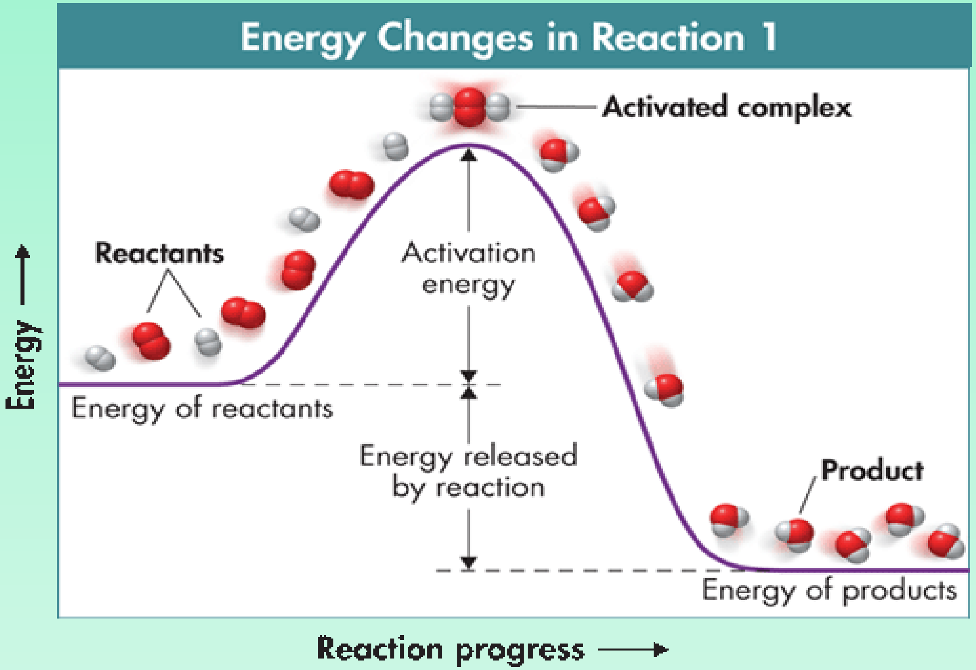


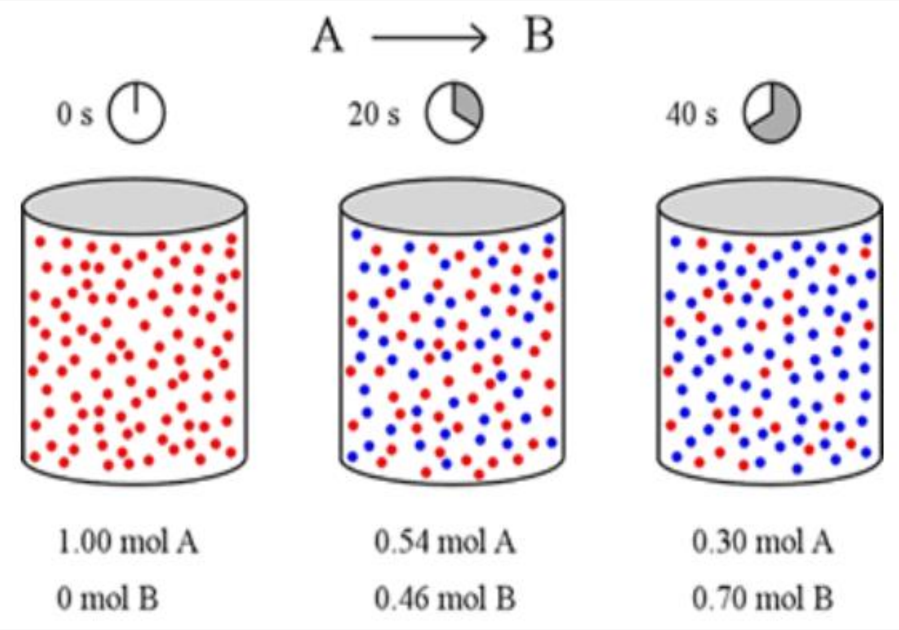
Chapter 7B

Chemical Reactions

Energy Changes in Reactions

Reaction Rates

Equilibrium



Chemical Reactions 2

Focus Points

- Label and identify components of energy relations in chemical reactions (activation energy, endothermic and exothermic energy flow).

- Recognize and analyze reaction rate and factors that affect it (temperature, surface area, pressure, concentration, stirring, catalysts).
- Distinguish physical and chemical equilibrium in terms of forward and reverse changes.
- Explain how equilibrium is shifted when changes in temperature, pressure, or concentration are introduced in a system.

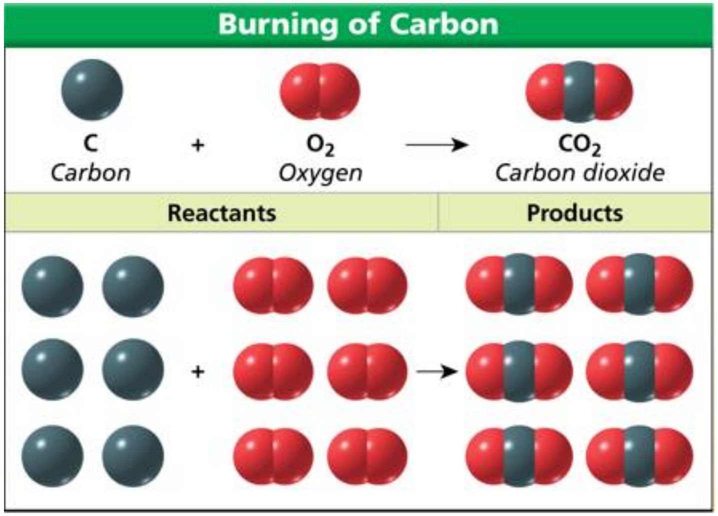
Describe Evidence of a Chemical Change.

For the chemical reaction shown:

1) Label reactants, products, "yields".

2) State the type of reaction.

3) Count the number of atoms (reactant and products) and say why this is relevant?



Describe Evidence of a Chemical Change.

For the chemical reaction shown:

1) Label reactants, products, "yields".

