Cosmo School

Chemistry

Class-9

Chapter-7

Chemical reactions

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Lecture sheet with worksheet-6

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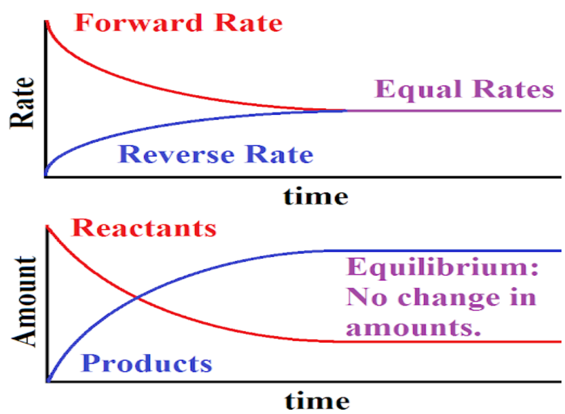
Unit-1: Chemical equilibrium

Sometimes chemical reactions are not unidirectional, they are reversible. the reactants produce the products which then go right back and produce reactants. This means there is both a forward and reverse reaction.

If the rate of the forward reaction, reactants to products, is the same as the reverse reaction, products to reactants, the reaction is said to be at equilibrium. This is called a dynamic equilibrium because both processes are occurring simultaneously, even though there is no overall observable change/no visible change.

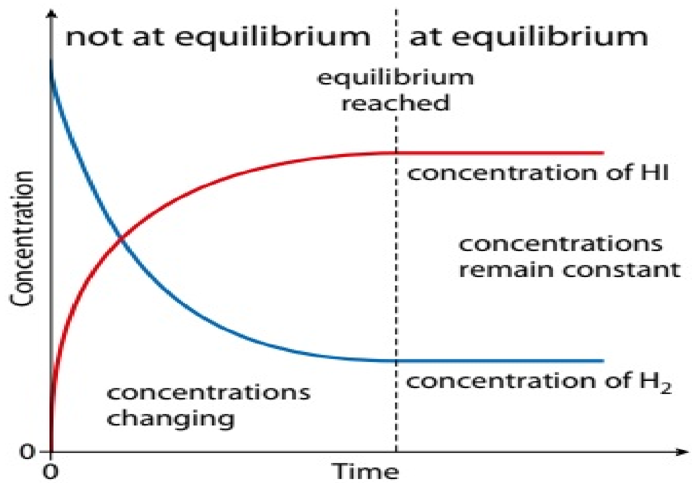
For a chemical system to be at equilibrium, it must meet two important criteria. It must be a reversible process. It must be taking place in a closed system. A closed system is one where there is no exchange of matter, only exchange of energy.

> We have learnt how to use stoichiometry to discuss limiting reagents and how much of the products to expect but these are for unidirectional reactions or irreversible reactions where we assume that all the reactants make products and then the reaction is over. But with equilibria it's a little more complicated to calculate what the concentrations of each substance will be at equilibrium. We will learn about that at higher class.



The amount of product produced from reactant per unit time is called the rate of reaction.

Example-1:

