REACTION RATE

REACTION RATE

- Fast / Slow Reactions
  - $AgNO_3 + NaCl$
  - $Mg + H_2O$
    - add phenolphthalein

REACTION RATE

rate of reaction - how quickly reactants disappear to form products

Chemical reactions indicate the overall change that is observed. Most reactions take place through a series of steps which are usually too quick to observe.

REACTION RATE

Factors Affecting Reaction Rates

1. Chemical nature of reactants
2. Surface area
3. Reactant concentration
4. Temperature
5. Presence of a catalyst

REACTION RATE

1. Chemical Nature

Precious metals were the first to be discovered because they were not very reactive.

Alkali metals are only found in nature in a compound.

What part of Gr. 11 chemistry does this relate to?

REACTION RATE

2. Surface Area

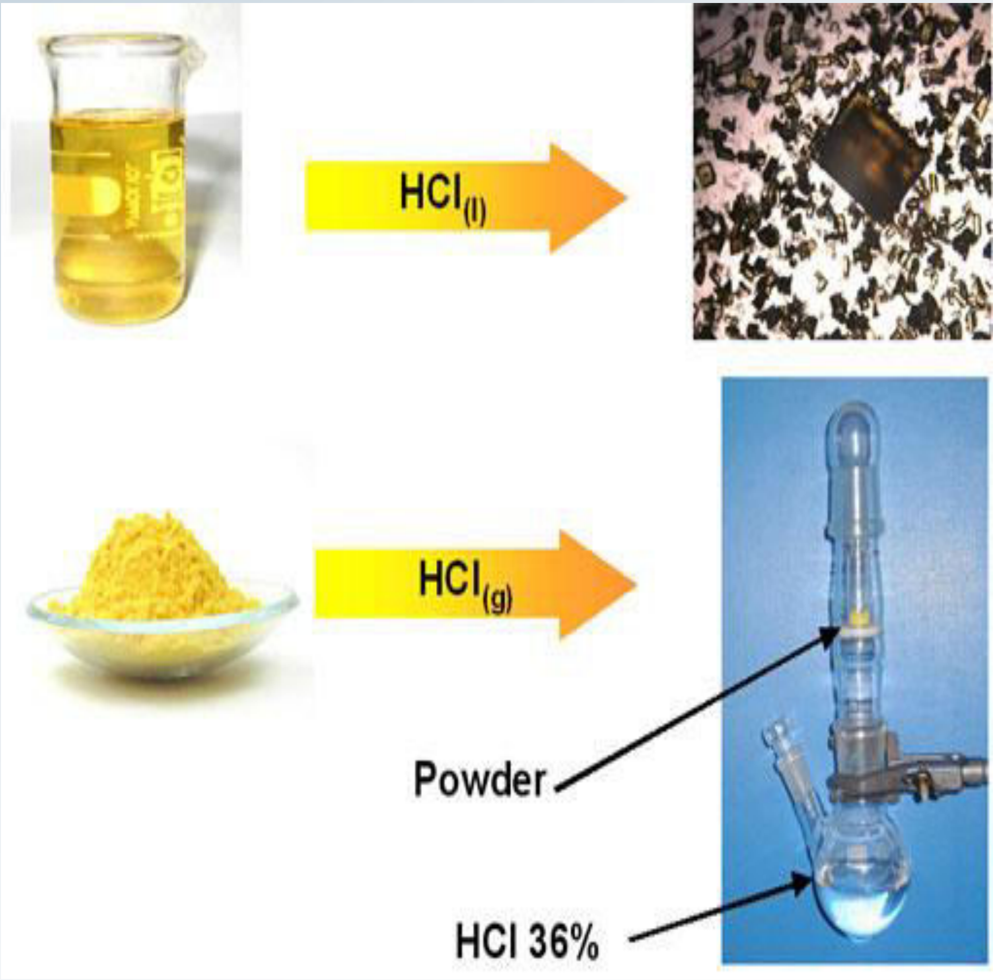
↑ surface area = ↑ reaction rate

The more available the reactants are to meet each other, the greater than chance for a reaction to occur.