Reactants ($C + O_2$) → Products (CO_2)

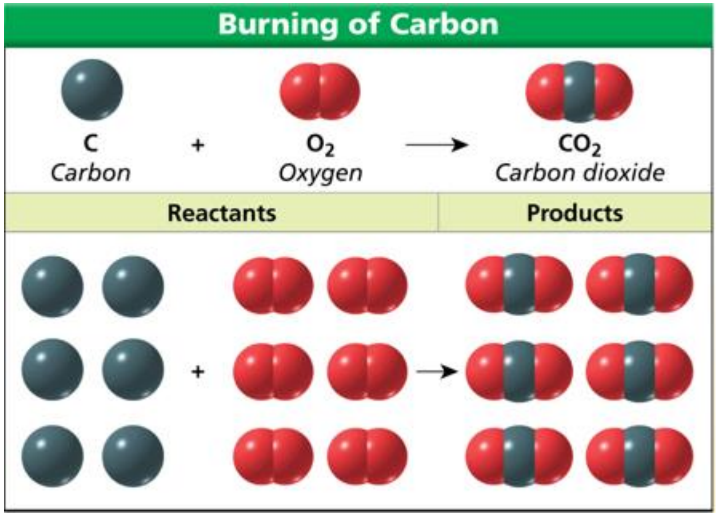
"→" means yields/produces/forms

2) State the type of reaction.

Synthesis or combination

3) Count the number of atoms (reactant and products) and say why this is relevant?

Law of Conservation of Mass



Determine the type of chemical reaction and then balance the following chemical equations.

a. $H_2O_2 \rightarrow H_2O + O_2$

b. $Mg + HCl \rightarrow H_2 + MgCl_2$

Determine the type of chemical reaction and then balance the following chemical equations.

WARM-UP

a. $H_2O_2 \rightarrow H_2O + O_2$

Decomposition

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

b. $Mg + HCl \rightarrow H_2 + MgCl_2$

Single Replacement

$$Mg + 2HCl \rightarrow H_2 + MgCl_2$$

Notice, coefficients are used to balance the equations (do not change formulas).

Ethylene, C_2H_4, burns in the presence of oxygen to produce carbon dioxide and water vapor. What type of chemical reaction is this? Write a balanced equation for this reaction.

1. Which of these statements best describes a double-replacement reaction?
    a. Two different compounds exchange positive ions and form two new compounds.
    b. An element takes the place of another element in a compound.
    c. One compound breaks down into two or more simpler substances.
    d. Two or more substances react to form a single substance.

Ethylene, C_2H_4, burns in the presence of oxygen to produce carbon dioxide and water vapor. What type of chemical reaction is this? Write a balanced equation for this reaction.

Combustion

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2\,H_2O$$

1. Which of these statements best describes a double-replacement reaction?
   a. **Two different compounds exchange positive ions and form two new compounds.**
   b. An element takes the place of another element in a compound.
   c. One compound breaks down into two or more simpler substances.
   d. Two or more substances react to form a single substance.

Chemical Change

WARM-UP

Write a balanced equation for the production of hydrogen chloride from hydrogen and chlorine gases.

Which of the following statements about oxidation-reduction reactions is true?

a. Oxidation-reduction reactions always involve a transfer of protons between atoms.
b. Oxidation is the process in which electrons are gained.
c. Oxidation and reduction always occur together.
d. Oxidation-reduction reactions always involve oxygen as one of the reactants.

Chemical Change

WARM-UP

Write a balanced equation for the production of hydrogen chloride from hydrogen and chlorine gases.

$$H_2^0 + Cl_2^0 \rightarrow 2H^{+1}Cl^{-1}$$

- *hydrogen (H_2) and chlorine (Cl_2) gases are both diatomic ("HOFBrINCl")*
- *This is a synthesis REDOX reaction … notice the change in the charges of H and Cl from left to right.*

Which of the following statements about oxidation-reduction reactions is true?

a. Oxidation-reduction reactions always involve a transfer of protons between atoms.

b. Oxidation is the process in which electrons are gained.

c. Oxidation and reduction always occur together.

d. Oxidation-reduction reactions always involve oxygen as one of the reactants.

Energy Changes in Reactions

All chemical reactions involve **heat** and/or **light**, which are forms of **energy**.

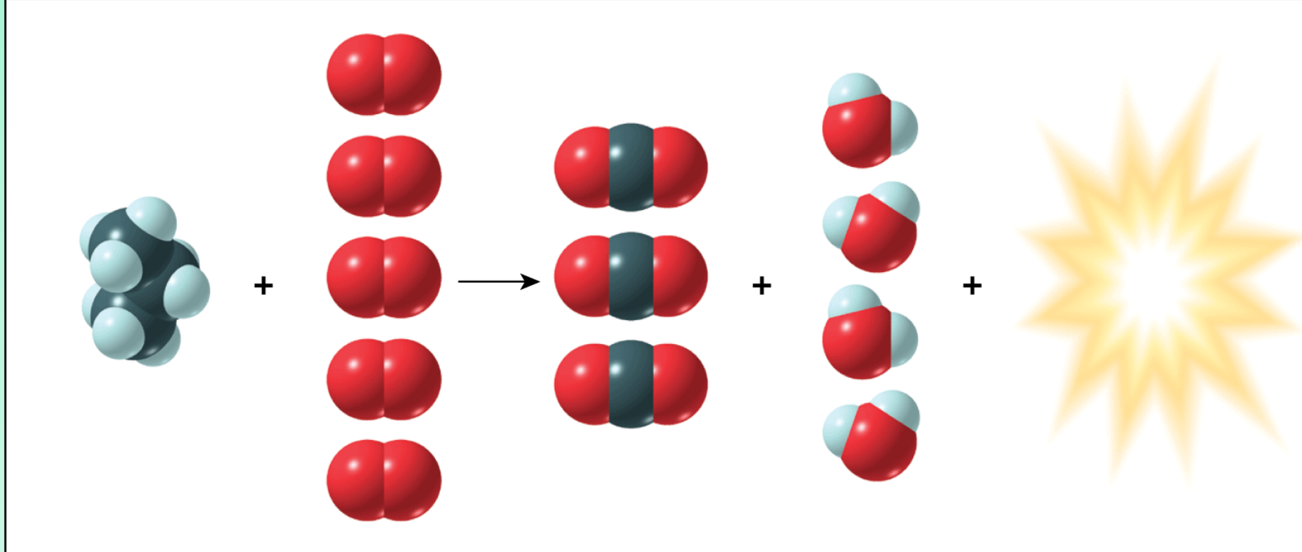
Chemical energy is stored in the chemical bonds of a substance.