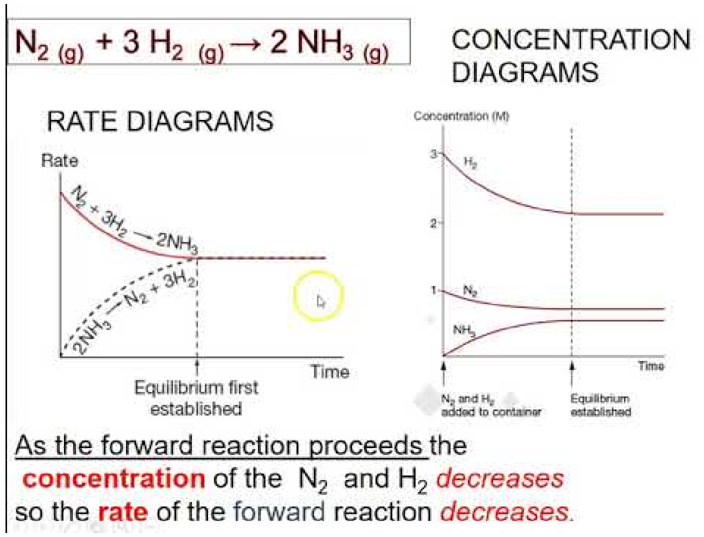


An example of a reaction at equilibrium is the reaction of hydrogen and iodine in a closed container to produce hydrogen iodide. At the start of the reaction, there is a high concentration of hydrogen and iodine, and the concentrations decrease as hydrogen iodide is formed. The concentration of hydrogen iodide increases as the forward reaction proceeds. As hydrogen iodide (HI) is formed, the reverse reaction is then able to occur. Over time, the concentrations of hydrogen, iodine, and hydrogen iodide remain constant. The reaction of hydrogen and iodine to produce hydrogen iodide is occurring at the same rate as the decomposition of hydrogen iodide to hydrogen and iodine. So there are no observable changes although both the forward and reverse reactions are occurring. The reaction has not 'stopped', but rather, has reached dynamic equilibrium.

What would happen to this reaction if the lid on top of the glass jar was opened? If the lid was removed, the system is no longer at equilibrium as both the reactants and products, or 'matter' would be able to escape the system.

In summary, a chemical system is said to be at equilibrium when the rate of the forward reaction is the same as the rate of the reverse reaction. There are no observable changes but both directions of the reaction are occurring, so it is a dynamic equilibrium.

Example-2:



As nitrogen and hydrogen react to form ammonia, the concentration of those gases drops, making them less likely to collide and keep reacting, so the rate of the forward reaction slows down. At the same time, the concentration of ammonia rises. More ammonia molecules are available to break up into the reactant gases. And the rate of the reverse reaction speeds up. Eventually, those processes reach a point where they happen at the same rate. At that point, there's no measurable change in the concentration of any gas. Nitrogen and hydrogen keep combining to form ammonia, while ammonia keeps breaking down into nitrogen and hydrogen at the same time.

The reaction basically never stops, it's just that we don't notice any changes at that point (equilibrium), because everything that happens in one direction is perfectly balanced out by what happens in the other direction. That's why reactants are written with a double arrow, indicating that the process runs both directions.

Unit-2: Le Chatelier's Principle

When the balance of some natural system gets disrupted, we say that it's out of equilibrium, and nature usually finds a way to restore the balance. In science, the word for balance is equilibrium.

Chemical equilibria can be disturbed by changes in the concentration of one or more substances or by changes in temperature or pressure. We describe these changes based on which way they force the equilibrium.

We say a change shifts the reaction to the right if it tends to make more products form and to the left if it tends to make more reactants form.

Le Chatelier's Principle, explains how a system/reaction at equilibrium does in response to "stresses"/conditions of a reaction /factors of a reaction.

Obtaining the maximum amount of product from a reaction depends on the proper set of reaction conditions.

When a chemical system/reaction at equilibrium is stressed, the system works to restore equilibrium. This is Le Chatelier's Principle. The stresses/factors are

- Changes to the concentration of either the reactants or products,
- Changes to the pressure, though this is only applicable to gaseous systems,
- Changes to the temperature.

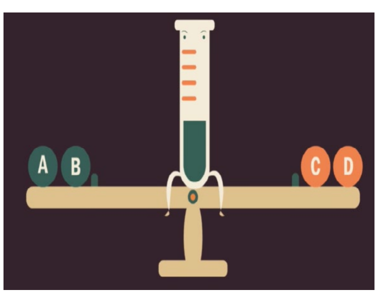
The Le Chatelier's Principle:

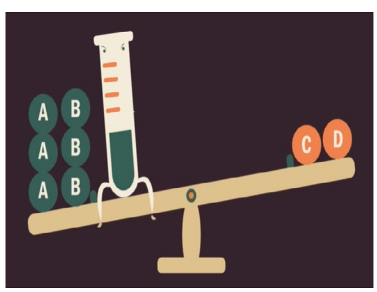
At the equilibrium of reversible reaction, if any of the factors (temperature, pressure and concentration of reactant) is changed, the equilibrium position will shift in such a way that the effect of factor is neutralized.

