E^\circ = +0.80 \text{ V}$; $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$, $+0.34 \text{ V}$; $\text{Fe}^{2+} + 2\text{e}^- \rightarrow \text{Fe}$, -0.44 V ; $\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn}$, -0.76 V . Which species is the strongest reducing agent?
- A. $\text{Ag}^+(\text{aq})$
 - B. $\text{Ag}(\text{s})$
 - C. $\text{Zn}^{2+}(\text{aq})$
 - D. $\text{Zn}(\text{s})$
- [1 point] 3. Which of the following molecules contains polar bonds but has no net dipole moment?
- A. SF_4
 - B. XeF_4
 - C. NH_3
 - D. H_2O
- [1 point] 4. Propane ($\text{CH}_3\text{CH}_2\text{CH}_3$, molar mass 44 g/mol), dimethyl ether (CH_3OCH_3 , 46 g/mol) and ethanol ($\text{CH}_3\text{CH}_2\text{OH}$, 46 g/mol) have similar molar masses. Which has the highest boiling point, and why?
- A. Propane, because it has the most hydrogen atoms
 - B. Dimethyl ether, because its oxygen atom gives it the strongest dipole-dipole forces
 - C. Ethanol, because its O-H bond allows hydrogen bonding between molecules
 - D. Ethanol and dimethyl ether boil at the same temperature, because they have the same molar mass

- [1 point] 5. Aluminum reacts with chlorine: $2\text{Al} + 3\text{Cl}_2 \rightarrow 2\text{AlCl}_3$. If 4.0 mol of Al is mixed with 4.5 mol of Cl_2 , what is the maximum amount of AlCl_3 that can form?
- A. 3.0 mol
 - B. 4.0 mol
 - C. 4.5 mol
 - D. 6.0 mol
- [1 point] 6. An unknown gas has a density of 1.25 g/L at 0°C and 1.00 atm, where the molar volume of an ideal gas is 22.4 L/mol. Molar masses: He 4.0, N_2 28.0, O_2 32.0, CO_2 44.0 g/mol. The gas is most likely:
- A. He
 - B. N_2
 - C. O_2
 - D. CO_2
- [1 point] 7. A 25.0 mL sample of 0.40 M CaCl_2 is diluted with water to a final volume of 100.0 mL. What is the concentration of chloride ions in the resulting solution?
- A. 0.10 M
 - B. 0.20 M
 - C. 0.40 M
 - D. 0.80 M
- [1 point] 8. For the reaction $\text{A} + \text{B} \rightarrow \text{products}$, three trials were run. Trial 1: $[\text{A}] = 0.10\text{ M}$, $[\text{B}] = 0.10\text{ M}$, initial rate $2.0 \times 10^{-4}\text{ M/s}$. Trial 2: $[\text{A}] = 0.20\text{ M}$, $[\text{B}] = 0.10\text{ M}$, rate $8.0 \times 10^{-4}\text{ M/s}$. Trial 3: $[\text{A}] = 0.10\text{ M}$, $[\text{B}] = 0.20\text{ M}$, rate $4.0 \times 10^{-4}\text{ M/s}$. What is the rate law?
- A. $\text{rate} = k[\text{A}][\text{B}]$
 - B. $\text{rate} = k[\text{A}]^2[\text{B}]$
 - C. $\text{rate} = k[\text{A}][\text{B}]^2$
 - D. $\text{rate} = k[\text{A}]^2[\text{B}]^2$
- [1 point] 9. A compound X decomposes by a first-order reaction with a half-life of 20.0 min. If the initial concentration of X is 0.80 M, what is its concentration after 60.0 min?
- A. 0.40 M
 - B. 0.27 M
 - C. 0.20 M
 - D. 0.10 M
- [1 point] 10. Given $\text{C(s)} + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$, $\Delta H^\circ = -394\text{ kJ/mol}$, and $\text{CO(g)} + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$, $\Delta H^\circ = -283\text{ kJ/mol}$, what is ΔH° for $\text{C(s)} + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO(g)}$?
- A. -677 kJ/mol
 - B. -283 kJ/mol
 - C. -111 kJ/mol
 - D. $+111\text{ kJ/mol}$

