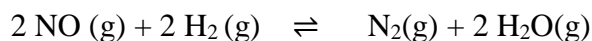


**THE UNIVERSITY OF ZAMBIA**  
**SCHOOL OF NATURAL SCIENCES**  
**DEPARTMENT OF CHEMISTRY**  
**ACADEMIC YEAR 2022**  
**TERM 1**  
**CHE 1000: INTRODUCTORY CHEMISTRY**

**ASSIGNMENT SHEET 5    Chemical and Acid-Base Equilibria    18<sup>th</sup> September 2023**

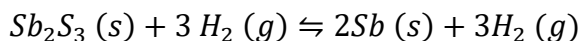
**Answer all the problems in a HARD COVER book and submit in ROOM 124 before 10:00 hrs on Thursday, 25<sup>th</sup> September 2023**

- Chemical equilibrium is achieved when the rate of forward and reverse reactions is equal.
  - What are the two (2) characteristics of chemical equilibrium?
  - Define heterogeneous and homogeneous equilibria.
  - State the relationship between equilibrium constant and Gibbs energy.
- Write the expression for  $K_C$  for the following reactions. In each case indicate whether the reaction is homogeneous or heterogeneous.
  - $3\text{NO}(\text{g}) \rightleftharpoons \text{N}_2\text{O}(\text{g}) + \text{NO}_2(\text{g})$
  - $\text{Ni}(\text{CO})_4 \rightleftharpoons \text{Ni}(\text{s}) + 4 \text{CO}(\text{g})$
- When the following reactions come to equilibrium, state whether the equilibrium mixture of each reaction contains mostly reactants or mostly products?
  - $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}); K_C = 1.5 \times 10^{-20}$
  - $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g}); K_p = 2.5 \times 10^9$
- The decomposition of nitrogen dioxide at room temperature is shown:
$$2\text{NO}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$$
If the  $K_p$  value is  $6.3 \times 10^{-13}$  for this reaction at room temperature, calculate  $K_C$  for reaction.
- Calculate the Standard Free Energy Change at  $25^\circ\text{C}$  given the Equilibrium constant of  $1.3 \times 10^4$ .
- The following equilibrium was attained at 823 K, calculated  $K_p$ .
$$\text{CoO}(\text{s}) + \text{H}_2(\text{g}) \rightleftharpoons \text{Co}(\text{s}) + \text{H}_2\text{O}(\text{g}); K_c = 67$$
- Ethelene and water react under appropriate conditions to give ethanol. The reaction is
$$\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g})$$
An equilibrium mixture of these gases at a certain temperature had the following concentrations:  $[\text{C}_2\text{H}_4] = 0.0148 \text{ M}$ ,  $[\text{H}_2\text{O}] = 0.0336 \text{ M}$  and  $[\text{C}_2\text{H}_5\text{OH}] = 0.180 \text{ M}$ . What is the value of  $K_c$  ?
- A mixture of 0.10 mol of NO, 0.050 mol of  $\text{H}_2$ , and 0.10 mol of  $\text{H}_2\text{O}$  is placed in a 1.0-L vessel at 300 K. The following equilibrium is established:



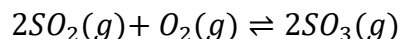
At equilibrium  $[\text{NO}] = 0.062 \text{ M}$ .

- a) Calculate the equilibrium concentrations of  $\text{H}_2$ ,  $\text{N}_2$ , and  $\text{H}_2\text{O}$ .
  - b) Calculate  $K_c$ .
9. At  $100^\circ\text{C}$  the equilibrium constant for the reaction  $\text{COCl}_2 (\text{g}) \rightleftharpoons \text{CO} (\text{g}) + \text{Cl}_2 (\text{g})$  has the value  $K_c = 2.19 \times 10^{-10}$ . Calculate the equilibrium concentrations of  $[\text{COCl}_2]$ ,  $[\text{CO}]$  and  $[\text{Cl}_2]$
10. The following was studied by analysing the equilibrium mixture for  $\text{H}_2\text{S}$  produced.



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  $440^\circ\text{C}$ , 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,  $\text{PbS}$ . If 1.029 g  $\text{PbS}$  was obtained, what is the value of  $K_c$  at  $440^\circ\text{C}$ .

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



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

- a)  $\text{O}_2 (\text{g})$  is added to the system.
  - b) The reaction mixture is heated.
  - c) A catalyst is added to the mixture.
  - d)  $\text{SO}_3 (\text{g})$  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  $\text{Ag}_2\text{CrO}_4$  at  $25^\circ\text{C}$  in  $0.200 \text{ M AgNO}_3$ .  $K_{sp}$  for



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  $0.150 \text{ M}$  lactic acid,  $\text{HC}_3\text{H}_5\text{O}_2$ ? What is the pH of the solution,  $K_a = 1.4 \times 10^{-4}$ .

17. Pyridine,  $C_5H_5N$ , is a bad smelling liquid that is a weak base in water. Its  $K_b = 1.51 \times 10^{-9}$ . 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?