W2	Learning Area	General Chemistry 2	Grade Level	Grade 12
	Quarter	Third Quarter	Date	March 22-26, 2021

I. LESSON TITLE	Chemical Equilibrium
II. MOST ESSENTIAL LEARNING COMPETENCIES (MELCs)	1. Explain chemical equilibrium in terms of the reaction rates of the forward and the reverse reaction. 2. Calculate equilibrium constant and the pressure or concentration of reactants or products in an equilibrium mixture. 3. State the Le Chatelier's principle and apply it qualitatively to describe the effect of changes in pressure, concentration and temperature on a system at equilibrium.
III. CONTENT/CORE CONTENT	✓ Chemical Equilibrium ✓ Equilibrium Constant ✓ Le Chatelier's principle

IV. LEARNING PHASES AND LEARNING ACTIVITIES

I. Introduction (Time Frame**:** 30 minutes)

Equilibrium is a balanced condition. A body in stable equilibrium will return to its previous state of equilibrium if it is disrupted. In a chemical reaction, the concentrations of reactants and products remain stable and there are no visible shifts in the environment when it reaches equilibrium. However, since reactant molecules continue to form product molecules when product molecules react to yield reactant molecules, there is a lot of activity at the molecular level.

At the end of the lesson, you will be able to:

1. Explain chemical equilibrium in terms of the reaction rates of the forward and the reverse reaction;
2. Calculate equilibrium constant and the pressure or concentration of reactants or products in an equilibrium mixture; and
3. State the Le Chatelier's principle and apply it qualitatively to describe the effect of changes in pressure, concentration, and temperature on a system at equilibrium.

What is your favorite carbonated drink? Did you know that in a carbonated drink, carbon dioxide is pushed into the solution by adding pressure? Carbonic acid is formed when carbon dioxide reacts with water, as seen in the equation below:

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

Carbon dioxide is released from the decomposition of carbonic acid when the container is opened and the pressure is released.

$$H_2CO_3 \longrightarrow CO_2 + H_2O$$

What do you notice from the two reactions? The two reactions are the reverse of each other and can be written as:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

This is referred to as a reversible reaction. A reversible reaction is one that can go in both directions. If the rates of forward and backward reactions are identical, **chemical equilibrium** exists.

Learning Task 1

Give an example of a chemical reaction in chemical equilibrium. Define chemical equilibrium using your chemical equation.

D. Development (Time Frame: 60 minutes)

Chemical Equilibrium and Equilibrium Constant

For any equilibrium reaction, an equilibrium constant (K_c)can be obtained if all the quantities in the expression can be determined experimentally. For a general case of a reversible reaction

$$aA + bB \rightleftharpoons cC + dD$$

where a, b, c and d are the stoichiometric coefficients for the reactants and products. The rate of the forward reaction is equal to the rate of the backward reaction, at equilibrium [A][B]=[C][D]. The ratio of the product [C][D] to the product [A][B] has a definite value at a given temperature. This is referred to as the equilibrium constant of the reaction designated as K_c. The equilibrium constant K is the ratio of the product of equilibrium substance concentrations to the product of reacting substance concentrations, each concentration being raised to the power of the substance's coefficient in the chemical equation.

At a fixed temperature for a given reaction: $K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$

Consider the reaction: $2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$

What is the equilibrium constant expression for the given reaction? The reactants are $NO_{(g)}$ and $O_{2(g)}$ which will be placed in the denominator and the product is $NO_{2(g)}$ in the numerator. Substituting from the given equilibrium constant

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b} = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

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The equilibrium constant expression for this reaction is $K_c = \frac{[NO_2]^2}{[NO]^2[O_2]}$

It is important to remember when writing the expression for K_c that if a pure liquid or solid is involved in a reaction, its concentration is excluded from the expression. At constant temperature, a pure liquid or solid has a constant concentration in moles per liter. This value has already been accounted for in K_c.

Learning Task 2

Write the equilibrium constant expression for each of the following reactions.

1. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$
2. $3O_{2(g)} \rightleftharpoons 2O_{3(g)}$
3. $2CO_{2(g)} \rightleftharpoons 2CO_{(g)} + O_{2(g)}$
4. $CH_3COOH_{(aq)} + C_2H_5OH \rightleftharpoons CH_3COOC_2H_{5(aq)} + H_2O_{(l)}$
5. $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

The partial pressures of reactants and products in gaseous reactants can also be used to express their concentrations. At constant temperature the pressure P of a gas is directly related to the concentration in mole/L of the gas, that is, pressure, P=(n/VRT). Assuming an ideal gas behavior, $K_p = \frac{[B]^b}{[A]^a}(RT^{\Delta n})$

where Δn= moles of gaseous products – moles of gaseous reactants.

