SCH 4U
RECOGNIZING EQUILIBRIUM

In some chemical reactions, both forward and reverse reactions occur – known as reversible reactions. Consider the following pair of reversed reactions:

(1) $2NO_{2(g)} \rightarrow N_2O_{4(g)}$ *AND* **(2)** $N_2O_{4(g)} \rightarrow 2NO_{2(g)}$

During reaction **(1),** the reactants collide with each other to form the products. In a closed container, reaction **(1)** initially has **forward rate > reverse rate**.
It makes sense that as soon as product molecules are formed, they are also colliding with one another. When product molecules collide with the correct orientation and sufficient energy to overcome the activation energy barrier, they will reform the reactants, in reaction **(2)**.
The forward and reverse reactions continue to occur until **forward rate = reverse rate** – and the concentrations of reactants and products stop changing. This is called ***EQUILIBRIUM***.

The equilibrium reaction is written as $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

Dynamic Equilibrium – observed when opposing forces are occurring at the same time and the same rate. (nothing is added or taken away and temperature must remain constant.)

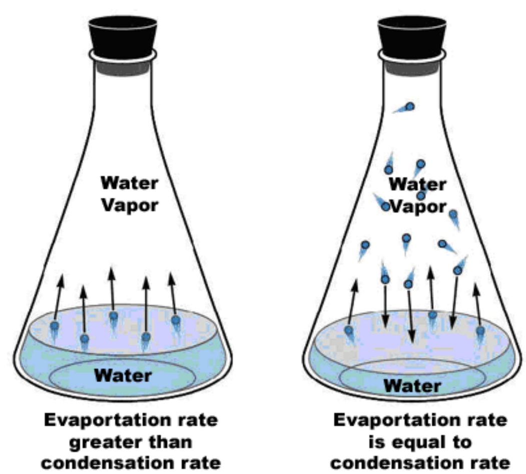
TWO TYPES OF EQUILIBRIUM

① PHYSICAL EQUILIBRIUM

Vapour Equilibrium – when the number of molecules vaporizing is equal to the number of molecules condensing.

Example:

The water ($H_2O_{(l)}$) in the first flask is evaporating faster than the water vapour is condensing. The water ($H_2O_{(l)}$) in the second flask is in equilibrium with its vapour ($H_2O_{(g)}$). At the particulate level, for every one molecule of water ($H_2O_{(l)}$) that evaporates, another water vapour molecule ($H_2O_{(g)}$) condenses to the liquid state.

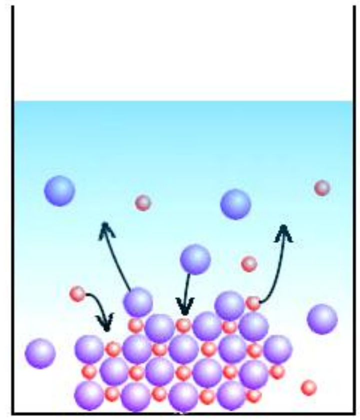


$H_2O_{(l)} \rightarrow H_2O_{(g)}$ $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$

Solution Equilibrium – when the number of particles dissolving is equal to the number of particles returning to crystal form (ie. precipitating).

Example:

The solubility of a solute (such as NaCl) in a solvent (such as water) is a physical property of matter. A saturated solution is one in which the solvent holds as much solute as is possible at a specific temperature. If too much solute is added to the already saturated solution, the undissolved solid remains in the flask. The dissolved solute is in dynamic equilibrium with the solid solute particles.



Eventually, the rate of dissolution will equal the rate of precipitation. The solution will be in equilibrium, but the ions wil continue to dissolve and precipitate.

② CHEMICAL EQUILIBRIUM

Chemical Equilibrium refers to the state of a closed system in which...

- the concentrations of the reactants and the concentrations of the products do not change with time
- the system does not display any further change in properties
- rate of formation of the products = rate of formation of the reactants

Chemical equilibrium only occurs when nothing is added or taken away from the system and temperature must remain constant. Almost all reactions are reversible.

The reaction of sodium metal with chlorine gas is **irreversible** – only the forward arrow is used.
$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$

Whereas, in a **reversible reaction**, the double arrow applies. For instance, the production of ammonia can achieve a state of equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

The rate of forward reaction is equal to the rate of reverse reaction. This means that for every molecule of $N_{2(g)}$ that combines with 3 molecules of $H_{2(g)}$, there is one molecule of $NH_{3(g)}$ that reacts with another molecule of $NH_{3(g)}$, which reform to make the reactants.

FOUR CONDITIONS that APPLY to ALL EQUILIBRIUM SYSTEMS

① Equilibrium is achieved in a reversible system when the rates of opposing changes is equal. The double arrow, indicates reversible changes.

② The observable (macroscopic) properties of a system at equilibrium are constant. At equilibrium, you will not notice changes in colour, pressure, concentration, pH.

③ Equilibrium can only be reached in a closed system, where nothing can enter or escape, including energy. Some changes are negligible, therefore equilibrium principles can be applied even if the system is not physically closed.

④ Equilibrium can be approached from either direction.

For example, in the reaction given by... $H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2HCl_{(g)}$
within a closed system, equilibrium will be reached whether you started with $HCl_{(g)}$, or with $H_{2(g)}$ and $Cl_{2(g)}$.

GRAPHS of EQUILIBRIUM:

How systems achieve equilibrium can be demonstrated through ***rate versus time*** graphs and ***concentration versus time*** graphs, such as the following.