- [1 point] 11. A 50.0 g sample of water at 25.0°C absorbs 2.09 kJ of heat. The specific heat capacity of water is 4.18 J g⁻¹ °C⁻¹. What is the final temperature of the water?
- A. 27.5°C
 - B. 30.0°C
 - C. 35.0°C
 - D. 45.0°C
- [1 point] 12. For $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$, $K_c = 0.50$ at a certain temperature. A vessel at that temperature contains $[\text{N}_2] = 2.0 \text{ M}$, $[\text{H}_2] = 1.0 \text{ M}$ and $[\text{NH}_3] = 2.0 \text{ M}$. Which statement is correct?
- A. $Q = 2.0 > K_c$, so the reaction proceeds toward the reactants
 - B. $Q = 2.0 > K_c$, so the reaction proceeds toward the products
 - C. $Q = 0.50 = K_c$, so the system is at equilibrium
 - D. $Q = 0.25 < K_c$, so the reaction proceeds toward the products
- [1 point] 13. The reaction $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ has $\Delta H^\circ = +57 \text{ kJ/mol}$. A sealed cylinder fitted with a piston holds the system at equilibrium. Which change increases the equilibrium amount of NO_2 ?
- A. Increasing the temperature
 - B. Pushing the piston in to decrease the volume at constant temperature
 - C. Adding argon gas at constant volume and temperature
 - D. Adding a catalyst
- [1 point] 14. A sparingly soluble salt dissolves as $\text{M}_2\text{X}(\text{s}) \rightleftharpoons 2\text{M}^+(\text{aq}) + \text{X}^{2-}(\text{aq})$ with $K_{sp} = 3.2 \times 10^{-11}$. What is the molar solubility of M_2X in pure water?
- A. $5.7 \times 10^{-6} \text{ M}$
 - B. $2.0 \times 10^{-6} \text{ M}$
 - C. $2.0 \times 10^{-4} \text{ M}$
 - D. $4.0 \times 10^{-4} \text{ M}$
- [1 point] 15. What is the pH of a 0.10 M solution of a weak monoprotic acid HA with $K_a = 1.0 \times 10^{-5}$?
- A. 1.0
 - B. 2.5
 - C. 3.0
 - D. 5.0

Calculations (2 questions)

- [10 points] 16. Weak-acid titration. A student titrates 25.0 mL of 0.100 M propanoic acid, $\text{HC}_3\text{H}_5\text{O}_2$ ($K_a = 1.3 \times 10^{-5}$), with 0.100 M NaOH at 25°C, where $K_w = 1.0 \times 10^{-14}$. Two indicators are available: methyl red, which changes color between pH 4.4 and 6.2, and phenolphthalein, which changes color between pH 8.2 and 10.0.

[2 points] (a) Write the equation for the ionization of propanoic acid in water and calculate the pH of the acid solution before any NaOH is added.

[2 points] (b) Calculate the volume of NaOH solution required to reach the equivalence point, and write the net ionic equation for the reaction that occurs during the titration.

[2 points] (c) Calculate the pH of the solution after 12.5 mL of the NaOH solution has been added. Justify the method you use.

[2 points] (d) Is the pH at the equivalence point less than, equal to, or greater than 7.0? Justify your answer with a chemical equation, and calculate the pH at the equivalence point.

[2 points] (e) Which of the two indicators should the student use to detect the equivalence point? Explain your choice in terms of the shape of the titration curve.

[4 points] 17. Electrochemistry. A galvanic cell is constructed from a zinc electrode in 1.0 M $\text{Zn}(\text{NO}_3)_2$ and a copper electrode in 1.0 M $\text{Cu}(\text{NO}_3)_2$, connected by a salt bridge and an external wire. Standard reduction potentials: $\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn}$, $E^\circ = -0.76 \text{ V}$; $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$, $E^\circ = +0.34 \text{ V}$. Faraday's constant $F = 96,500 \text{ C}$ per mole of electrons; molar mass of $\text{Cu} = 63.5 \text{ g/mol}$.

[1 point] (a) Write the balanced overall cell reaction and calculate the standard cell potential.

[1 point] (b) Identify the anode, and state the direction in which electrons flow through the external wire.

[2 points]

- (c) In a separate electrolysis experiment, a current of 2.00 A is passed through aqueous CuSO_4 for 1930 s. Calculate the mass of copper deposited at the cathode.