Example 1: The following equilibrium process has been studied at 230°C.

$$2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$$

In one experiment the concentrations of the reacting species at equilibrium are found to [NO]= 0.0542 M, [O_2] =0.127 M, and [NO_2]=15.5 M. Calculate the equilibrium constant of the reaction at this temperature.

$$K_c = \frac{[NO_2]^2}{[NO]^2[O_2]} = \frac{(15.5)^2}{(0.0542)^2(0.127)} = 6.44 \times 10^5$$

Example 2: A mixture of 0.500 mol H2 and 0.500 mol I2 was placed in a 1.00 L stainless steel flask at 430°C. The equilibrium constant Kc for the reaction $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ is 54.3 at this temperature. Calculate the concentrations of H_2, I_2 and HI at equilibrium.

	$H_{2(g)}$	$I_{2(g)}$	$HI_{(g}$
Initial(M)	.500	.500	0.000
Change(M)	-x	-x	+2x
Equilibrium(M)	(0.500-x)	(0.500-x)	2x

$Kc = \frac{[HI]^2}{[H_2][I_2]}$ Substituting , $54.3 = \frac{(2x)^2}{(0.500-x)(0.500-x)}$

Taking the square root of both sides, $7.37 = \frac{2x}{0.500-x}$ multiplying both sides with 0.500-x

$3.685 - 7.37x = 2x$

$x = 0.393$ M

[H_2]=(0.500-0.393 M) M = 0.107 M

[I_2]=(0.500-0.393 M) M = 0.107 M

[HI]=(2 x 0.393 M) M = 0.786 M

Le Chatelier's Principle

Chemical equilibrium is described as the balance of forward and backward reactions. Changes in the experimental conditions can throw the balance off and cause the equilibrium position to change, resulting in the formation of more or less of the desired product. When a change in concentration, pressure, volume, or temperature occurs, there is a general rule that can help us predict the direction in which an equilibrium reaction will pass. This is regulated by *Le Chatelier's* principle, which states that if an external stress is applied to an equilibrium system, the system changes to partially offset the stress.

Following Le Chatelier's principle, if a reactant or product is added to an equilibrium system, the equilibrium will change to absorb the added material. The changes in volume are responsible for the changes in pressure. If the volume will increase, the reaction will shift toward the side that has more moles of gas. An increase in temperature for an endothermic reaction shifts the equilibrium to the right; for an exothermic reaction, it shifts the equilibrium to the left. Catalysts influence the time it takes to reach equilibrium, but they have no effect on K.

Consider this example:

Heating solid sodium bicarbonate in a closed vessel establishes the following equilibrium: $2NaHCO_{3(s)} \rightleftharpoons Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$

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What would happen to the equilibrium position if

a) Some of the CO_2 were removed from the system
There will be a shift position of equilibrium to the right

b) Some solid Na_2CO_3 were added to the system
No effect since it is solid that is added.

c) Some of the solid $NaHCO_3$ were removed from the system? The temperature remains constant.
No effect since it is a solid that is removed.

E. Engagement (Time Frame: 60 minutes)

Answer the following tasks to check your understanding on equilibrium constant and the Le Chateliers' Principle

Learning Task 3

Answer the following problem.

A 1.00 mole sample of NOCl was placed in a 2.00 L reactor and heated to 227°C until the system reached equilibrium. The contents of the reactor were then analyzed and found to contain 0.056 mole of Cl_2. Calculate K at this temperature. The equation is as follows:

$$2NOCl(g) \rightleftharpoons 2NO_{(g)} + Cl_{2(g)}.$$

Learning Task 4

For the following reactions, write how each of the changes will affect the indicated quantity, assuming a container of fixed size. Write increase, decrease, or no change. For a chemical added, write how it would respond after the addition.

$$H_{2(g)} + Br_{2(g)} \rightleftharpoons 2HBr_{(g)} \qquad \Delta H° = -103.7kJ$$

