Rate of Reaction and Factors Affecting Rates of Reaction

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Chemical Kinetics

- A fundamental question addressed in chemical reactions is ***"how fast does the reaction occur?"***
- Kinetics is the study of the ***rate*** of chemical reactions; rate is a ***time dependent*** process

[redacted]

- Rate units are concentration over time, e.g., M/s
- Concentration may increase (product) or decrease (reactant) over time

A + B → C

[redacted]

Chemical Kinetics

Reaction of butyl chloride (C_4H_9Cl) with water

$CH_3(CH_2)_2CH_2\text{-}Cl(l) + H_2O(l) \rightarrow CH_3(CH_2)_2CH_2\text{-}OH(l) + HCl$

Example of a substitution reaction

Chemical Kinetics

- **Rate may be expressed in three main ways:**

1. Average reaction rate: a measure of the change in concentration with time

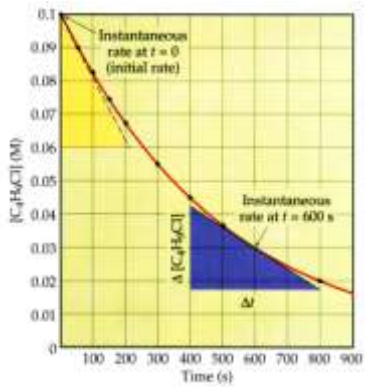
2. Instantaneous rate: rate of change of concentration at any particular instant during the reaction

3. Initial rate: instantaneous rate at t = 0

- that is, when the reactants are first mixed

TABLE 14.2 Rate Data for Reaction of C_4H_9Cl with Water

Time, t (s)	$[C_4H_9Cl]$ (M)	Average Rate (M/s)
0.0	0.1000	1.9×10^{-4}
50.0	0.0905	1.7×10^{-4}
100.0	0.0820	1.6×10^{-4}
150.0	0.0741	1.4×10^{-4}
200.0	0.0671	1.22×10^{-4}
300.0	0.0549	1.01×10^{-4}
400.0	0.0448	0.80×10^{-4}
500.0	0.0368	0.560×10^{-4}
800.0	0.0200	
10,000	0	



Chemical Kinetics

- When plotting **Concentration versus Time** for a chemical reaction, tangent at any point on the curve (drawn through the concentration points) defines the ***instantaneous rate*** of the reaction
- The ***average rate*** of a reaction over some time interval is determined through triangulation of concentration plot (slope of hypotenuse of right triangle)
- The rate of the reaction ***decreases*** over time as the reactants are consumed
- Rate expression must be consistent with stoichiometry

2A + B → 3C

$$Rate = -\frac{\Delta[B]}{\Delta t} = -\frac{1}{2}\frac{\Delta[A]}{\Delta t} = \frac{1}{3}\frac{\Delta[C]}{\Delta t}$$

Chemical Kinetics

- Rate of change of concentration with time.

$$2\ Fe^{3+}(aq) + Sn^{2+} \rightarrow 2\ Fe^{2+}(aq) + Sn^{4+}(aq)$$

$t = 38.5$ s $\quad [Fe^{2+}] = 0.0010$ M

$\Delta t = 38.5$ s $\quad \Delta[Fe^{2+}] = (0.0010 - 0)$ M

$$\text{Rate of formation of } Fe^{2+} = \frac{\Delta[Fe^{2+}]}{\Delta t} = \frac{0.0010\ \text{M}}{38.5\ \text{s}} = 2.6\text{x}10^{-5}\ \text{M s}^{-1}$$

Chemical Kinetics

$$2\ Fe^{3+}(aq) + Sn^{2+}(aq) \rightarrow 2\ Fe^{2+}(aq) + Sn^{4+}(aq)$$

$$\frac{\Delta[Sn^{4+}]}{\Delta t} = \frac{1}{2}\frac{\Delta[Fe^{2+}]}{\Delta t} = -\frac{1}{2}\frac{\Delta[Fe^{3+}]}{\Delta t}$$

Chemical Kinetics

$$a\ A + b\ B \rightarrow c\ C + d\ D$$

Rate of reaction = rate of disappearance of reactants

$$= -\frac{1}{a}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b}\frac{\Delta[B]}{\Delta t}$$

= rate of appearance of products

$$= \frac{1}{c}\frac{\Delta[C]}{\Delta t} = \frac{1}{d}\frac{\Delta[D]}{\Delta t}$$

Chemical Kinetics

- The rate of a reaction is dependent on the concentration of reactants
- As reactant concentrations decrease, the reaction rates decrease
- The rate of a reaction depends on the following variables:
  - ***reactant concentration***
  - ***temperature***
  - ***presence and concentration of a catalyst***
  - ***surface area of solids, liquids or catalysts***
  - ***chemical nature of reactants***

Speed of a Reaction

Rate can be measured two ways

- how fast a reactant disappears

- how fast a product appears

Factors Affecting Reaction Rate Temperature

- Increased temperature; increases reaction rate
  - molecules move faster
  - making more collisions
  - making higher energy collisions

Factors Affecting Reaction Rate Surface Area

- Increased surface area; increases reaction rate
  - smaller particles
  - collisions take place on the surface
  - more area means more collisions

Factors Affecting Reaction Rate Concentration

- Increased concentration; increases reaction rate
  - more particles per volume
  - more collisions

Is more better?

- A reaction stops when it is out of one or more reactant.
- The reactant that there is not enough of is called the limiting reactant.
- So it doesn't matter how much of the other reactant is added.

Factors Affecting Reaction Rate Catalyst

- A substance that speeds up a reaction without being used up itself.
- How does it work?
  - Lowers the activation energy
  - Example
    - Enzymes
      - Speed up the reactions necessary for cell function

Factors Affecting Reaction Rate Inhibitor

- A substance that slows down a reaction
- It won't stop a reaction completely
- Examples:
  - preservatives
    - in food and medicines

Factors Affecting Reaction Rate
Chemical Nature

- Chemical reactivity of individual elements largely depends on the organization of the valence electrons
- Periodic table has elements grouped in periods based on similar chemical activity
  - Periods 1 and 7 tend to contain very active elements