Energy changes in chemical reactions are determined by changes that occur in chemical bonding.

Energy Changes in Reactions

Chemical reactions involve the **breaking of chemical bonds** in the **reactants** (propane and oxygen) and the **formation of new chemical bonds** in the **products** (carbon dioxide and water).

Propane Combustion



C_3H_8 *propane*	+	$5O_2$ *oxygen*	$\longrightarrow$	$3CO_2$ *carbon dioxide*	+	$4H_2O$ *water*	+	Heat
8 C–H, 2 C–C *bonds broken*		5 O=O *bonds broken*	$\longrightarrow$	6 C=O *bonds formed*		8 O–H *bonds formed*		

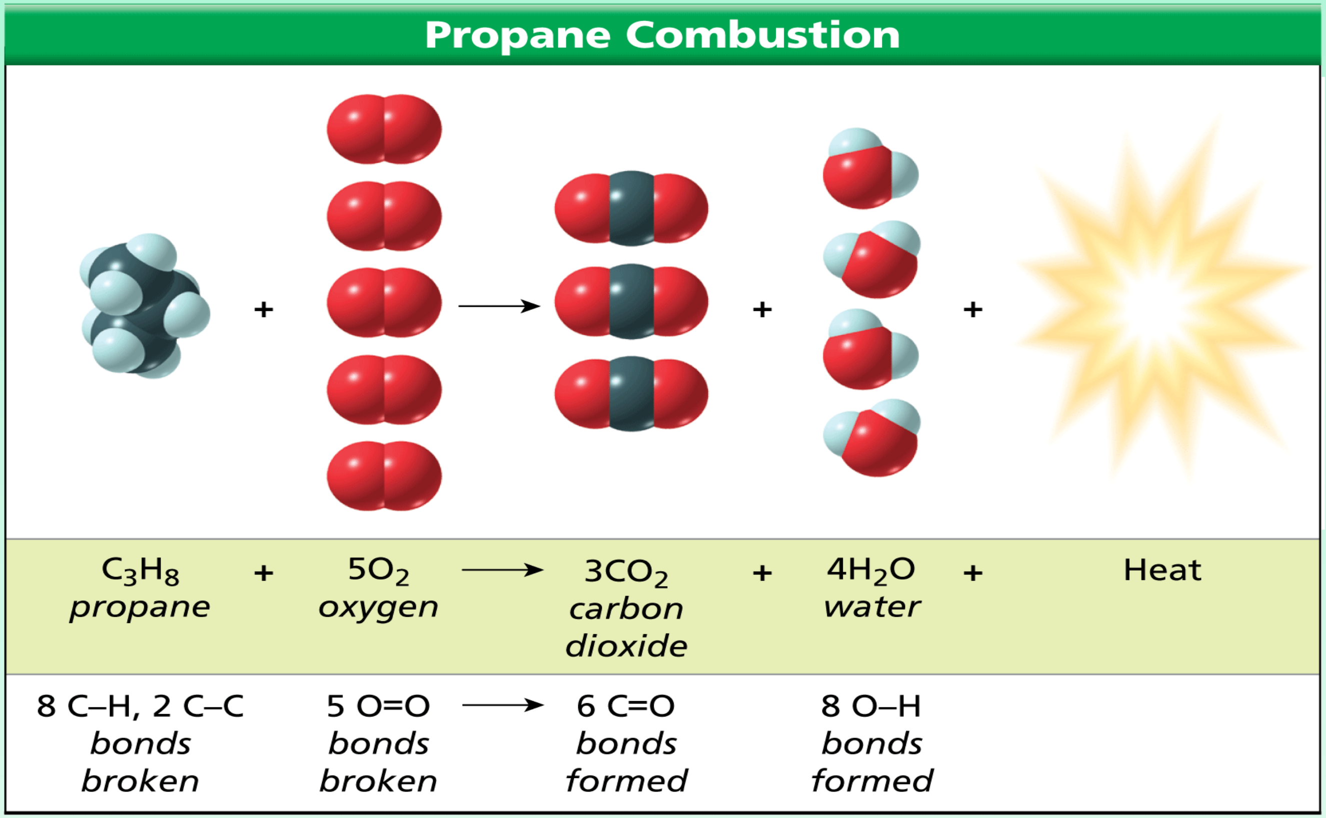
Energy Changes in Reactions

The breaking of reactant bonds and formation of new bonds involves

Activation Energy

the minimum energy needed for a reaction to begin.

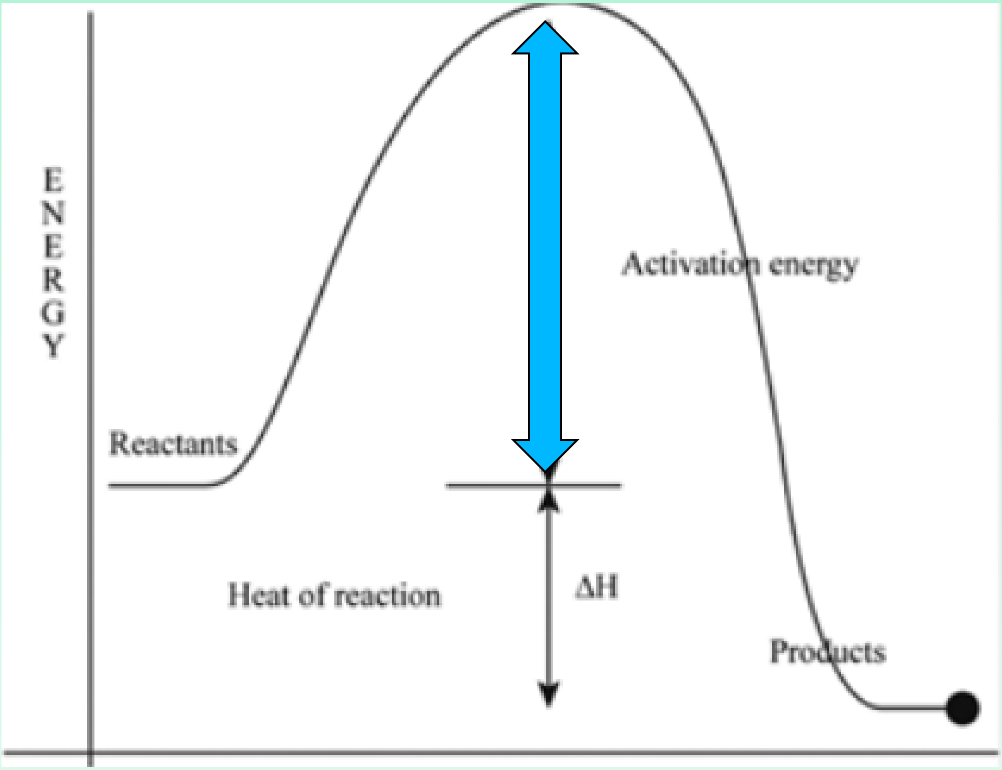
In the case of grilling with propane, a spark provides enough energy to break the bonds of reacting molecules and get the reaction started.



