Chemical Kinetics: Rates of Reaction

STUDY LIST From Paul Groves

I can…

Reaction Rates

☐ give the correct units to describe the rate of a reaction.
Rate = $\frac{\Delta[chemical]}{\Delta time}$ Units = $\frac{M}{s}, or\ molL^{-1}s^{-1}$

☐ discuss the rate as the rate of **disappearance** of reactant or the rate of **appearance** of product.

- Watch your signs because -Δ[Reactants] = Δ[Products]

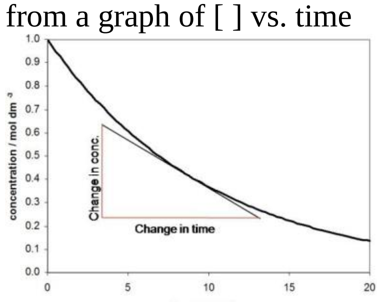
☐ use **coefficients** to change one rate to another ("rate in terms of...")
Example: 2A + 3B → 4C

$$-\frac{1}{2}\frac{\Delta[A]}{\Delta t} = -\frac{1}{3}\frac{\Delta[B]}{\Delta t} = \frac{1}{4}\frac{\Delta[C]}{\Delta t}$$

☐ list ways to speed up a reaction

- Increase **concentration** of reactants
- Increase **temperature** of the rxn
- Increase **surface area**
- Add a **catalyst**

☐ determine the **average rate** of a reaction as well as the **instantaneous rate** of a reaction from a graph of [ ] vs. time



Example – to find the rate at 8min, find the slope of the tangent line at 8min.

☐ describe a catalyst as a substance that speeds up a reaction without getting used up, and describe how a catalyst works.

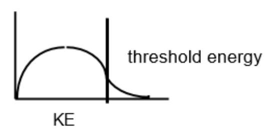
- Provides an alternate pathway with a lower activation energy.
- Helps orient the molecules for proper collisions.

☐ determine the order of the reaction by graphical methods. Use the graph to find the value of k.

- Look for the straight line plots to determine order if needed
C → [ ] vs t = 0^{th} order, slope = -k
N → ln[ ] vs t = 1^{st} order, slope = -k
R → 1/[ ] vs t = 2^{nd} order, slope = k

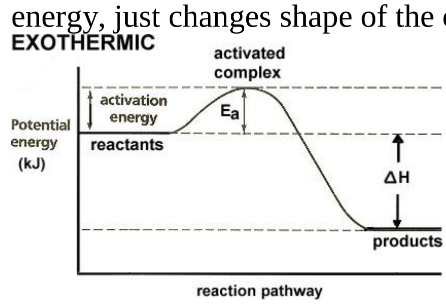
KE & PE Diagrams

☐ draw a kinetic energy distribution



☐ sketch the change in the KE distribution if the reactants are warmed or cooled.

☐ state that the only thing that moves the threshold energy is adding a catalyst. Temperature does not shift the threshold energy, just changes shape of the curve.



☐ Explain that a catalyst lowers the E_a by changing the way the reaction occurs.

Half Life

☐ determine the half-life of a chemical from graphical data, or in a word problem.

☐ use the integrated rate law to solve half-life problems involving in-between times.

- $ln\frac{[A]_0}{[A]_t} = kt$
- Special case of half life
ln (2) = 0.693 = $kt_{1/2}$

Rate Laws:

- ☐ write the rough rate law to show how the rate of a reaction depends on concentration.
  Ex: $N_2 + 3H_2 \rightarrow 2NH_3$
  Rate = k $[N_2]^x[H_2]^y$

- ☐ determine the order of reaction with respect to a chemical using the method of initial rates by inspection.

- ☐ determine orders of reactions using the mathematical method of initial rates.

- ☐ solve for the specific rate constant, k, and determine the correct units.

Reaction Mechanisms:

- ☐ explain that a reaction often occurs in several “elementary steps” that often involve only two particles at a time.

- ☐ combine the elementary steps in a mechanism to identify the overall reaction, the intermediates, and a catalyst.

- ☐ state that the slowest step in a mechanism is called the “rate determining step” and is linked to the rate law.

- ☐ give an example of a chain reaction mechanism for $H_2 + Cl_2$ or for the destruction of ozone (O_3) by stratospheric chlorine atoms.

- ☐ label steps in a chain reaction mechanism as initiation, propagation, and termination steps.

Reaction Order--Graphical Method:

- ☐ identify the integrated rate laws for zero, first, and second order reactions.

- ☐ explain that the integrated rate laws can be set into the form “y = mx + b” which means that a graph indicate the order of reaction and the value of the rate constant, k.

- ☐ state the straight-line graph that is identified with each reaction order.

- ☐ use the slope of the straight-line graph to determine the value of k.

Arrhenius Equation:

- ☐ use the Arrhenius equation to calculate the rate constant, k, using R = 8.31 J/mol K.

- ☐ graphically or algebraically determine the activation energy, E_a, from rate or k data at different temperatures.

- ☐ explain that a rate increase with temperature means that the rate constant, k, has increased proportionately.

- ☐ explain that the slope of a graph of ln k vs. $1/T = -E_a/R$.

Chain Reaction Mechanisms:

- ☐ cite two examples of chain reaction mechanisms and label the elementary steps as initiation, propagation, and termination steps.

From the AP Exam:

$$\ln[\mathrm{A}]_t - \ln[\mathrm{A}]_0 = -kt$$

$$\frac{1}{[\mathrm{A}]_t} - \frac{1}{[\mathrm{A}]_0} = kt$$

$$\ln k = \frac{-E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

$$\begin{aligned}\text{Gas constant, } R &= 8.31 \text{ J mol}^{-1}\text{ K}^{-1}\\ &= 0.0821 \text{ L atm mol}^{-1}\text{ K}^{-1}\\ &= 62.4 \text{ L torr mol}^{-1}\text{ K}^{-1}\\ &= 8.31 \text{ volt coulomb mol}^{-1}\text{ K}^{-1}\end{aligned}$$