REACTION RATE

2. Surface Area

A. Heterogeneous Reaction
- reactants are in different phases or states
- reaction will occur at the interface between phases or states
- So the area of contact between the phases (i.e. surface area) determines the rate of reaction



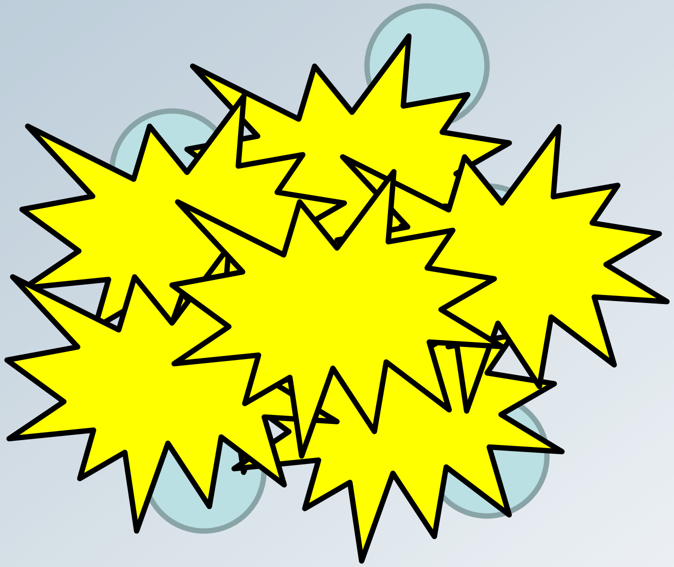
B. Homogeneous Reaction
- reactants are all in the same phase

REACTION RATE

3. Concentration

↑ concentration = ↑ reaction rate

More chemicals results in more particles which can participate in a reaction.



CONCENTRATED

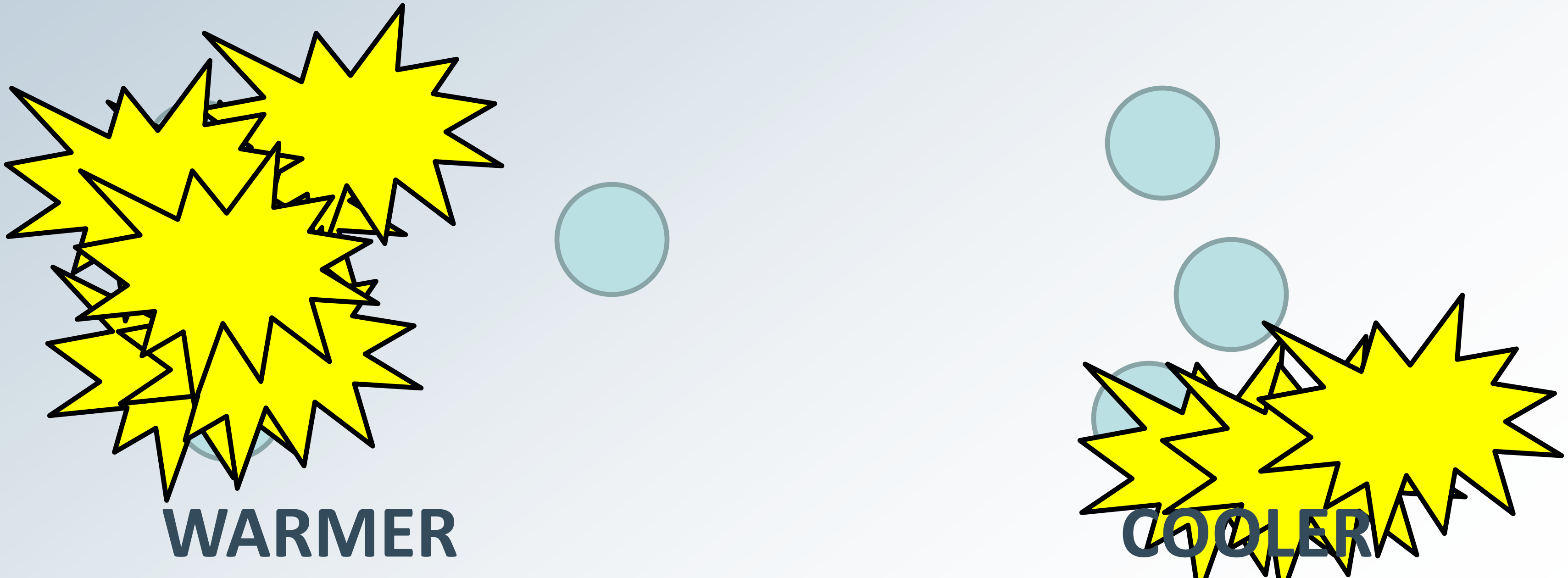
DILUTE

REACTION RATE

4. Temperature

$\uparrow$ temperature = $\uparrow$ reaction rate

Increased temperature is due to increased particle motion. The greater the motion of a particle, the greater the chance it will encounter another reactant.