Activation Energy

Enzymes, heat, or electricity commonly yield the activation energy needed in chemical reactions.

In many chemical reactions, a catalyst is added to the reaction mixture. A **catalyst** is a substance that speeds up the reaction but is not used up (or part of) in the reaction.



Energy Changes in Reactions

All Chemical Reactions require Activation Energy:

the minimum energy needed for a reaction to begin.

Activation Energy Demo → *Add sulfuric acid to sugar [1:05]*

http://somup.com/cF6vqVnhdn

$$C_{12}H_{22}O_{11} \rightarrow 12C_{(s)} + 11H_2O_{(g)}$$

Sulfuric acid is a catalyst (not part of the reaction)

Stirring Provided "Activation Energy"

Exothermic Reactions

Chemical reactions represent changes in bonding & energy

As with propane, w*hat happens to energy in the reaction below?*

$2H_{2\ (g)}$	+	$O_{2\ (g)}$	→	$2H_2O_{\ (g)}$	**+**	**energy**
Hydrogen		Oxygen		diHydrogen monOxide		

Is energy a reactant or product?

Exothermic Reactions

As with propane, w*hat happens to energy in the reaction below?*

$$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)} + \textbf{energy}$$

Hydrogen   Oxygen   diHydrogen monOxide

Notice that energy is a ***product****.*

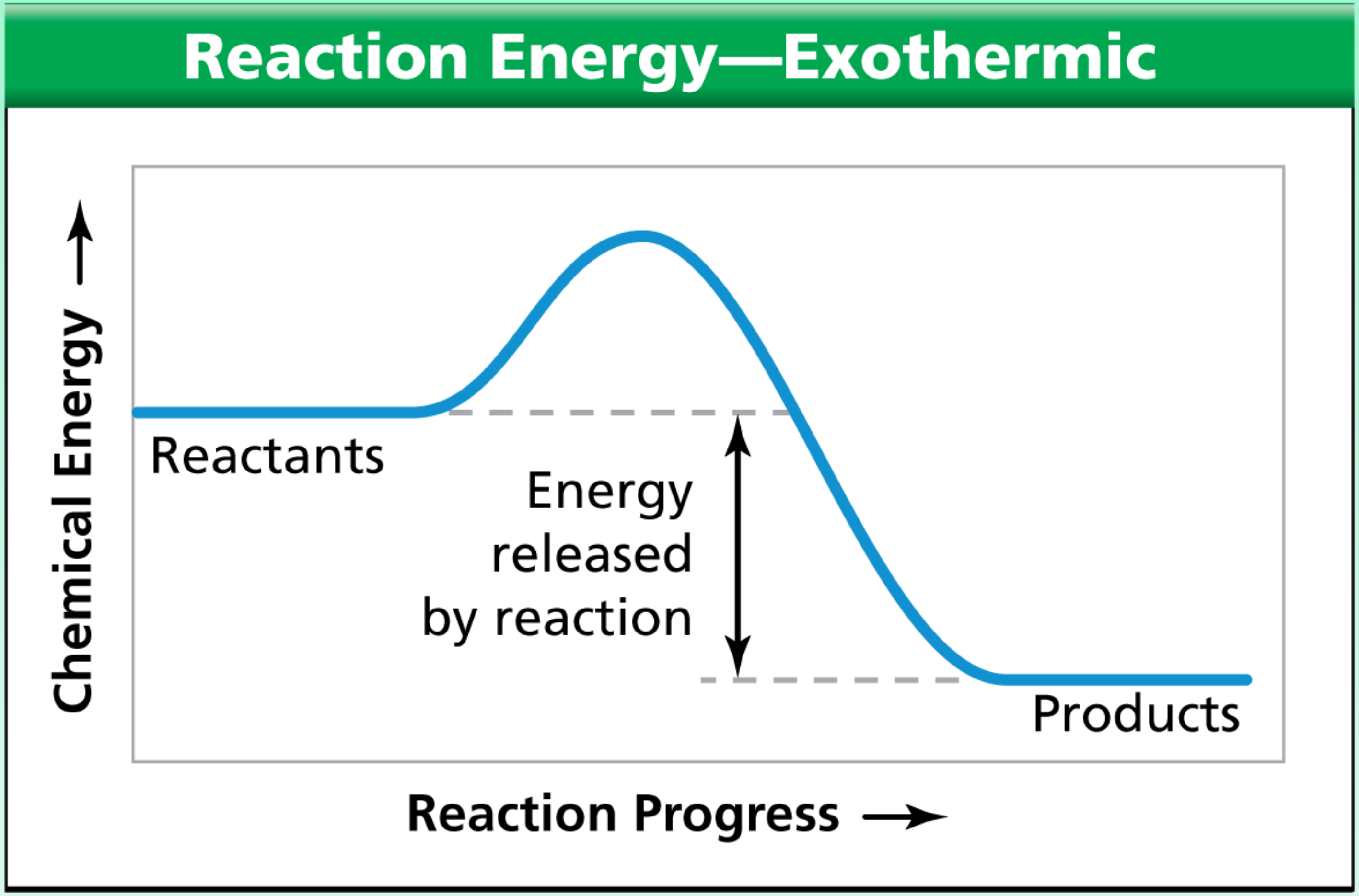
A chemical reaction that releases energy to its surroundings is called an **exothermic reaction.**

