

AP Chemistry - Packet #1 - Equilibrium

1) Ammonia hydrogen sulfide is a crystalline solid that decomposes as follows: $\text{NH}_4\text{HS}(s) \rightarrow \text{NH}_3(g) + \text{H}_2\text{S}(g)$

(a) Some solid NH_4HS is placed in an evacuated vessel at 25°C . After equilibrium is attained, the total pressure inside the vessel is found to be 0.659 atmosphere. Some solid NH_4HS remains in the vessel at equilibrium. For this decomposition, write the expression for K_p and calculate its numerical value at 25°C .

(b) Some extra NH_3 gas is injected into the vessel containing the sample described in part (a). When equilibrium is reestablished at 25°C , the partial pressure of NH_3 is twice the partial pressure of H_2S . Calculate the numerical value of the partial pressure of NH_3 and the partial pressure of H_2S in the vessel after the NH_3 has been added and equilibrium has been reestablished.

(c) In a different experiment, NH_3 gas and H_2S gas are introduced into an empty 1.00-liter vessel at 25°C . The initial partial pressure of each gas is 0.500 atmosphere. Calculate the number of moles of solid NH_4HS that is present when equilibrium is established.

2) At 25°C the solubility product constant, K_{sp} , for strontium sulfate, SrSO_4 , is 7.6×10^{-7} . The solubility product constant for strontium fluoride, SrF_2 , is 7.9×10^{-10}

(a) What is the molar solubility of SrSO_4 in pure water at 25°C ?

(b) What is the molar solubility of SrF_2 in pure water at 25°C ?

(c) An aqueous solution of $\text{Sr}(\text{NO}_3)_2$ is added slowly to 1.0 liter of a well-stirred solution containing 0.020 mole F^- and 0.10 mole SO_4^{2-} at 25°C . (You may assume that the added $\text{Sr}(\text{NO}_3)_2$ solution does not materially affect the total volume of the system.) Which salt precipitates first? What is the concentration of strontium ion, Sr^{2+} , in the solution when the first precipitate begins to form?

(d) As more $\text{Sr}(\text{NO}_3)_2$ is added to the mixture in (c) a second precipitate begins to form. At that stage, what percent of the anion of the first precipitate remains in solution?

3) Solve the following problem: $\text{H}_2(g) + \text{CO}_2(g) \rightleftharpoons \text{H}_2\text{O}(g) + \text{CO}(g)$

When $\text{H}_2(g)$ is mixed with $\text{CO}_2(g)$ at 2,000 K, equilibrium is achieved according to the equation above. In one experiment, the following equilibrium concentrations were measured.

$$[\text{H}_2] = 0.20 \text{ mol/L}$$

$$[\text{CO}_2] = 0.30 \text{ mol/L}$$

$$[\text{H}_2\text{O}] = [\text{CO}] = 0.55 \text{ mol/L}$$

(a) What is the mole fraction of $\text{CO}(g)$ in the equilibrium mixture?

(b) Using the equilibrium concentrations given above, calculate the value of K_c , the equilibrium constant for the reaction.

(c) Determine K_p , in terms of K_c for this system.

(d) When the system is cooled from 2,000 K to a lower temperature, 30.0 percent of the $\text{CO}(g)$ is converted back to $\text{CO}_2(g)$. Calculate the value of K_c at this lower temperature.

(e) In a different experiment, 0.50 mole of $\text{H}_2(g)$ is mixed with 0.50 mole of $\text{CO}_2(g)$ in a 3.0-liter reaction vessel at 2,000 K. Calculate the equilibrium concentration, in moles per liter, of $\text{CO}(g)$ at this temperature.

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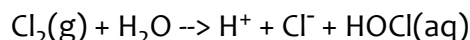
- 4) The acid ionization constant, K_a , for propanoic acid, C_2H_5COOH , is 1.3×10^{-5} .
- (a) Calculate the hydrogen ion concentration, $[H^+]$, in a 0.20-molar solution of propanoic acid.
- (b) Calculate the percentage of propanoic acid molecules that are ionized in the solution in (a).
- (c) What is the ratio of the concentration of propanoate ion, $C_2H_5COO^-$, to that of propanoic acid in a buffer solution with a pH of 5.20 ?
- (d) In a 100-milliliter sample of a different buffer solution, the propanoic acid concentration is 0.35-molar and the sodium propanoate concentration is 0.50-molar. To this buffer solution, 0.0040 mole of solid NaOH is added. Calculate the pH of the resulting solution.



Hypochlorous acid, HOCl, is a weak acid commonly used as a bleaching agent. The acid-dissociation constant, K_a , for the reaction represented above is 3.2×10^{-8} .

- (a) Calculate the $[H^+]$ of a 0.14-molar solution of HOCl.
- (b) Write the correctly balanced net ionic equation for the reaction that occurs NaOCl is dissolved in water and calculate the numerical value of the equilibrium constant for the reaction.
- (c) Calculate the pH of a solution made by combining 40.0 milliliters of 0.14-molar HOCl and 10.0 milliliters of 0.56-molar NaOH.
- (d) How many millimoles of solid NaOH must be added to 50.0 milliliters of 0.20-molar HOCl to obtain a buffer solution that has a pH of 7.49? Assume that the addition of the solid NaOH results in a negligible change in volume.

- (e) Household bleach is made by dissolving chlorine gas in water, as represented below.

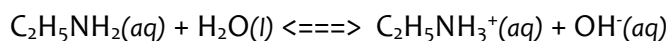


Calculate the pH of such a solution if the concentration of HOCl in the solution is 0.065 molar.

6. A pure 14.85 g sample of the weak base ethylamine, $C_2H_5NH_2$, is dissolved in enough distilled water to make 500. mL of solution.

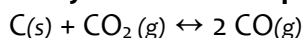
- (a) Calculate the molar concentration of the $C_2H_5NH_2$ in the solution.

The aqueous ethylamine reacts with water according to the equation below.



- (b) Write the equilibrium-constant expression for the reaction between $C_2H_5NH_2(aq)$ and water.
- (c) Of $C_2H_5NH_2(aq)$ and $C_2H_5NH_3^+(aq)$, which is present in the solution at the higher concentration at equilibrium? Justify your answer.
- (d) A different solution is made by mixing 500. mL of 0.500 M $C_2H_5NH_2$ with 500. mL of 0.200 M HCl. Assume that volumes are additive. The pH of the resulting solution is found to be 10.93.
- (i) Calculate the concentration of $OH^-(aq)$ in the solution.
- (ii) Write the net-ionic equation that represents the reaction that occurs when the $C_2H_5NH_2$ solution is mixed with the HCl solution.
- (iii) Calculate the molar concentration of the $C_2H_5NH_3^+(aq)$ that is formed in the reaction.
- (iv) Calculate the value of K_b for $C_2H_5NH_2$.

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7. Solid carbon and carbon dioxide gas at 1,160 K were placed in a rigid 2.00 L container, and the reaction represented above occurred. As the reaction proceeded, the total pressure in the container was monitored. When equilibrium was reached, there was still some $\text{C}(s)$ remaining in the container. Results are recorded in the table below.

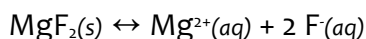
Time (hours)	Total Pressure of Gases in Container at 1,160 K (atm)
0.0	5.00
2.0	6.26
4.0	7.09
6.0	7.75
8.0	8.37
10.0	8.37

- (a) Write the expression for the equilibrium constant, K_p for the reaction.
- (b) Calculate the number of moles of $\text{CO}_2(g)$ initially placed in the container. (Assume that the volume of the solid carbon is negligible.)
- (c) For the reaction mixture at equilibrium at 1,160 K, the partial pressure of the $\text{CO}_2(g)$ is 1.63 atm. Calculate
- the partial pressure of $\text{CO}(g)$, and
 - the value of the equilibrium constant, K_p
- (d) If a suitable solid catalyst were placed in the reaction vessel, would the final total pressure of the gases at equilibrium be greater than, less than, or equal to the final total pressure of the gases at equilibrium without the catalyst? Justify your answer. (Assume that the volume of the solid catalyst is negligible.)

In another experiment involving the same reaction, a rigid 2.00 L container initially contains 10.0 g of $\text{C}(s)$, plus $\text{CO}(g)$ and $\text{CO}_2(g)$, each at a partial pressure of 2.00 atm at 1,160 K.

- (e) Predict whether the partial pressure of $\text{CO}_2(g)$ will increase, decrease, or remain the same as this system approaches equilibrium. Justify your prediction with a calculation.

8.



In a saturated solution of MgF_2 at 18°C, the concentration of Mg^{2+} is 1.21×10^{-3} molar. The equilibrium is represented by the equation above.

- (a) Write the expression for the solubility-product constant, K_{sp} , and calculate its value at 18°C.
- (b) Calculate the equilibrium concentration of Mg^{2+} in 1.000 liter of saturated MgF_2 solution at 18°C to which 0.100 mole of solid KF has been added. The KF dissolves completely. Assume the volume change is negligible.
- (c) Predict whether a precipitate of MgF_2 will form when 100.0 milliliters of a 3.00×10^{-3} -molar $\text{Mg}(\text{NO}_3)_2$ solution is mixed with 200.0 milliliters of a 2.00×10^{-3} -molar NaF solution at 18°C. Calculations to support your prediction must be shown.
- (d) At 27°C the concentration of Mg^{2+} in a saturated solution of MgF_2 is 1.17×10^{-3} molar. Is the dissolving of MgF_2 in water an endothermic or an exothermic process? Give an explanation to support your conclusion.