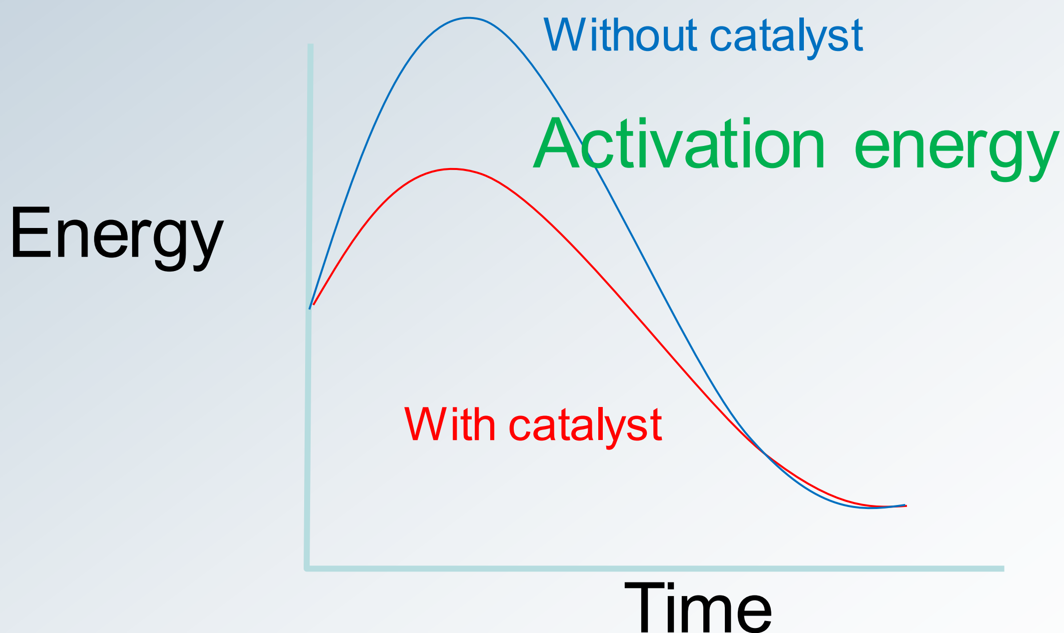


REACTION RATE

5. Catalysts

catalyst - a compound that increases the rate of a chemical reaction without being consumed in the reaction

The presence of a catalyst allows a reaction to occur faster.



Lowers the amount of energy that is required for the reaction to occur (called "**activation energy**")

REACTION RATE

RATE EQUATION:

The most common method of changing a reaction rate is through changing the ________ of reactants.

Mathematically:

$$\textbf{rate} = \frac{\Delta\textbf{concentration}}{\Delta\textbf{time}}$$

Units?

mol / s

mol / L • s = M / s

REACTION RATE

RATE EQUATION:

$$A + 3B \rightarrow 2D$$

$$\text{rate} = \frac{-\Delta[A]}{\Delta t} = \frac{-\Delta[B]}{3\Delta t} = \frac{\Delta[D]}{2\Delta t}$$

Stoichiometrically, reactant B is consumed 3 times as fast as reactant A

Product D is formed 2 times as fast as reactant A is consumed

REACTION RATE

Example:

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$$

If the rate of formation of N_2 was 0.27 mol L^{-1} s^{-1},

a) At what rate was water being formed?

b) At what rate was ammonia being consumed?

a) $\Delta[H_2O] = 6/2\ \Delta[N_2]$

$\Delta[H_2O] = 3\ \Delta[N_2]$

$\Delta[H_2O] = 3\ (0.27 \text{ mol L}^{-1} \text{ s}^{-1})$

$\Delta[H_2O] = 0.81 \text{ mol L}^{-1} \text{ s}^{-1}$

b) Since 4 moles of NH_3 are consumed for every 2 moles of N_2 formed:

$= 2 \times (0.27 \text{ mol L}^{-1} \text{ s}^{-1})$

$= 0.54 \text{ mol L}^{-1} \text{ s}^{-1}$

REACTION RATE

RATE LAW EQUATION:

$$\text{rate} = \frac{\Delta\text{concentration}}{\Delta\text{time}}$$

For a reaction:

$$A + B \rightarrow C + D$$

$$\text{rate} \propto [A]^m[B]^n$$

$$\text{rate} = k[A]^m[B]^n$$

REACTION RATE

RATE LAW EQUATION:

$$rate = k[A]^x[B]^y$$

x & **y** - values determined by experiment

k - the rate constant

- determined by the reaction and the conditions the experiment was conducted in

REACTION RATE

RATE LAW EQUATION:

EXAMPLE 1

Write out the rate law equation for:

$$H_2SeO_3 + 6\ I^- + 4\ H^+ \rightarrow Se + 2\ I_3^- + 3\ H_2O$$

$$\textbf{rate} = k[H_2SeO_3]^x[I^-]^y[H^+]^z$$

REACTION RATE

RATE LAW EQUATION:

EXAMPLE 1 $\text{rate} = k[H_2SeO_3]^x[I^-]^y[H^+]^z$

At 0°C, $k = 5.0 \times 10^5$

$x = 1, y = 3, z = 2$

Rewrite the rate law.

What is the unit for rate?

What are the units for k in this case?