In exothermic reactions, the energy released as the products form is greater than the energy required to break the bonds in the reactants.

https://screencast-o-matic.com/watch/cFe0DXD4w2 Flaming Bubbles (0:38)

Exothermic Reactions

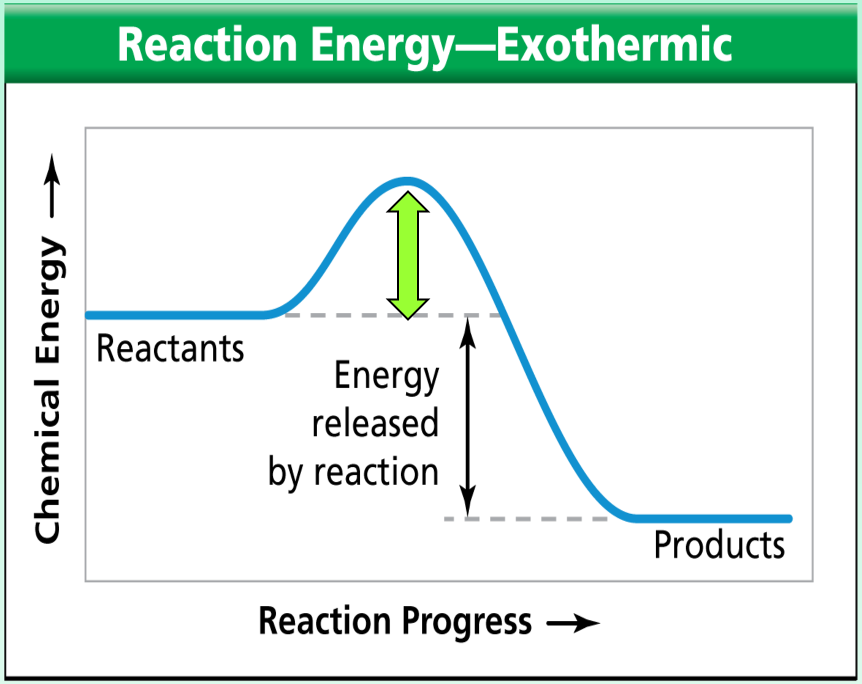
In exothermic reactions, the chemical energy of the reactants is greater than the chemical energy of the products … "**downhill**".



Exothermic Reactions

The chemical energy reaches a peak (**activation energy**) before the reactants change into products.

- This peak represents the amount of energy required to break the chemical bonds of the reactants.
- Particles must collide with enough energy to break these bonds, or the reaction will not occur.



Endothermic Reactions

Chemical reactions represent changes in bonding & energy

What happens to energy in the reaction below?

$2\ KClO_{3\ (s)}$ **+** **energy** → $2\ KCl_{\ (s)}$ + $3\ O_{2\ (g)}$

Potassium Chlorate   Potassium Chloride   Oxygen

Is energy a reactant or product?

