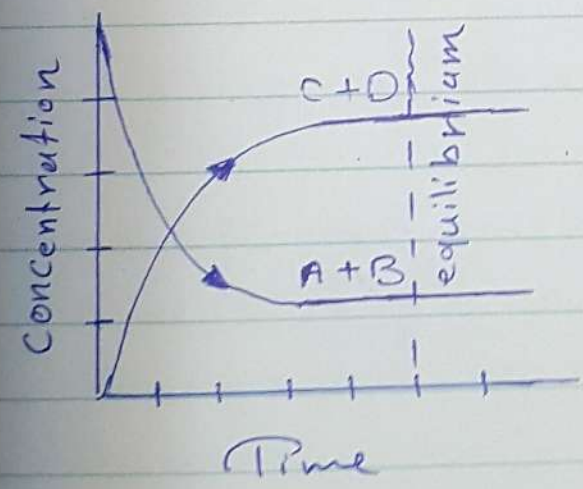
Chemical Equilibrium

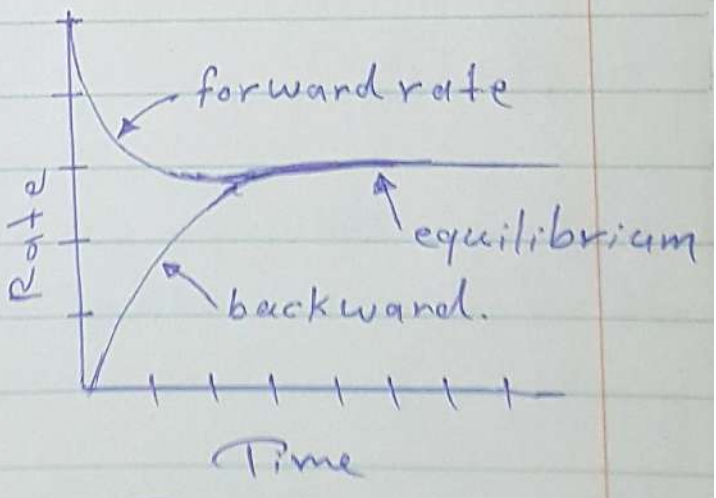
Chemical equilibrium:- is the state of a chemical reaction when the concentration of the products and reactants are unchanged over time, in other words, the forward rate of reaction equals the backward rate of reaction. Chemical equilibrium is also known as dynamic equilibrium.

In chemical equilibrium, the concentration of reactants and products are constant, and forward rate, backward rate are equal as shown below

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



The concentrations are constant



The rates are equal

Types of chemical equilibrium

① Homogeneous Equilibrium
② Heterogeneous Equilibrium

Homogeneous equilibrium :- in this type, the reactants and the products of chemical equilibrium are all in the same phases for example

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)} \qquad K = \frac{[HI]^2}{[H_2][I_2]}$$

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)} \qquad K = \frac{[NO]^2}{[N_2][O_2]}$$

Heterogeneous equilibrium, in this type of chemical equilibrium, the reactants and the products are present in different phases for example

$$CO_{2(g)} + C_{(s)} \rightleftharpoons 2CO_{(g)} \qquad K = \frac{[CO]^2}{[CO_2]}$$

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)} \qquad K = \frac{[CO_2]}{1} = [CO_2]$$

where the constant K is called the equilibrium constant. This formulation of a chemical equilibrium is termed the law of mass action, or sometimes the law of Guldberg and Waage.

Question (1) A chemical system is known to react according to the balanced reaction $2A + B \rightleftharpoons 2C$. when an equilibrium reaction mixture was analyzed, the following concentrations were found $[A] = 1 \times 10^{-2}\ M$, $[B] = 4 \times 10^{-4}\ M$ and $[C] = 2 \times 10^{-5}\ M$, what is the value of the equilibrium constant ?.

$$K = \frac{[C]^2}{[A]^2[B]} = \frac{(2\times10^{-5}\ \text{mole/liter})^2}{(1\times10^{-2}\ \text{mole/liter})^2 \times (4\times10^{-9}\ \text{mole/liter})}$$

$K = 1\times10^{3}$ liters/mole

Question (2)

The partial pressure each of cl_2 and CO are 0.46 atm and 0.45 atm respectively. the total pressure for a mixture of gases at equilibrium is 0.58 atm calculate k_p for reaction $CO + cl_2 \rightleftharpoons COcl_2$

$$CO + cl_2 \rightleftharpoons COcl_2$$

0.45 0.46 0

$0.45-x$ $0.46-x$ x at equilibrium

Total pressure $= P_{CO} + P_{cl_2} + P_{COcl_2}$ at equilibrium

$0.58\ atm = (0.45-x)+(0.46-x)+x$

$x = P_{COcl_2} = 0.33\ atm$

$P_{CO} = 0.45 - 0.33 = 0.12\ atm$ at equilibrium

$P_{cl_2} = 0.46 - 0.33 = 0.13\ atm$ at equilibrium

$$K_p = \frac{P_{COcl_2}}{P_{CO} \times P_{cl_2}} = \frac{0.33}{(0.13)(0.12)} = 21.15$$

and to calculate K_c at 395 °C

$\Delta n = \Sigma n_p - \Sigma n_R$ for gases only

$\Delta n = 1 - 2 = -1$

$K_c = K_p (RT)^{-\Delta n} \rightarrow K_c = 21.15 \times (0.082 * 668)$

$K_c = 21.15 \times 54.77 = 1.15 \times 10^{3}$

Effect of Conditions on Chemical Equilibrium

Some of the factors that influence either the position of a chemical equilibrium or the value of the equilibrium constant, or both.

1- Nature of the reaction system
2- Concentration
3- Acitivity
4- Temperature
5- Catalysis.

The principle of Le Chatelier

If a stress is applied to a system at equilibrium, the equilibrium will be displaced in the direction which tends to diminish the effect of the stress. The factors of Chatelier are Concentration change, a change in temperature and change in pressure.

Question (3) what is the meaning of the statement A chemical equilibrium (Homework)