$L^5 \cdot mol^{-5} \cdot s^{-1}$

REACTION RATE

RATE LAW EQUATION:

EXAMPLE 1

$$\text{rate} = 5.0\text{x}10^5 L^5 mol^{-5} s^{-1} [H_2SeO_3]^1 [I^-]^3 [H^+]^2$$

Determine the rate of reaction at 0°C given:

$[H_2SeO_3] = 2.0\text{x}10^{-2}$ M

$[I^-] = 2.0\text{x}10^{-3}$ M

$[H^+] = 1.0\text{x}10^{-3}$ M

REACTION RATE

RATE LAW EQUATION:

EXAMPLE 1

$$\text{rate} = 5.0\text{x}10^5 L^5 mol^{-5} s^{-1}[2.0\text{x}10^{-2}M]^1[2.0\text{x}10^{-3}M]^3[1.0\text{x}10^{-3}M]^2$$

$$= 5.0\text{x}10^5 L^5 mol^{-5} s^{-1}[2.0\text{x}10^{-2} mol\ L^{-1}]\text{x}[8.0\text{x}10^{-9} mol^3\ L^{-3}]$$

$$\text{x}[1.0\text{x}10^{-6} mol^2\ L^{-2}]$$

$$= 8.0\text{x}10^{-11} mol\ L^{-1}\ S^{-1}$$

$$= 8.0\text{x}10^{-11}\ mol/L\cdot s$$

Therefore the rate of the reaction at 0°C is $8.0\text{x}10^{-11}$ mol/L·s

REACTION RATE

RATE LAW EQUATION:

EXAMPLE 2

The rate law for the decomposition of HI is:

$$\text{rate} = k[HI]^2 = 2.5\text{x}10^{-4} \text{ mol L}^{-1}\text{s}^{-1}$$

When [HI] is 0.0558 M, what is the value of the rate constant?

REACTION RATE

RATE LAW EQUATION:

EXAMPLE 2

$$\text{rate} = k[HI]^2 = 2.5\times10^{-4}\ \text{mol L}^{-1}\text{s}^{-1}$$

$$\text{rate} = k[HI]^2$$

$$\frac{(2.5\times10^{-4}\ \text{mol L}^{-1}\text{s}^{-1})}{(0.0558\ \text{mol L}^{-1})^2} = k$$

$$8.0\times 10^{-2}\ \text{mol}^{-1}\ \text{L s}^{-1} = k$$

$$8.0\times 10^{-2}\ \text{L mol}^{-1}\ \text{s}^{-1} = k$$

Therefore the value of the rate constant is $8.0\times 10^{-2}\ \text{L mol}^{-1}\ \text{s}^{-1}$

REACTION RATE

RATE LAW EXPONENTS:

$$rate = k[A]^x[B]^y$$

Exponents of the rate law are <u>NOT</u> related to the coefficients of the balanced chemical reaction. ☹ They may be by coincidence, but do not make this assumption.

REACTION RATE

RATE LAW EXPONENTS:

The exponents are related to the order of the reaction.

order of a reaction - experimentally determined by changing one [reactant] at a time and looking at how the reaction rate changes.

REACTION RATE

RATE LAW EXPONENTS:

Given $[X]^1$:

- first order reaction
- when [X] is doubled, the reaction rate is doubled (multiplying by 2^1)
- when [X] is tripled, the reaction rate is tripled (multiplying by 3^1)
- when [X] is halved, the reaction rate is halved (multiplying by $½^1$)

REACTION RATE

RATE LAW EXPONENTS:

Given $[Y]^2$:

- second order reaction
- when [Y] is doubled, the rate increases by four (2^2)
- when [Y] is tripled, the rate increases by 9 (3^2)
- when [Y] is halved, the rate decreased by 4 $(\frac{1}{2}^2)$

REACTION RATE

RATE LAW EXPONENTS:

Given $[Z]^0$:

- zeroth order reaction
- increasing or decreasing [Z] will result in no change of reaction rate (multiplying by $x^0 = 1$)

REACTION RATE

REACTION ORDER:

The order of a reaction is the <u>sum of the rate law exponents.</u>

What is the order of the reaction which has the rate law of rate = $k[X]^2[Y]^2$ and reaction of $X + Y + Z \rightarrow A + B$? **4**

What are the units of k for this reaction?

$L^3\ mol^{-3}\ s^{-1}$

REACTION RATE

REACTION ORDER:

Identify the order of the reaction and units of k:

a) rate = k[N] **1^{st} order, s^{-1}**

b) rate = $k[D]^{1/2}[E]^2$ **2.5 order, $L^{1.5}$ $mol^{-1.5}$ s^{-1}**

c) rate = $k[J]^{-3}[L]^2$ **-1 order, mol^2 L^{-2} s^{-1}**