Changes	[H2]	[Br2]	[HBr]	K value
1. Some H2 added				
2. Some HBr added				
3. Some H2 removed				
4. Some HBr removed				
5. The temperature is increased				
6. The temperature is decreased				
7. Pressure is increased, and the container volume decreased				

Numerous chemical equilibria must be preserved in the human body to ensure physiological well-being. The body must adjust to changing environmental factors to continue to work. A sudden change in altitude can cause altitude sickness, as the body adjusts to the low oxygen content in the air. The combination of oxygen with the hemoglobin molecules which carries oxygen through the blood is represented by the equation: $Hb_{(aq)} + O_{2(aq)} \rightleftharpoons HbO_{2(aq)}$

The partial pressure of oxygen is just 0.014 atm at 3km altitude compared with 0.2 atm at sea level. According to Le Chatelier's principle, a drop-in oxygen causes the equilibrium to change from right to left, depleting the supply of oxyhemoglobin, and resulting in hypoxia. If given enough time, the body can compensate by producing more hemoglobin molecules. After that, the equilibrium will transition back to oxyhemoglobin formation. The rise in hemoglobin output requires two to three weeks to meet the body's basic needs.

A. Assimilation (Time Frame: 5 minutes)

Chemical equilibrium is a reversible process in which the rates of the forward and backward reactions are equal and the concentrations of reactants and products do not change with time.

For the general chemical reaction $aA + bB \rightleftharpoons cC + dD$ the concentrations of reactants and products at equilibrium are related by the equilibrium constant expression.

Le Chatelier's principle states that if an external stress is applied to a system at chemical equilibrium, the system will adjust to partially offset the stress. The value of the equilibrium constant for a particular reaction is only affected by changes in temperature. The equilibrium concentrations of reactants and products may be affected by changes in concentration, pressure, or volume. The addition of a catalyst speeds up the process of reaching equilibrium while leaving the equilibrium concentrations of reactants and products unchanged.

V. ASSESSMENT (Time Frame: 15 minutes)

(Learning Activity Sheets for Enrichment, Remediation or Assessment to be given on Weeks 3 and 6)

Read each item carefully and choose the correct answer.

1.Which of the following is true regarding the concentration of products, for a chemical reaction that is already at equilibrium, assuming no disruptions to the equilibrium?

a. The concentrations of products will not change because there are no more reactants.
b. The concentrations of products will not change because the limiting reagent is gone.

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c. The concentrations of products will not change because the forward and reverse rates are equal.
d. The concentrations of products will change continually because of reversibility.

2. Which of the following are equal for a chemical system at equilibrium?
   a. the rate of the forward and reverse reaction
   b. the concentrations of reactant and products are equal
   c. the rate constants for the forward and reverse reactions are equal
   d. the time that a particular atom or molecule spends as a reactant and product are equal
3. If heat is added to an endothermic reaction, in which direction will the equilibrium shift according to Le Chatelier's principle?
   a. to the left
   b. to the right
   c. cannot be determined
   d. equilibrium does not shift
4. A catalyst__________
   a. favors forward reaction
   b. favors the backward reaction
   c. cannot predict the reaction
   d. has no effect on the reaction
5. What is the equilibrium constant expression K_c for the reaction below?

$$CH_3OH_{(l)} \rightleftharpoons CO_{(g)} + 2\,H_{2(g)}$$

   a. $K_c = [CO][H_2]$
   b. $K_c = [CO][H_2]^2$
   c. $K_c = \frac{[CO][H_2]^2}{[CH_3OH]}$
   d. $K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$

VI. REFLECTION (Time Frame: 10 minutes)

- Communicate your personal assessment as indicated in the Learner's Assessment Card.

Personal Assessment on Learner's Level of Performance

Using the symbols below, choose one which best describes your experience in working on each given task. Draw it in the column for Level of Performance (LP). Be guided by the descriptions below:

☆ - I was able to do/perform the task without any difficulty. The task helped me in understanding the target content/ lesson.
✓ - I was able to do/perform the task. It was quite challenging, but it still helped me in understanding the target content/lesson.
? – I was not able to do/perform the task. It was extremely difficult. I need additional enrichment activities to be able to do/perform this task.

Learning Task	LP	Learning Task	LP	Learning Task	LP	Learning Task	LP
Number 1		Number 3		Number 5			
Number 2		Number 4					

VII. REFERENCES

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Prepared by:	Maria Cristina M. Briones	Checked by:	Jocelyn Reyes Roxane L. Llona Leilane P.Legacion