

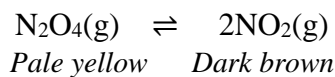
**The University of Zambia**  
**School of Natural Sciences**  
**Chemistry Department**  
**2020/21 ACADEMIC YEAR TERM**

**CHE1000 - INTRODUCTORY CHEMISTRY**

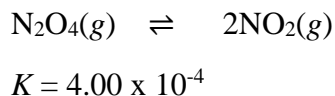
**TUTORIAL SHEET 10:**  
**TOPIC: Chemical Equilibrium**

**July 2021**

1. Dark brown nitrogen dioxide ( $\text{NO}_2$ ) exists in equilibrium with pale yellow dinitrogen tetraoxide ( $\text{N}_2\text{O}_4$ ): This reaction is an example of a homogeneous dynamic equilibrium.



- a) Explain what is meant by 'dynamic equilibrium'.  
b) Explain why the equilibrium is homogeneous.
2. The equilibrium mixture of  $\text{N}_2\text{O}_4(\text{g})$  and  $\text{NO}_2(\text{g})$  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  $\text{N}_2\text{O}_4(\text{g})$  is placed in a 10.0 L vessel and allowed to reach equilibrium according to the equation:



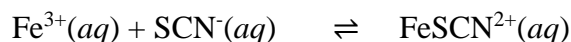
Calculate the equilibrium concentrations of:  $\text{N}_2\text{O}_4(\text{g})$  and  $\text{NO}_2(\text{g})$ .

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:



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

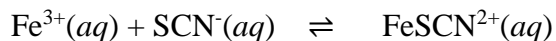
5. Consider the reaction represented by the equation:



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

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

6. Consider the reaction given by the equation below:



Trial number	$\text{Fe}^{3+}$	$\text{SCN}^{-}$	$\text{FeSCN}^{2+}$
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

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

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

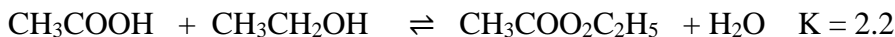
EQUILIBRIUM	REACTION	ENTHALPY CHANGE
1	$\text{A} + \text{B} \rightleftharpoons \text{C} + \text{D}$	negative
2	$\text{A} + \text{B} \rightleftharpoons \text{C} + \text{D}$	positive
3	$\text{A} + \text{B} \rightleftharpoons 2\text{C} + \text{D}$	negative
4	$\text{A} + \text{B} \rightleftharpoons 2\text{C}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

- 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.
- 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.
- 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

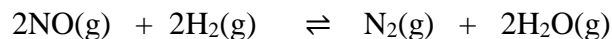
8. Consider the following reaction with the given equilibrium constant:



For the following mixtures (a-c), will the concentration of  $\text{H}_2\text{O}$  increase or decrease, or remain the same as equilibrium is established.

- a)  $[\text{CH}_3\text{COOH}] = 0.010 \text{ M}$ ;  $[\text{CH}_3\text{CH}_2\text{OH}] = 0.010 \text{ M}$ ;  $[\text{CH}_3\text{COO}_2\text{C}_2\text{H}_5] = 0.22 \text{ M}$ ;  
 $[\text{H}_2\text{O}] = 0.10 \text{ M}$
- b)  $[\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5] = 0.22 \text{ M}$ ,  $[\text{H}_2\text{O}] = 0.0020 \text{ M}$ ,  $[\text{CH}_3\text{CO}_2\text{H}] = 0.0020 \text{ M}$ ,  $[\text{C}_2\text{H}_5\text{OH}] = 0.10 \text{ M}$
- c)  $[\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5] = 0.88 \text{ M}$ ,  $[\text{H}_2\text{O}] = 0.12 \text{ M}$ ,  $[\text{CH}_3\text{CO}_2\text{H}] = 0.044 \text{ M}$ ,  $[\text{C}_2\text{H}_5\text{OH}] = 6.0 \text{ M}$

9. Consider the following reaction:



A mixture of  $0.100 \text{ M NO}$ ,  $0.050 \text{ M H}_2$ ,  $0.100 \text{ M H}_2\text{O}$  and no  $\text{N}_2$  was allowed to reach equilibrium. At equilibrium the concentration of  $\text{NO}$  was found to be  $0.062 \text{ M}$

- a) Determine the value of  $K_c$
- b) Write an expression of  $K_p$  using value of  $K_c$  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)  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
- b)  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
- c)  $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g})$
- d)  $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

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



12. At a particular temperature,  $12 \text{ mol SO}_3(\text{g})$  is placed into a  $3.0 \text{ L}$  rigid container, and the  $\text{SO}_3$  dissociates by the reaction:



At equilibrium  $3.0 \text{ mol SO}_2$  is present. Calculate the  $K$  for this reaction.

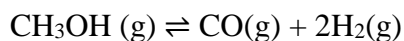
13. At 35 °C,  $K = 1.6 \times 10^{-5}$  for the reaction:



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

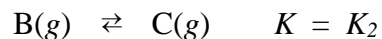
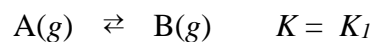
- a) 2.0 mol pure NOCl in a 2.0 L
- b) 1.0 mol NOCl and 1.0 mol NO in a flask 1.0 L

14. At 327 °C, the equilibrium concentrations are  $[\text{CH}_3\text{OH}] = 0.15 \text{ M}$ ,  $[\text{CO}] = 0.24 \text{ M}$ ,  $[\text{H}_2] = 1.1 \text{ M}$



Calculate  $K_p$  at this temperature.

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



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