Chapter 2

1. Meaning and Measurement of Rate

- Rate is defined as the change in concentration of products or reactants in a course of time.

$$\text{Average Reaction Rate} = \frac{\text{change in concentration}}{\text{change in time}}$$

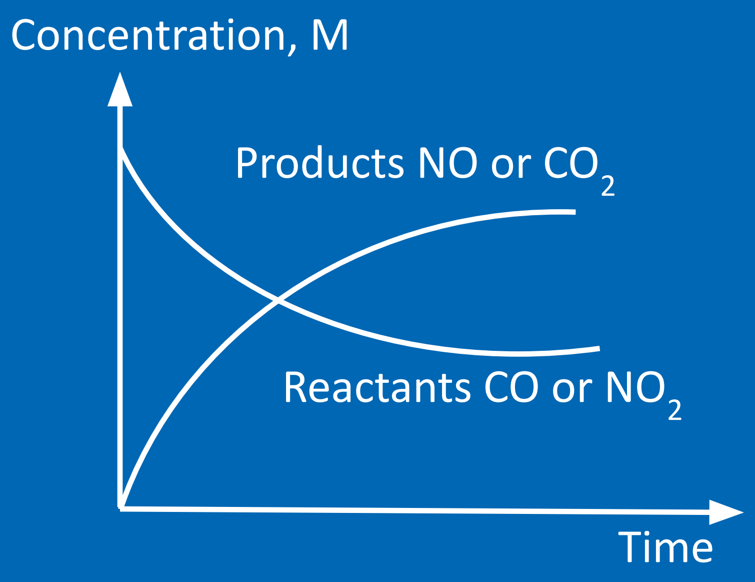
- Reaction rate is the maximum at the beginning of reaction.
- The reaction rate decreases as the concentration of reactants decrease.
- The study of reaction rates and reaction mechanisms is chemical kinetics.

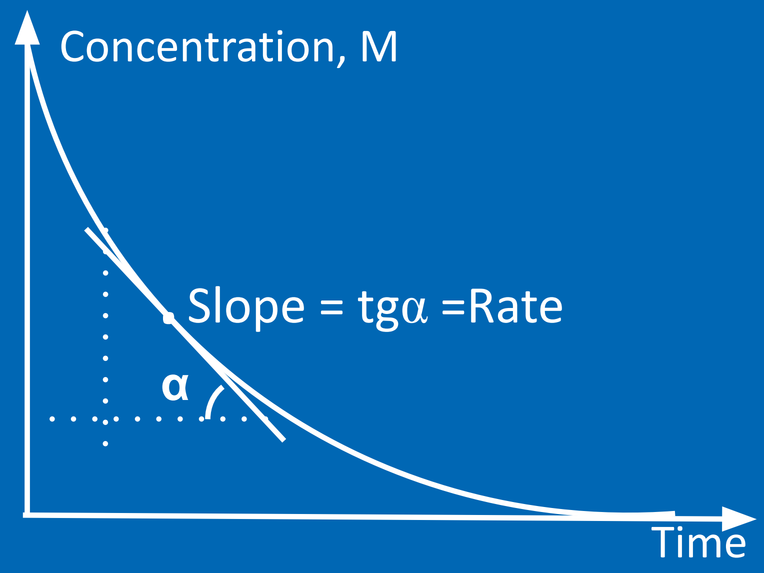
Chapter 2

1. Meaning and Measurement of Rate

Lets have closer look to the reaction below.

$$NO_2(g) + CO(g) \longrightarrow NO(g) + CO_2(g)$$





Chapter 2

1. Meaning and Measurement of Rate

$$NO_2(g) + CO(g) \longrightarrow NO(g) + CO_2(g)$$

Rate expressions as follows;

$$\text{Rate} = -\frac{\Delta[CO]}{\Delta t} \qquad \text{Rate} = -\frac{\Delta[NO_2]}{\Delta t}$$

$$\text{Rate} = +\frac{\Delta[CO_2]}{\Delta t} \qquad \text{Rate} = +\frac{\Delta[NO]}{\Delta t}$$

Chapter 2

1. Meaning and Measurement of Rate

Example 1

Find the rate relationship of reactants and products for the given reaction.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Solution