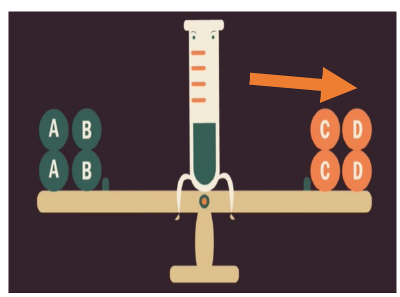
Unit-3: Changes in concentration

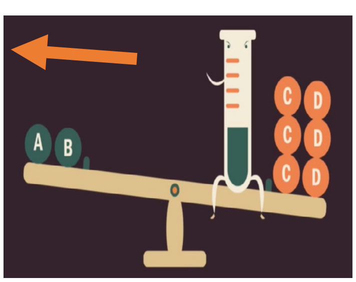
$$A + 2B \rightleftharpoons C + D$$

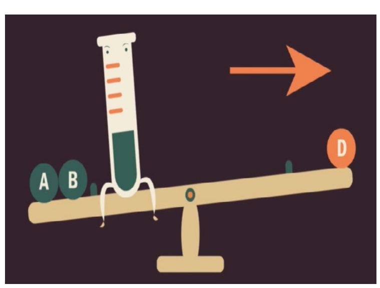
Let's describe a hypothetical reaction at equilibrium. If we added more A and B, the system becomes stressed and is no longer at equilibrium. To counteract the stress, the system forms more C and D, in order to remove the excess A and B. The equilibrium, therefore, "shifts" to the right. As you can see, equilibrium has now been restored. If we added more C and D, the system becomes stressed and is also no longer at equilibrium. To counteract the stress, the system forms more A and B. Therefore, equilibrium shifts to the left. Now if we remove C and D as they are being produced, or in other words, if the concentration of C and D is decreased, The system is now stressed and no longer at equilibrium. To counteract the stress, more C and D are produced, so equilibrium shifts to the right. When concentration increases, equilibrium shifts to the opposite side of the reaction. When concentration decreases, equilibrium shifts to the same side of the reaction.











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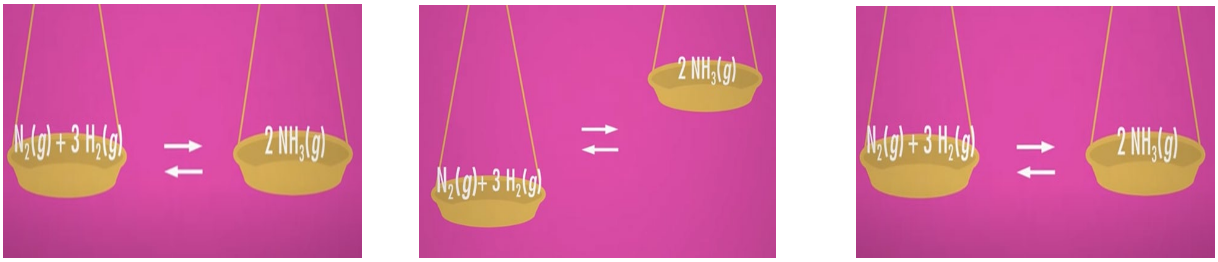

For example, once the Haber reaction for ammonia production is at equilibrium, if we add more nitrogen gas to container the existing hydrogen would have more nitrogen to react with. Thus, it would begin forming more ammonia, sending the reaction to the right until the reaction balances itself again.
Removing some of the ammonia would have the same effect.There would be less ammonia available to break down, So the formation of the ammonia would temporarily exceed the formation of nitrogen and hydrogen, and the reaction would again shift to the right until the balance is restored.

Exercise:

1. What is reversible and irreversible reaction?
2. What is meant by chemical equilibrium? Explain with graph.
3. Chemical equilibrium is a dynamic state –Explain.
4. What is rate of reaction? Explain the rate of forward and reverse reactions at equilibrium with graph.
5. Mention the Le Chatelier's principle.
6. Explain the effect of concentration on the following reactions-
   i) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$
   ii) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$
   iii) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$
   iv) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$