Rate of Reaction (Kinetics)

Unit: Kinetics & Equilibrium

MA Curriculum Frameworks (2016): HS-PS1-5

Mastery Objective(s): (Students will be able to…)

- List and explain factors that affect the rate of a chemical reaction.

Success Criteria:

- Descriptions convey how each factor affects the rate of reaction.

Tier 2 Vocabulary: intermediate

Language Objectives:

- Explain what it means for a reaction to happen faster *vs.* slower, and how each factor affects the reaction rate.

Labs, Activities & Demonstrations:

- Drop of food coloring in hot *vs.* cold water.

Notes:

reactants: the compounds consumed in the chemical reaction; compounds that *react*.

products: the compounds created by the chemical reaction; compounds that are *produced.*

intermediates: compounds that are produced in one step of a multi-step reaction and consumed by a later step.

Use this space for summary and/or additional notes:

reaction rate (*k*): the rate at which products are formed in a chemical reaction,

usually expressed in units of: $\frac{\text{mol}}{\text{L}\cdot\text{s}}$ or $\frac{\text{M}}{\text{s}}$ (where M = molarity = $\frac{\text{mol}}{\text{L}}$)

The reaction rate is related to the activation energy. A reaction with higher activation energy will happen more slowly, because fewer of the collisions will have enough energy to enable the molecules to react. Conversely, a reaction with lower activation energy will happen more quickly.

The equation for rate of reaction is: $\ln(k) = -\frac{RT}{E_a}$ or $k = e^{-RT/E_a}$

Quantitative rate calculations are studied in AP® Chemistry. In this course, you need to understand how the equation shows that a higher temperature will speed up the reaction (larger value of *k*), and a higher activation energy will slow down the reaction (smaller value of *k*).

rate-limiting step (or rate-determining step): the step that determines the overall rate of the reaction. In a multi-step reaction, the rate-limiting step is the slowest step.

For example, in the multi-step reaction:

$$\text{A} \xrightarrow{\text{fast}} \text{B} \xrightarrow{\text{slow}} \text{C} \xrightarrow{\text{fast}} \text{D}$$

- A → B will happen faster than B can get used up, so B will accumulate and the first reaction will not affect the overall rate.
- C → D will happen fast, which means as soon as C is produced, it will react to produce D.

Therefore, the rate of B → C, which happens slowly, is what determines the overall rate of the reaction A → D.

catalyst: a substance that speeds up a reaction by lowering the activation energy of (and therefore speeding up) the rate-limiting (slowest) step.

Use this space for summary and/or additional notes:

Factors that Affect Reaction Rates

- concentration of reactants: higher concentration means more frequent collisions = faster rate. (Only applies to molecules involved in the rate-determining step.) For gases, higher pressure = higher concentration.
- surface area of reactants: more surface area means higher probability of a collision = faster rate.
- temperature: higher temperature = faster because faster-moving molecules collide more often, and because faster-moving molecules have more kinetic energy to overcome the activation energy.
- nature of the reactants: weak bonds are easier to break than strong bonds. Reactions involving dissolved ions are very fast, because bonds are already broken.
- catalysts: catalysts *speed up reactions* in any of several ways:
  - bring molecules into the correct orientation for an effective collision (equivalent to increasing the concentration and/or surface area)
  - assist in breaking of bonds in the reactant(s) and/or formation of bonds in the products (equivalent to changing the nature of the reactants and/or lowering the activation energy)

  Catalysts are not reactants; they are not consumed by the reaction.

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Homework Problems

Consider the following decomposition reaction:

$$2\ N_2O_5 \rightarrow 2\ N_2 + 5\ O_2$$

This reaction happens in three steps:

1. $2\ N_2O_5 + 2\ H_2O \rightarrow 4\ HNO_3$ fast
2. $2\ HNO_3 \rightarrow N_2 + 3\ O_2 + H_2$ slow
3. $2\ H_2 + O_2 \rightarrow 2\ H_2O$ very fast

Answer the following questions:

1. Which compounds are intermediates in this reaction?

2. If you wanted to speed up the overall reaction, which of the three steps would you try to speed up? Explain why, and give an example of how you might do this.

Use this space for summary and/or additional notes: