AP Chemistry Test: Conceptual Understanding

Instructions: Please answer all questions to the best of your ability. Show your work for all short answer questions. This test is designed to assess your conceptual understanding of AP Chemistry concepts.

Multiple Choice (2 points each):

1. Which of the following is NOT a valid unit for measuring pressure? a) atm b) mmHg c) Pa d) K
2. Which of the following pairs of compounds represents an example of a strong electrolyte and a weak electrolyte, respectively? a) HCl and HF b) CH3COOH and NH3 c) NaCl and CaCl2 d) H2SO4 and HNO3
3. Which of the following statements is TRUE about the enthalpy change for an endothermic reaction? a) It is always positive. b) It is always negative. c) It can be positive or negative depending on the reaction conditions. d) It is always zero.
4. A sample of gas is heated at constant volume. Which of the following will NOT change? a) Temperature b) Pressure c) Average kinetic energy of the gas molecules d) Number of moles of gas
5. Which of the following is the correct equilibrium expression for the reaction: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$? a) K = [SO3] / [SO2] [O2] b) K = [SO3]^2 / [SO2]^2 [O2] c) K = [SO2]^2 [O2] / [SO3]^2 d) K = [SO2] [O2] / [SO3]

True/False (2 points each):

6. True or False: The oxidation state of an element in its elemental form is always zero.
7. True or False: A spontaneous reaction will always proceed at a fast rate.
8. True or False: The boiling point of a solution is always higher than the boiling point of the pure solvent.
9. True or False: A catalyst increases the rate of a reaction by lowering the activation energy.
10. True or False: The enthalpy change for a reaction is independent of the pathway taken.

Short Answer (4 points each):

11. Explain the difference between a strong acid and a weak acid in terms of their dissociation in water.
12. What is Le Chatelier's Principle? How can it be used to predict the effects of changes in temperature, pressure, or concentration on a chemical equilibrium?
13. Describe the factors that affect the rate of a chemical reaction.
14. What are the four quantum numbers and what information do they provide about an electron in an atom?

Reading Passage (8 points):

Read the following passage about the Haber-Bosch process and answer the questions below.

The Haber-Bosch process is a crucial industrial process that produces ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2). The reaction is as follows:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The reaction is exothermic and favors the formation of ammonia at high pressure and low temperature. However, the rate of the reaction is slow at low temperatures, requiring a catalyst to increase the rate. The Haber-Bosch process operates at high temperatures (around 450°C) and high pressures (around 200 atm) to

achieve a reasonable rate and yield.

Questions:

15. Explain why the Haber-Bosch process operates at high temperatures despite the fact that the reaction is exothermic and favors ammonia formation at lower temperatures.
16. How does the use of a catalyst affect the equilibrium position of the Haber-Bosch reaction?
17. Describe the effect of increasing the pressure on the equilibrium position of the Haber-Bosch reaction.
18. Briefly discuss the significance of the Haber-Bosch process in terms of its impact on society.

Bonus Question (5 points):

19. Calculate the pH of a 0.10 M solution of acetic acid (CH3COOH) if its Ka is 1.8 x 10^-5. Show your work.

Answer Key:

Multiple Choice:

1. d) K
2. a) HCl and HF
3. a) It is always positive.
4. d) Number of moles of gas
5. b) K = [SO3]^2 / [SO2]^2 [O2]

True/False:

6. True
7. False
8. True
9. True
10. True

Short Answer:

11. Strong acids completely ionize in water, meaning they donate all their protons (H+ ions) to water molecules. Weak acids only partially ionize, meaning they only donate a fraction of their protons.
12. Le Chatelier's Principle states that if a change of condition is applied to a system at equilibrium, the system will shift in a direction that relieves the stress. For example, increasing the temperature of an exothermic reaction will shift the equilibrium to favor the reactants. Increasing the pressure on a reaction involving gases will favor the side with fewer moles of gas.
13. The rate of a chemical reaction is affected by several factors including:
    - **Temperature:** Higher temperatures increase the rate of reaction by providing more energy to reactant molecules.
    - **Concentration:** Higher concentration of reactants increases the frequency of collisions between them, leading to a faster reaction rate.
    - **Surface Area:** Greater surface area of reactants (e.g., powdered solids) increases the rate of reaction as more reactant molecules are exposed to the other reactant.
    - **Catalyst:** A catalyst speeds up the reaction by providing an alternate pathway with lower activation energy.
14. The four quantum numbers are:
    - **Principal Quantum Number (n):** Describes the energy level of the electron (n = 1, 2, 3...).
    - **Angular Momentum Quantum Number (l):** Describes the shape of the electron's orbital (l = 0 for s orbitals, l = 1 for p orbitals, l = 2 for d orbitals, etc.).
    - **Magnetic Quantum Number (ml):** Describes the orientation of the orbital in space (ml = -l, -l+1, ... , 0, ... l-1, l).
    - **Spin Quantum Number (ms):** Describes the intrinsic angular momentum of the electron, which is called spin (ms = +1/2 or -1/2).

Reading Passage:

15. While the Haber-Bosch process is exothermic and favors ammonia formation at lower temperatures, the rate of reaction is very slow at low temperatures. To achieve a reasonable rate, the process operates at high temperatures, even though this slightly shifts the equilibrium towards the reactants.
16. A catalyst does not affect the equilibrium position of a reaction. It only speeds up the rate at which the

equilibrium is reached.

17. Increasing the pressure in the Haber-Bosch process will shift the equilibrium towards the side with fewer moles of gas, which is the product side (2 moles of NH3). This favors the formation of ammonia.
18. The Haber-Bosch process is crucial for the production of ammonia, which is used in the manufacture of fertilizers, explosives, and other essential products. It has drastically increased food production worldwide, but also has environmental implications due to the high energy consumption and the potential release of greenhouse gases.

Bonus Question:

19.

ICE Table:

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    CH3COOH(aq)  ⇌   H+(aq)  +  CH3COO−(aq)
I      0.10 M             0              0
C     −x                 +x             +x
E     0.10−x             x              x
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Ka = [H+][CH3COO−] / [CH3COOH] = 1.8 x 10^−5

1.8 x 10^−5 = x^2 / (0.10 − x)

Since Ka is small, we can assume x is negligible compared to 0.10.

1.8 x 10^−5 ≈ x^2 / 0.10

x^2 ≈ 1.8 x 10^−6

x ≈ √(1.8 x 10^−6) ≈ 1.34 x 10^−3

[H+] = x ≈ 1.34 x 10^−3 M

pH = −log[H+] ≈ −log(1.34 x 10^−3) ≈ **2.87**