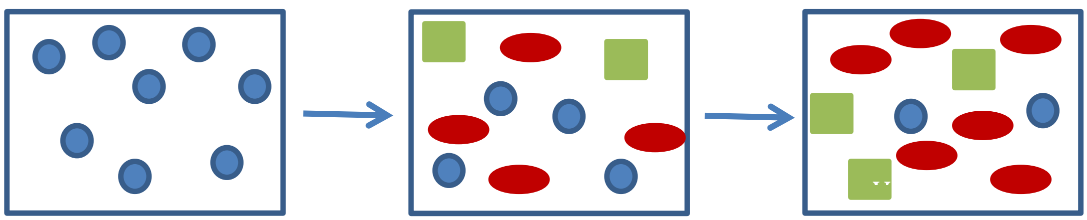
Kinetics: Rate of Chemical Reactions

The diagram below depicts the progress of a reaction. Each shape and color represents a different substance. The three boxes represent the concentrations of each substance as the indicated time elapses. Refer to the diagram to answer questions 1 – 4.



Time = 0 seconds   Time = 15 seconds   Time = 30 seconds

1. Question: Select all images that represent reactants. There may be more than one reactant.
   a. 
   b. 
   c. 

   Answer: The amount of reactant will decrease as the reaction progresses. Therefore answer b is the reactant.

2. Question: Which statement is ***true***?
   a. The rate of change of substance is twice the magnitude as the rate of change of substance .
   b. The rate of change of substance is equal to the rate of change of substance .
   c. The rate of change of substance is twice the magnitude as the rate of change of substance .
   d. The rate of change of substance is equal in magnitude but opposite in sign to the rate of change of substance .

   Answer: The rate of change is determined by the change in concentration of the substance divided by the change in time.
   Answer a. is true. In the first 15 second time interval twice as much of is formed than . Therefore Δ [ ]/15 s will be twice as big as Δ [ ]/15 s.

3. Question: If each colored image represents 0.10 M of the substance, determine the rate (in M/s) of change of substance over the first 15 seconds.

   Answer: The rate of change for substance is determined by (at 15 seconds - at 0 seconds)/15 seconds.
   Remember, each is equal to 0.10 M.
   Therefore the rate of change of = (0.4 M – 0.8 M)/15 s = –0.027 M/s

Kinetics: Comparing Rate of Change for Reactants and Products

1. Question: Consider the following reaction:

$$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$$

If, at some point during the reaction, the rate of disappearance of N_2O_5 is 0.15 M/s, what is the rate of appearance of O_2?

Answer: For the reaction given in the problem:

$$\text{Rate} = -\frac{\Delta[N_2O_5]}{2\Delta t} = \frac{\Delta[N_2O_4]}{2\Delta t} = \frac{\Delta[O_2]}{\Delta t}$$

The term "rate of disappearance of N_2O_5" is represented by: $-\frac{\Delta[N_2O_5]}{\Delta t}$. The "rate of formation of O_2" is represented by: $\frac{\Delta[O_2]}{\Delta t}$. Use only the portion of the expression that is required for this problem:

$$-\frac{\Delta[N_2O_5]}{2\Delta t} = \frac{\Delta[O_2]}{\Delta t}$$

Put in the value given for the rate of disappearance of N_2O_5. And solve for $\frac{\Delta[O_2]}{\Delta t}$.

$$\frac{0.15\ \text{M}}{2\ \text{s}} = \frac{\Delta[O_2]}{\Delta t} = 0.075\ \text{M/s}$$

2. Question: Consider the following reaction

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

At some point during the reaction, the rate of appearance of NO is 0.0100 M/s. What is the rate of disappearance of O_2 at this same point in the reaction?

Answer: For the reaction given in the problem:

$$\text{Rate} = -\frac{\Delta[NH_3]}{4\Delta t} = -\frac{\Delta[O_2]}{5\Delta t} = \frac{\Delta[NO]}{4\Delta t} = \frac{\Delta[H_2O]}{6\Delta \mathrm{t}}$$

The term "rate of appearance for NO" is represented by $\frac{\Delta[NO]}{\Delta t}$. The "rate of disappearance of O_2 is represented by $-\frac{\Delta[O_2]}{\Delta t}$.

Put in the given information for the rate of appearance of NO and solve for $-\frac{\Delta[O_2]}{\Delta t}$.

$$-\frac{\Delta[O_2]}{5\Delta t} = \frac{0.0100\ \text{M}}{4\ \text{s}}$$

$$-\frac{\Delta[O_2]}{5\Delta t} \times \frac{5}{1} = \frac{0.0100\ \text{M}}{4\ \text{s}} \times \frac{5}{1}$$

$$-\frac{\Delta[O_2]}{\Delta t} = \frac{0.0100\ \text{M} \times 5}{4\ \text{s}} = 0.0125\ \text{M/s}$$

Kinetics: The Rate Law

1. Question: The rate law of the reaction

$$2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O(g)$$

is rate = $k[H_2][NO]^2$. Which of the following statements is/are ***false***?

   a. The reaction is 3rd order overall.
   b. The reaction is 2nd order in H_2.
   c. The reaction is 2nd order in NO.
   d. The reaction is 1st order in H_2O.

   Answer: The power to which the concentration is raised in the rate law determines the order. Therefore, the reaction is first-order in H_2 and 2nd order in NO. This means that b is false and c is true. The overall order is determined by adding the two powers together. Since, 1 + 2 = 3, the reaction is third-order, overall. Also, d is false because products are not included in the rate law.

2. Question: The rate law of the reaction

$$2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O(g)$$

is rate = $k[H_2][NO]^2$. What will be the effect on the rate of the reaction if the concentrations of both H_2 and NO are doubled?

   Answer: One way to determine the effect of concentration changes on the rate is to do two separate calculations. In the second calculations use twice the concentration of the two reactants as used in the first calculation. In the example below, 1 M concentrations were used in the first calculation and 2 M was used for the second calculation.

   Rate = $k(1\text{ M})(1\text{ M})^2 = 1\text{ M}^3k$ Rate = $k(2\text{ M})\,(2\text{ M})^2 = 8\text{ M}^3k$

   Therefore as the concentrations of each substance are doubled, the rate is increased by a factor of eight (8).