THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
ACADEMIC YEAR 2022
TERM 1
CHE 1000: INTRODUCTORY CHEMISTRY

ASSIGNMENT SHEET 5 Chemical and Acid-Base Equilibria 18rd September 2023

Answer all the problems in a HARD COVER book and submit in ROOM 124 before 10:00 hrs on Thursday, 25th September 2023

1. Chemical equilibrium is achieved when the rate of forward and reverse reactions is equal.
   a) What are the two (2) characteristics of chemical equilibrium?
   b) Define heterogeneous and homogeneous equilibria.
   c) State the relationship between equilibrium constant and Gibbs energy.
2. Write the expression for K_C for the following reactions. In each case indicate whether the reaction is homogeneous or heterogeneous.
   a) $3NO\ (g) \rightleftharpoons N_2O(g) + NO_2(g)$
   b) $Ni(CO)_4 \rightleftharpoons Ni(s) + 4\ CO(g)$
3. When the following reactions come to equilibrium, state whether the equilibrium mixture of each reaction contains mostly reactants or mostly products?
   a) $N_2\,(g) + O_2\,(g) \rightleftharpoons 2NO(g);\ K_C = 1.5 \times 10^{-20}$
   b) $2SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$; Kp = 2.5 X 10^9
4. The decomposition of nitrogen dioxide at room temperature is shown:

   $$2NO_2(g) \leftrightharpoons 2NO(g) + O_2(g)$$

   If the Kp value is 6.3×10^{-13} for this reaction at room temperature, calculate K_C for reaction.
5. Calculate the Standard Free Energy Change at 25°C given the Equilibrium constant of 1.3×10^4.
6. The following equilibrium was attained at 823 K, calculated Kp.

   $$CoO\ (s) + H_2\,(g) \rightleftharpoons Co(s) + H_2O\ (g);\ Kc = 67$$

7. Ethelene and water react under appropriate conditions to give ethanol. The reaction is

   $$C_2H_4(g) + H_2O\ (g) \leftrightharpoons C_2H_5OH(g)$$

   An equilibrium mixture of these gases at a certain temperature had the following concentrations: $[C_2H_4] = 0.0148\ M, [H_2O] = 0.0336\ M\ and\ [C_2H_5OH] = 0.180\ M.$ What is the value of Kc ?
8. A mixture of 0.10 mol of NO, 0.050 mol of H_2, and 0.10 mol of H_2O is placed in a 1.0-L vessel at 300 K. The following equilibrium is established:

$$2\ NO\ (g) + 2\ H_2\ (g) \quad \rightleftharpoons \quad N_2(g) + 2\ H_2O(g)$$

At equilibrium [NO] = 0.062 M.

a) Calculate the equilibrium concentrations of H_2, N_2, and H_2O.

b) Calculate Kc.

9. At 100°C the equilibrium constant for the reaction $COCl_2\ (g) \leftrightharpoons CO\ (g) + Cl_2(g)$ has the value Kc = 2.19×10^{-10}. Calculate the equilibrium concentrations of $[COCl_2]$, [CO] and $[Cl_2]$

10. The following was studied by analysing the equilibrium mixture for H_2S produced.

$$Sb_2S_3\ (s) + 3\ H_2\ (g) \leftrightharpoons 2Sb\ (s) + 3H_2\ (g)$$

A vessel whose volume was 2.50 L was filled with 0.0100 mol of antimony(III)sulphide, and 0.0100 mol hydrogen gas. After the mixture came to equilibrium in a closed vessel at 440 ℃, the gaseous mixture was removed, and the hydrogen sulphide was dissolved in water. Sufficient lead (II) ion was added to react completely with the hydrogen sulphide to precipitate lead (II) sulphide, PbS. If 1.029 g PbS was obtained, what is the value of Kc at 440 ℃.

11. Consider the following equilibrium, for which $\Delta H < 0$

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

How will each of the following changes affect an equilibrium mixture of the three gases?

a) O_2 (g) is added to the system.

b) The reaction mixture is heated.

c) A catalyst is added to the mixture.

d) SO_3 (g) is removed from the system.

12. Write the K_{sp} expression for calcium fluoride.

13. Copper (I) chloride has $K_{sp} = 1.9 \times 10^{-7}$. Calculate the molar solubility of Copper (I) chloride in pure water.

14. Calculate the molar solubility of Ag_2CrO_4 at 25 ℃ in 0.200 M $AgNO_3$. Ksp for Ag_2CrO_4 at 25 ℃ is 1.2×10^{-12}

15. An acid can be described as Arrhenius Acid or Bronsted-Lowry Acid or Lewis Acid.

a) Give the definition of each the following:

i. Arrhenius Acid

ii. Bronsted-Lowry Acid

iii. Lewis Acid

b) Give limitation of Arrhenius definition of an Acid

16. What are the concentrations of all the species at equilibrium in 0.150 M lactic acid, $HC_3H_5O_2$? What is the pH of the solution, Ka =1.4×10^{-4}.

17. Pyridine, C_5H_5N, is a bad smelling liquid that is a weak base in water. Its $Kb = 1.51 \times 10^{-9}$. What is the pH of a 0.20 M aqueous solution of this compound?
18. Calculate the pH of 0.20 M NaCN.
19. What is the percentage ionization in a 0.15 M solution of HF? What is the pH of the solution?
20. How many grams of ammonium chloride would have to be dissolved in 500 mL of 0.20 M NH_3 to prepare a a solution buffered at pH = 10.00.
21. Calculate the pH of the 0.20 M NH_3/0.20 M NH_4Cl buffer. What is the pH of the buffer after the addition of 10.0 mL of 0.10 M HCl to 65.0 mL of the buffer?