

Chapter 11 – Rates

Michael Brodskiy

Instructor: Mr. Morgan

January 26, 2021

- General Rate = Change in concentration per change in time.
- Rate is dependent on concentration – More collisions, more reactions, faster rate.
- Rate Law Formula = $k[A]^m$, where k is a constant, A is the reactant, and m is the order.
- If there are two reactants, then the rate = $k[A]^m[B]^n$, where B is the other reactant, and n is the order for the second reactant
- Order – Tells how rate changes when concentration changes (0, 1, 2)
- Example: Calculate k for $\text{CH}_3\text{CHO} \longrightarrow \text{CH}_4 + \text{CO}$

Concentration:	.1	.2	.3	.4
Rate:	.085	.34	.076	1.4

$$\begin{aligned} \frac{Rate_1}{Rate_2} &= \left(\frac{(\text{CH}_3\text{CHO})_1}{(\text{CH}_3\text{CHO})_2} \right)^m \\ \frac{.085}{.34} &= \left(\frac{.1}{.2} \right)^m \\ m &= 2 \\ .085 &= k(.1)^2 \\ k &= 8.5 \end{aligned} \tag{1}$$

- Example: Calculate k for $2\text{NO} + \text{Cl}_2 \longrightarrow 2\text{NOCl}$

Experiment	NO	Cl ₂	Rate
1	.0125	.0255	$2.27 \cdot 10^{-5}$
2	.0125	.051	$4.55 \cdot 10^{-5}$
3	.025	.0255	$9.08 \cdot 10^{-5}$

$$\begin{aligned}
\frac{Rate_1}{Rate_3} &= \left(\frac{(NO)_1}{(NO)_3} \right)^m \\
\frac{Rate_1}{Rate_2} &= \left(\frac{(Cl_2)_1}{(Cl_2)_2} \right)^n \\
\frac{2.27}{9.08} &= \left(\frac{.0125}{.025} \right)^m \\
& \qquad m = 2 \\
\frac{2.27}{4.5} &= \left(\frac{.0225}{.051} \right)^n \\
& \qquad n = 1 \\
2.27 \cdot 10^{-5} &= k[.0125]^2[.0255]^1 \\
& \qquad k = 5.7
\end{aligned} \tag{2}$$

- The temperature dependence of the rate is contained in the rate constant, k
- Concentration and Time
 1. For first order reactions: $\ln \left(\frac{x_0}{x_f} \right) = kt$
 2. For second order reactions: $\frac{1}{x_f} - \frac{1}{x_0} = kt$
 3. Half Life: $t_{1/2} = \frac{.693}{k} = \frac{\ln(2)}{k}$
 4. x_0 is the initial concentration, x_f is the final concentration, k is the rate constant, t is time, and $t_{1/2}$ is the half life.
- If half life is constant over a period of time, the reaction is first order.
- For the AP test, it is written as such: $\ln[A] - \ln[A_0] = -kt$
- To determine order, graph the concentration vs time. Must be a linear fit:
 1. A vs Time means it is of zeroth order
 2. $\ln[A]$ vs Time means it is of first order
 3. $\frac{1}{[A]}$ vs Time means it is of second order
- Activation Energy – Reactions occur because of collisions. These collisions must have enough energy to break bonds (E_a). Only collisions having sufficient energy to break bonds and proper orientation will lead to products.
- In a graph, the difference between the maximum and react energy is E_a . The difference between the maximum and products is E'_a . $\Delta H = E_a - E'_a$. If $E_a > E'_a$, the reaction is endothermic. If $E'_a > E_a$, the reaction is exothermic. The maximum is where intermediates are formed, also known as the Activated Complex.

- Catalyst – A substance that lowers the reaction energy without being used up.
- Homogeneous – Two things in the same phase (liquid and liquid)
- Heterogeneous – Two things in different phases (liquid and solid)