The University of Zambia
School of Natural Sciences
Chemistry Department
2020/21 ACADEMIC YEAR TERM

CHE1000 - INTRODUCTORY CHEMISTRY

TUTORIAL SHEET 10: **July 2021**
TOPIC: Chemical Equilibrium

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1. Dark brown nitrogen dioxide (NO_2) exists in equilibrium with pale yellow dinitrogen tetraoxide (N_2O_4): This reaction is an example of a homogeneous dynamic equilibrium.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$
Pale yellow *Dark brown*

   a) Explain what is meant by 'dynamic equilibrium'.
   b) Explain why the equilibrium is homogeneous.

2. The equilibrium mixture of $N_2O_4(g)$ and $NO_2(g)$ is put in an airtight gas syringe.
   a) State what happens to the colour of the mixture if the volume inside the gas syringe is decreased.
   b) Explain your answer.

3. A 1.00 mol sample of $N_2O_4(g)$ is placed in a 10.0 L vessel and allowed to reach equilibrium according to the equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

$K = 4.00 \times 10^{-4}$

   Calculate the equilibrium concentrations of: $N_2O_4(g)$ and $NO_2(g)$.

4. A 2.0 mol sample of ammonia is introduced into a 1.00 L container. At a certain temperature, the ammonia partially dissociates according to the equation:

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

   At equilibrium 1.00 mol of ammonia remains. Calculate the value for *K*.

5. Consider the reaction represented by the equation:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

   Initial: 6.00 *M* $Fe^{3+}(aq)$ and 6.00 *M* $SCN^{-}(aq)$

Determine the Equilibrium concentration of $FeSCN^{2+}$, where K = 0.333

6. Consider the reaction given by the equation below:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

Trial number	Fe^{3+}	SCN^{-}	$FeSCN^{2+}$
Trial #1	9.00 *M*	5.00 *M*	1.00 *M*
Trial #2	3.00 *M*	2.00 *M*	5.00 *M*
Trial #3	2.00 *M*	9.0 *M*	6.0 *M*

The equilibrium constant, K for this reaction= 0.333

a) Find the reaction quotient, Q, and predict the direction of the reaction.
b) Find the equilibrium concentrations for all species.

7. The 6 reactions represented below show different homogenous gaseous equilibria.

EQUILIBRIUM	**REACTION**	**ENTHALPY CHANGE**
1	$A + B \rightleftharpoons C + D$	negative
2	$A + B \rightleftharpoons C + D$	positive
3	$A + B \rightleftharpoons 2C + D$	negative
4	$A + B \rightleftharpoons 2C + D$	positive
5	$2A + B \rightleftharpoons C + D$	negative
6	$2A + B \rightleftharpoons C + D$	positive

a) Write down the reference numbers (**1-6**) of *all equilibria which fit the following descriptions and give an explanation* in each case.
   - Equilibrium yield increases when temperature is increased at constant pressure.

b) Write down the reference numbers (**1-6**) of *all equilibria which fit the following descriptions and give an explanation* in each case.
   - Equilibrium yield increases when pressure is increased at constant temperature.

c) Write down the reference numbers (**1-6**) of *all equilibria which fit the following descriptions and give an explanation* in each case.
   - Equilibrium yield is not altered by changing pressure.

d) Write down the reference numbers (**1-6**) of *all equilibria which fit the following descriptions and give an explanation* in each case.

- Equilibrium yield is increased by decreasing the pressure and decreasing the temperature

8. Consider the following reaction with the given equilibrium constant:

$$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COO_2C_2H_5 + H_2O \quad K = 2.2$$

For the following mixtures (a-c), will the concentration of H_2O increase or decrease, or remain the same as equilibrium is established.

a) $[CH_3COOH] = 0.010$ M; $[CH_3CH_2OH] = 0.010$ M; $[CH_3COO_2C_2H_5] = 0.22$M; $[H_2O] = 0.10$M

b) $[CH_3CO_2C2H5] = 0.22$ M, $[H_2O] = 0.0020$M, $[CH_3CO_2H] = 0.0020$M, $[C_2H_5OH] = 0.10$M

c) $[CH_3CO_2C_2H_5] = 0.88$ M, $[H_2O] = 0.12$M, $[CH_3CO_2H] = 0.044$ M, $[C_2H_5OH] = 6.0$ M

9. Consider the following reaction:

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

A mixture of 0.100M NO, 0.050M H_2, 0.100M H_2O and no N_2 was allowed to reach equilibrium. At equilibrium the concentration of NO wa found to be 0.062M

a) Determine the value of Kc

b) Write an expression of Kp using value of Kc above.

10. Predict the shift in the equilibrium position of the following processes if the volume is increased: Also give a reason for the predicted shift.

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

b) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

c) $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$

d) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

11. In the following reaction, in which direction will the equilibrium shift if there is an increase in <u>temperature</u> and the enthalpy of reaction is given such that $\Delta H = -92.5kJ$?

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad (\Delta H = -92.5 \text{ kJ})$$

12. At a particular temperature, 12 mol $SO_3(g)$ is placed into a 3.0L rigid container, and the SO_3 dissociates by the reaction:

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

At equilibrium 3.0 mol SO_2 is present. Calculate the K for this reaction.

13. At 35 ^{o}C, K= 1.6 x 10^{-5} for the reaction:

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

Calculate the concentrations of all species at equilibrium for each of the following original mixture:

a) 2.0 mol pure NOCl in a 2.0 L
b) 1.0 mol NOCl and 1.0 mol NO in a flask 1.0 L

14. At 327 ^{o}C, the equilibrium concentrations are $[CH_3OH] = 0.15$ M, $[CO] = 0.24$ M, $[H_2] = 1.1$ M

$$CH_3OH\ (g) \rightleftharpoons CO(g) + 2H_2(g)$$

Calculate Kp at this temperature.

15. Given the equilibrium constants for the following two reactions:

$$A(g) \rightleftarrows B(g) \qquad K = K_1$$

$$B(g) \rightleftarrows C(g) \qquad K = K_2$$

Derive the equilibrium constant for the reaction, $A(g) \rightleftarrows C(g)$ in terms of K_1 and K_2.