1.) Given the equation: $2 \text{NO}(g) + 2 \text{H}_2(g) \rightarrow \text{N}_2(g) + 2 \text{H}_2\text{O}(g)$
   And the assumed mechanism:
   1. $2 \text{NO}(g) \rightarrow \text{N}_2\text{O}_2(g)$
   2. $\text{N}_2\text{O}_2(g) + \text{H}_2(g) \rightarrow \text{N}_2\text{O}(g) + \text{H}_2\text{O}(g)$
   3. $\text{N}_2\text{O}(g) + \text{H}_2(g) \rightarrow \text{N}_2(g) + \text{H}_2\text{O}(g)$

   List any intermediate species. Note the molecularity of each step. Write a rate equation for the third step. Do the elementary steps add up to the overall reaction?

2.) Given the equation: $2 \text{NO}_2(g) \rightarrow 2 \text{NO}(g) + \text{O}_2(g)$
   And two proposed mechanisms:
   A 1. $\text{NO}_2(g) \rightarrow \text{NO}(g) + \text{O}(g)$ slow step
      2. $\text{O}(g) + \text{NO}_2(g) \rightarrow \text{NO}(g)$
   B 1. $\text{NO}_2(g) + \text{NO}_2(g) \rightarrow \text{OONO}(g) + \text{NO}(g)$ slow step
      2. $\text{OONO}(g) \rightarrow \text{NO}(g) + \text{O}_2(g)$

   Write an overall rate equation for each mechanism. How could one disprove one or both of the two proposed mechanisms in a laboratory?

3.) Given the equation: $2 \text{NO}_2\text{Cl}(g) \rightarrow 2 \text{NO}_2(g) + \text{Cl}_2(g)$
   And the assumed mechanism
   1. $\text{NO}_2\text{Cl}(g) \leftrightarrow \text{NO}_2(g) + \text{Cl}(g)$ fast, equilibrium, where $k_1$ is constant for forward rxn and $k_{-1}$ is constant for reverse reaction
   2. $\text{NO}_2\text{Cl}(g) + \text{Cl}(g) \rightarrow \text{NO}_2(g) + \text{Cl}_2(g)$ slow, $k_2$ is constant

   Write an overall rate equation.

4.) Given the following reaction coordinate diagram:
How many steps does the illustrated reaction have? Is the reaction endo- or exothermic? If the first step is in equilibrium, use the diagram to explain why fast steps are often in equilibrium.

5.) Explain why increasing the temperature of a sample increases its reaction’s rate constant.

EQUILIBRIUM

EQUILIBRIUM CONSTANT

6.) Given the reaction: \( \text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g}) \)
   At 1200K, \( K_{\text{eq}} = 0.26 \), and at equilibrium, \([\text{CH}_4] = 0.13\text{M}, [\text{CO}] = 0.81\text{M}, [\text{H}_2\text{O}(\text{g})] = 0.53\text{M}. \)
   What is \([\text{H}_2]\) ?

7.) Given the reaction: \( \text{CO}_2(\text{g}) + \text{C(\text{graphite})} \rightleftharpoons 2\text{CO}(\text{g}) \)
   At 1080K, and at equilibrium, \( P_{\text{co}_2} = 0.159\text{atm}, P_{\text{co}} = 0.598\text{atm} \)
   What is \( K_p \)? What is \( K_c \)?

8.) Given the reaction: \( 2\text{HBr}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{Br}(\text{g}) \)
   At 425°C, \( K_c = 4.18*10^{-9} \). \( P_{\text{HBr}} = 0.2\text{atm}, P_{\text{H}_2} = P_{\text{Br}_2} = 0.001\text{atm} \)
   Is the system at equilibrium? If not, how will the reaction shift to reach equilibrium?

9.) Given the reaction: \( \text{Co}^{3+}(\text{aq}) + 6\text{NH}_3(\text{aq}) \rightleftharpoons \text{Co(NH}_3)_6^{3+}(\text{aq}) \) at equilibrium
   How will \([\text{NH}_3]\) be affected if \( \text{Co}^{3+} \) is added? If \( \text{HCl} \) is added? If water is added?

EQUILIBRIUM CALCULATIONS

10.) A solution is made by dissolving 0.074mol \( \text{C}_6\text{H}_{10}\text{I}_2 \) in \( \text{CCl}_4 \). The resulting solution has a volume of 2.00L.
   When the reaction: \( \text{C}_6\text{H}_{10}\text{I}_2(\text{aq}) \rightleftharpoons \text{C}_6\text{H}_{10}(\text{aq}) + \text{I}_2(\text{aq}) \) has come to equilibrium at 35°C, the concentration of \( \text{I}_2 \) is 0.028M. Calculate \( K \).

11.) A tank initially contains 13.40atm of \( \text{H}_2\text{S} \) at 800K. At that temperature, \( K_p = 3.2*10^{-7} \). \( \text{H}_2\text{S} \) reacts as follows: \( 2\text{H}_2\text{S}(\text{g}) \rightleftharpoons 2\text{H}_2(\text{g}) + \text{S}_2(\text{g}) \). What is the partial pressure of \( \text{H}_2 \) when the reaction has come to equilibrium?

12.) 3.35atm \( \text{H}_2\text{S} \) is removed from the equilibrium system in question 11. What is the partial pressure of \( \text{H}_2 \) when the reaction has come to equilibrium?

13.) Calculate \( K \) for the reaction: \( \text{Fe}(\text{s}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{FeO}(\text{s}) + \text{H}_2(\text{g}) \)
   Given: \( \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \) \( K = 1.6 \)
   \( \text{FeO}(\text{s}) + \text{CO}(\text{g}) \rightleftharpoons \text{Fe}(\text{s}) + \text{CO}_2(\text{g}) \) \( K = 0.67 \)
ACIDS AND BASES

14.) A. Write an equation for the reaction that occurs when HC₂H₃O₂ donates a proton to water. Identify each species as acid, base, conjugate base, or conjugate acid.
   B. Write an equation for the reaction that occurs when CN⁻ accepts a proton from water. Identify each species as acid, base, conjugate base, or conjugate acid.

15.) Are solutions of the following solutes in water acidic, basic, or neutral?
   A. NH₄Cl
   B. Fe(NO₃)₂
   C. KBr

16.) pKₐ for C₆H₅CO₂H is 4.20. What is Kₐ for its conjugate base, C₆H₅CO₂⁻?

17.) A solution with a total volume of 2.00L was made with 0.048mol PhCOOH. The solution has a pH of 2.8 at equilibrium. Given the reaction:
   PhCOOH(aq) ↔ PhCOO⁻(aq) + H₃O⁺(aq), find pKₐ.

18.) What is the pH of the solution that results from mixing 50.0mL of 0.020 M NH₃ and 12.5mL of 0.080 M HBr? Given Kₐ = 5.6*10⁻¹⁰ for ammonium ion.

19.) What is the pH of a 0.34M solution of H₂CO₃? What are the concentrations of H₃O⁺, HCO₃⁻, and CO₃²⁻? Given Kₐ = 4.2*10⁻⁷ for H₂CO₃, Kₐ = 4.8*10⁻¹¹ for HCO₃⁻.