Endothermic Reactions

Endothermic Reactions → *What happens to energy?*

$2\ KClO_{3\ (s)}$ + **energy** → $2\ KCl_{\ (s)}$ + $3\ O_{2\ (g)}$

Potassium Chlorate → Potassium Chloride + Oxygen

Energy is commonly added in the form of heat & electricity

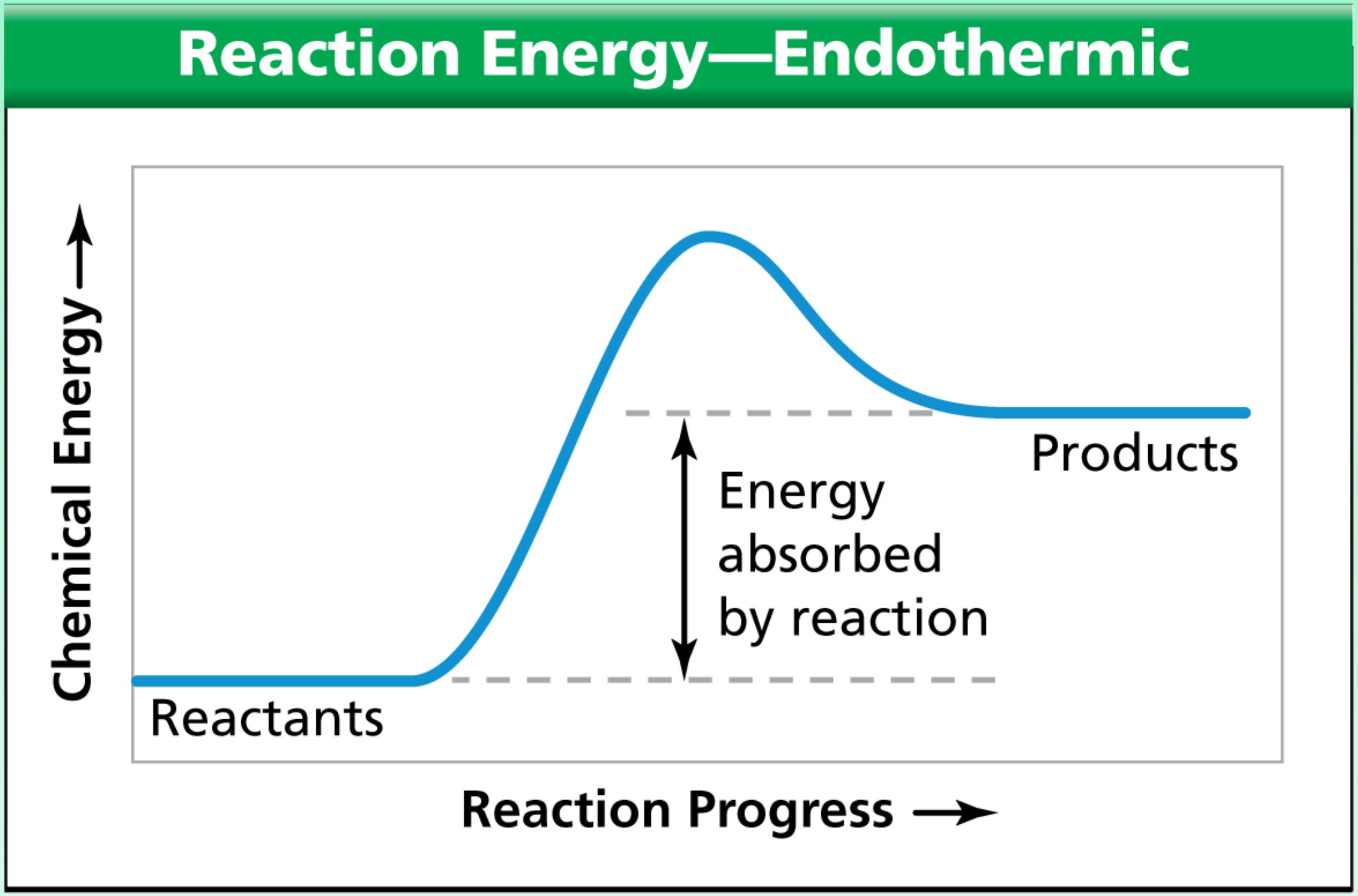
*Notice that energy is a **reactant**.*

A chemical reaction that absorbs energy from its surroundings is called an **endothermic reaction.**

In an endothermic reaction, more energy is required to break the bonds in the reactants than is released by the formation of the products.

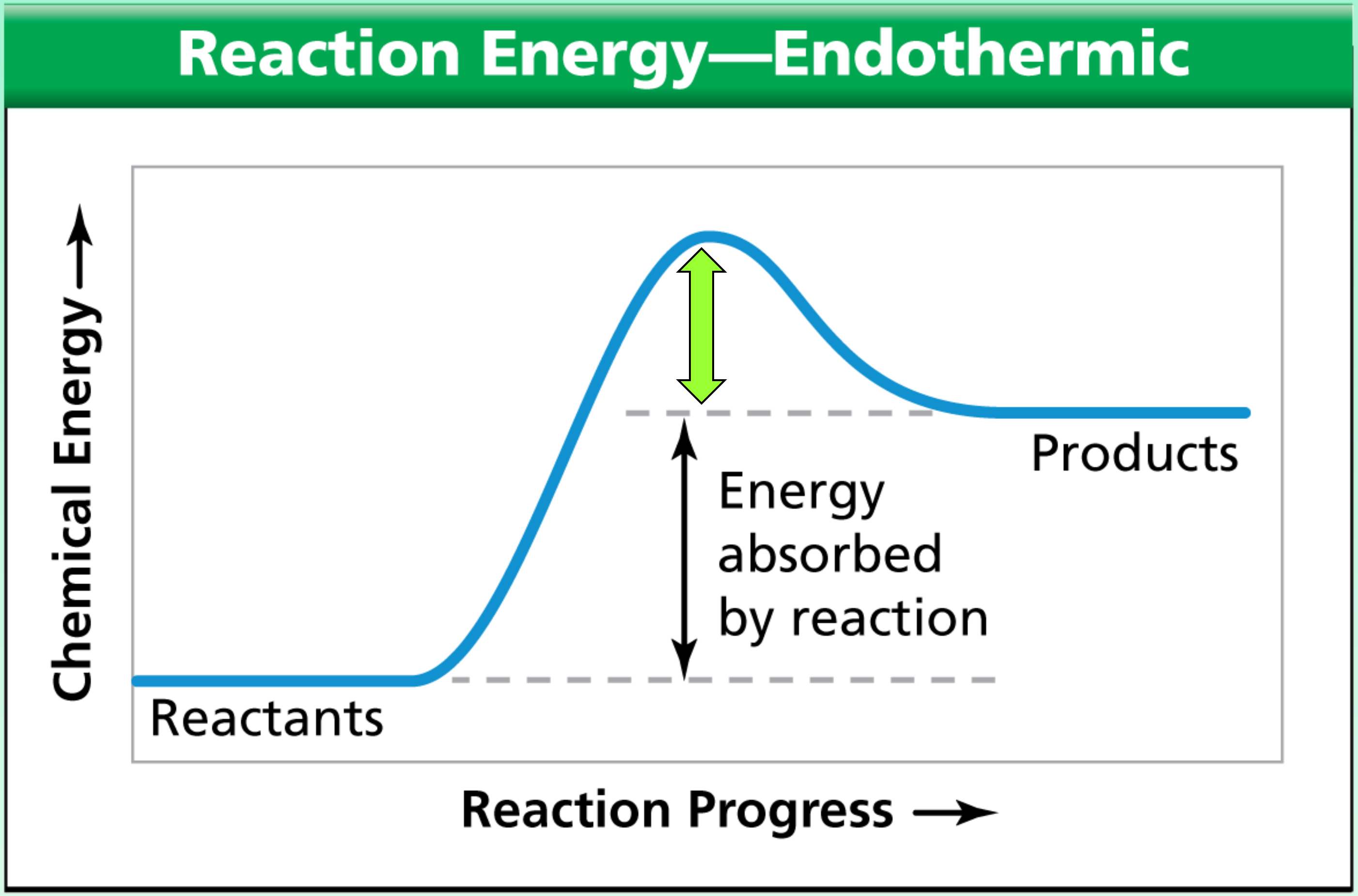
Endothermic Reactions

In an endothermic reaction, the energy of the products is greater than the energy of the reactants … "**uphill**".



Endothermic Reactions

The chemical energy reaches a peak (**activation energy**) before the reactants change into products.



Identifying Reaction Energy

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + 136.6\ kcal$

This reaction is:

O exothermic

O endothermic

Heat is a:

O reactant

O product

The energy of the ___ is greater than the energy of the ___.

$2HgO(s) + 43.4\ kcal \rightarrow 2Hg(l) + O_2(g)$

This reaction is:

O exothermic

O endothermic

Heat is a:

O reactant

O product

The energy of the ___ is greater than the energy of the ___.

Identifying Reaction Energy

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) +$ **136.6 kcal**

This reaction is:

- exothermic (heat is released)

Heat is a:

- product (right side)

The energy of the <u>reactants</u> is greater than the energy of the <u>products</u>. Therefore, energy is released or given off.

$2HgO(s) +$ **43.4 kcal** $\rightarrow 2Hg(l) + O_2(g)$

This reaction is:

- Endothermic (heat is absorbed)

Heat is a:

- Reactant (left side)

The energy of the <u>products</u> is greater than the energy of the <u>reactants</u>. Therefore, energy is taken in or absorbed.