Rate expressions as follows;

$$\text{Rate} = -\frac{\Delta[N_2]}{\Delta t} \quad \text{Rate} = -\frac{\Delta[H_2]}{\Delta t} \quad \text{Rate} = +\frac{\Delta[NH_3]}{\Delta t}$$

Rate relationship

$$\text{Rate} = -\frac{\Delta[N_2]}{\Delta t} = -\frac{\Delta[H_2]}{3\Delta t} = +\frac{\Delta[NH_3]}{2\Delta t}$$

- The decomposition of dinitrogen pentoxide can be represented by the equation;
- $$2N_2O_5 \longrightarrow 4NO_2 + O_2$$
- The concentration of dinitrogen pentoxide decreases from 0,008 M to 0,004 M in 20 seconds. Find the average rate of consumption of dinitrogen pentoxide

- RateN_2O_5 = (0.008 – 0.004)/20 = 0.0002 = 2.10 $^{-4}$ mol/L. s

1. Meaning and Measurement of Rate

Example 2

In the following decomposition reaction,

$$2N_2O_5 \rightarrow 4NO_2 + O_2$$

oxygen gas is produced at the average rate of 9.1×10^{-4} mol · L^{-1} · s^{-1}. Over the same period, what is the average rate of the following:

- the production of nitrogen dioxide.
- the loss of nitrogen pentoxide.

1. Meaning and Measurement of Rate

Solution

rate NO_2 production = $4 \times (9.1 \times 10^{-4}\ mol \cdot L^{-1} \cdot s^{-1})$

= **$3.6 \times 10^{-3}\ mol \cdot L^{-1} \cdot s^{-1}$**

rate loss of N_2O_5 = $2 \times (9.1 \times 10^{-4}\ mol \cdot L^{-1} \cdot s^{-1})$

= **$1.8 \times 10^{-3}\ mol \cdot L^{-1} \cdot s^{-1}$**

Chapter 2

3. Rate Expression and Rate Constant

Consider the one step following reaction;

$$mA + nB \rightarrow \text{products}$$

- The rate expression is proportional to the product of [A] (to some power *m*) and [B] (to some power *n*). To create an equation instead of a proportion, use the rate constant *k*.

$$\text{Rate} = k[A]^m[B]^n$$

- m and n are order of reaction with respect to related substance, and k depends only on temperature and activation energy.
- Solids and liquids are not included in the expression, only gaseous and aqueous ions are indicated in the rate expression.

3. Rate Expression and Rate Constant

Example 10

Write the possible rate expression of the following reactions.

a. $Cl_2(g) + H_2(g) \rightarrow 2HCl(g)$

b. $Fe(s) + Cl_2(g) \rightarrow FeCl_3(g)$

c. $Fe_2O_3(s) + 3H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(s) + 3H_2O(l)$

d. $Ca(s) + 2Ag^{+}(aq) \rightarrow 2Ca^{+2}(aq) + Ag(s)$

Solution

a. Rate = $k[Cl_2][H_2]$

b. Rate = $k[Cl_2]$

c. Rate = $k[H_2SO_4]^3$

d. Rate = $k[Ag^{+}]^2$

3. Rate Expression and Rate Constant

Example 11

Write the rate expression of the following one step reaction, determine the order of reaction in terms of N_2 and H_2, and overall order.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Solution

Rate = $k[N_2][H_2]^3$

Order in terms of N_2 is 1 and 3 in terms of H_2

Overall order is 1+3 = 4

Temperature

- The increase in temperature increases rate of reaction. And rate can be calculated by the formula below.

$$Vt_2 = Vt_1 . \gamma^{(t2 - t1)/10}$$

γ is a constant and given in the question.

Vt_1 = velocity at initial temperature,

Vt_2 = velocity at final temperature

Ex: If temperature increases 10 ^0C, rate increases 3 times. How many ^0C must the temperature be increased so that rate can increase 27 times?

If $t_2 - t_1 = 10$ **Vt_2 = 3Vt_1**

Then $\frac{Vt_2}{Vt_1} = 3 = \gamma^{10/10}$ $3 = \gamma^{1}$ so $\gamma = 3$

If **Vt_2** = 27.**Vt_1** then $\frac{Vt_2}{Vt_1} = 27 = 3^{(t2 - t1)/10}$

$(t_2 - t_1)/ 10 = 3$

So **$t_2 - t_1 = 30$ ^0C**