THINK ABOUT IT

Diamond and graphite are both made of pure carbon yet have very different properties.

Diamond spontaneously reacts to form graphite. Theoretically, graphite can be made into diamond as well.

Why is it NOT common to see diamond jewelry changing into graphite: C(diamond) → C(graphite) ?

Reaction Rate

- **Reaction rate is how fast reactants are converted into products.**
- *Reaction rate tells how the concentration of reactant or product change with time.*
- Reaction rates depend on "activation energy".

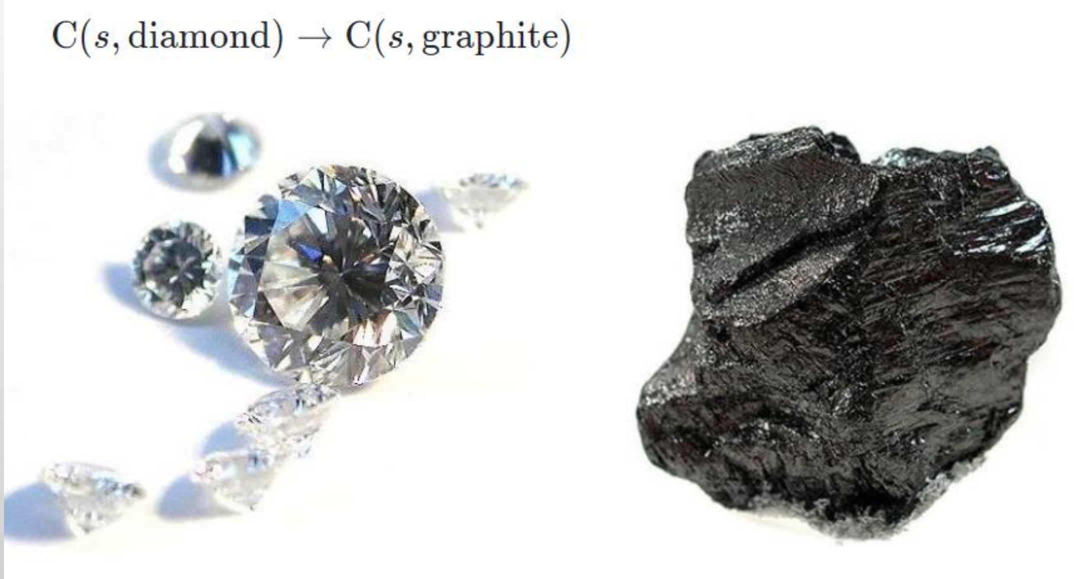
Reaction rate affects how chemical and physical reactions proceed.

Reaction Rates

Any change that happens over a period of time can be expressed as a rate.

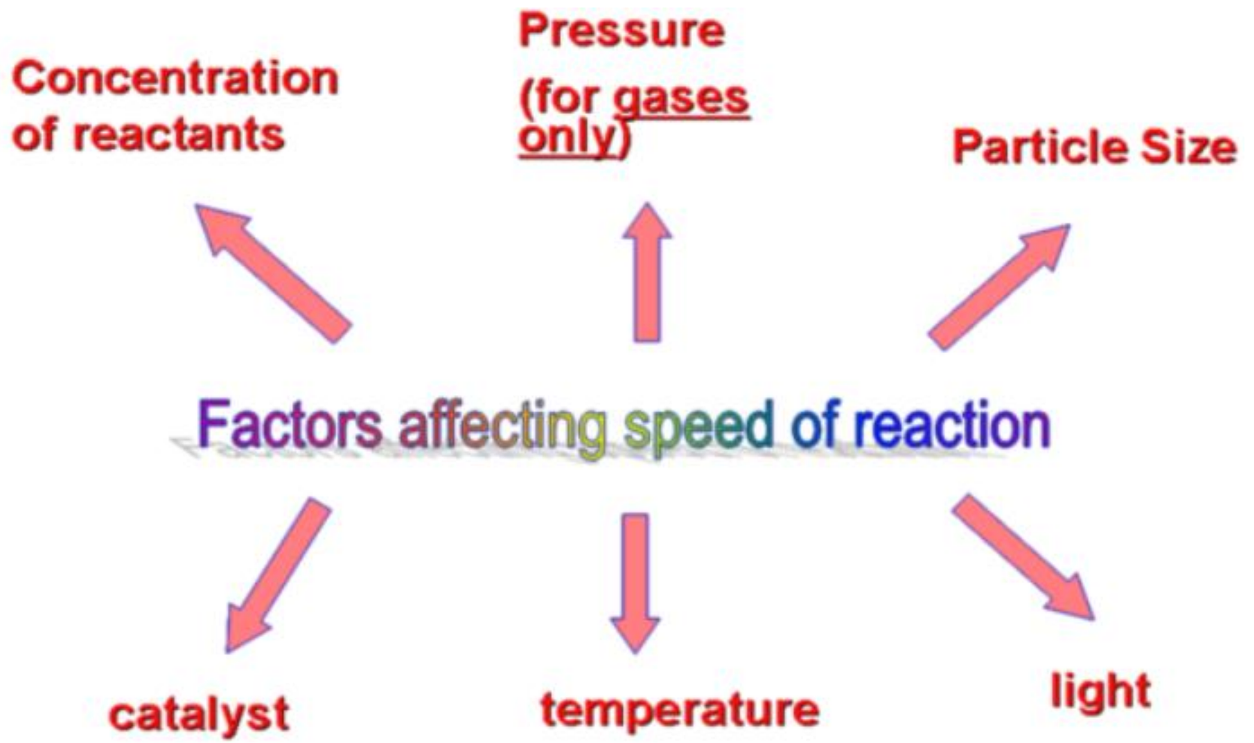
Theoretically, diamond can turn to graphite, but the reaction rate is 0.

Reaction rate does NOT indicate the extent of a reaction (how much product or reactant exists at equilibrium).



Collisions & Reaction Rate

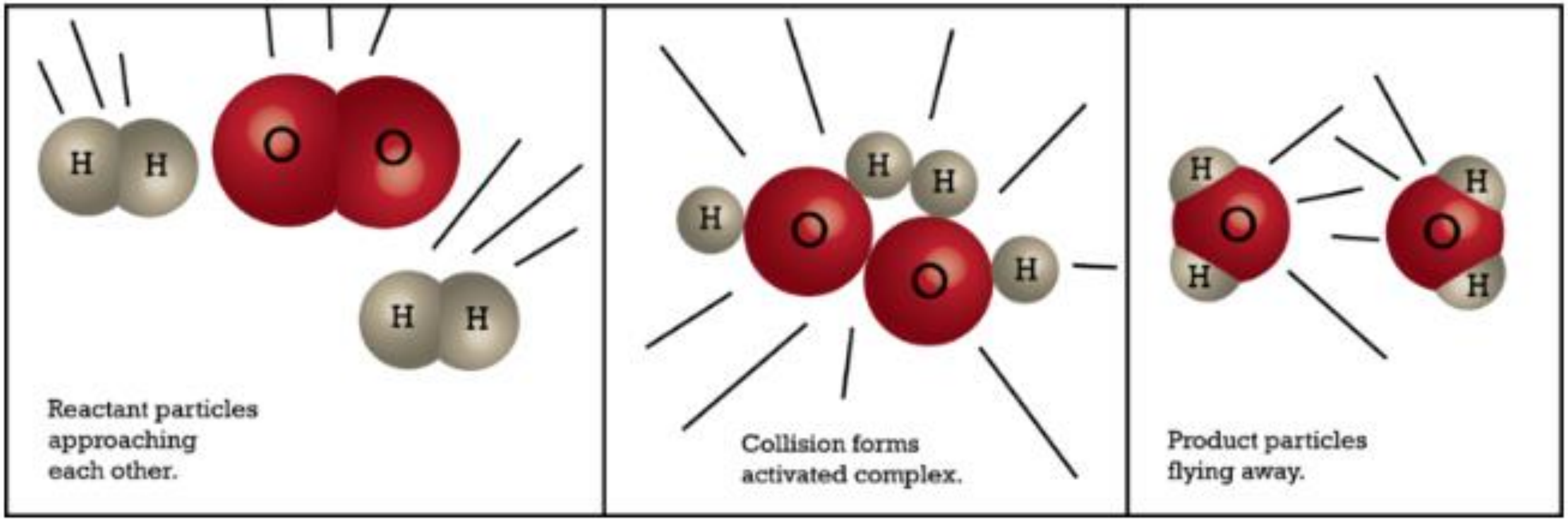
What affects the rate at which a reaction proceeds?



What is involved in all of these factors?

Collisions & Reaction Rate

Reactants must collide to form products.



Reaction rate depends on the collisions.

Collisions & Reaction Rate

What parameters are important regarding collisions?

- Consider trying to score a goal in soccer … how does the player score a goal?

- Consider a boxing match … if there is no knockout, how do judges determine the winner?

- Consider the carnival game of using a spray gun to hit a target in order to fill a balloon (so it pops).

Collision Theory

Every reaction begins with collisions of molecules or particles

TWO Important parameters:

1. The **number** of collisions

   Balloons stay "filled" because air molecules constantly collide against the sides of the balloon. Without sufficient collisions, the balloon will deflate.

2. The **effectiveness** of the collisions

   - Sufficient **energy**

     one may hit a billiard cue ball into another ball, but if the energy is insufficient, the ball will not go in the desired pocket.

   - Proper **orientation** of reactant particles

     One may have the correct key to the correct lock, but the key must be inserted right side up into the lock hole or it won't work.

Real Life Application of Collision Theory - BOXING

Boxers are scored by the "collision theory".

Each time a boxer "hits" their opponent (**NUMBER** of collisions) **effectively** (with sufficient force / **energy** & **orientation**) they score a point.

A boxer can hit their opponent many times, but is there **EFFECTIVENESS** (sufficient force or **ENERGY** to their blows)? They want to maximize the energy behind each collision.

The **ORIENTATION** of the blows a boxer inflicts on his opponent means everything.

e.g. To hit someone in the stomach verses the jaw makes a difference. To punch using the fist versus a back hand makes a difference, etc.

Factors Affecting Reaction Rate

STRATEGY

Reactions require collisions.

- There are many factors that affect the **frequency** and **energy** of collisions and thereby affect reaction rate
  - ?
  - ?
  - ?
  - ?
  - ?

Factors Affecting Reaction Rate

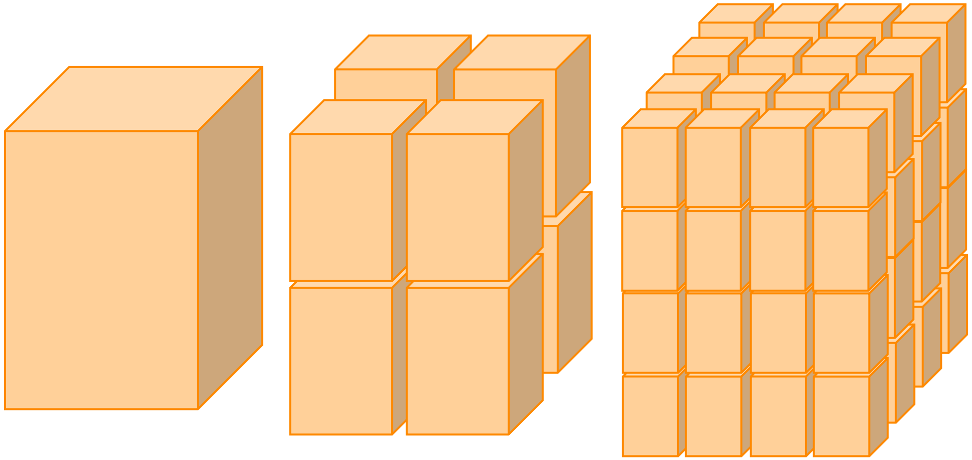
STRATEGY

Reactions require collisions.

- There are many factors that affect the **frequency** and **energy** of collisions and thereby affect reaction rate
  - Surface area (particle size)
  - Concentration of reactants
  - Temperature
  - Agitation or Stirring
  - Catalyst

Effects of Surface Area on Reaction Rate

- Reactions occur at **surfaces.**
- Increasing surface area increases the number of particle collisions.

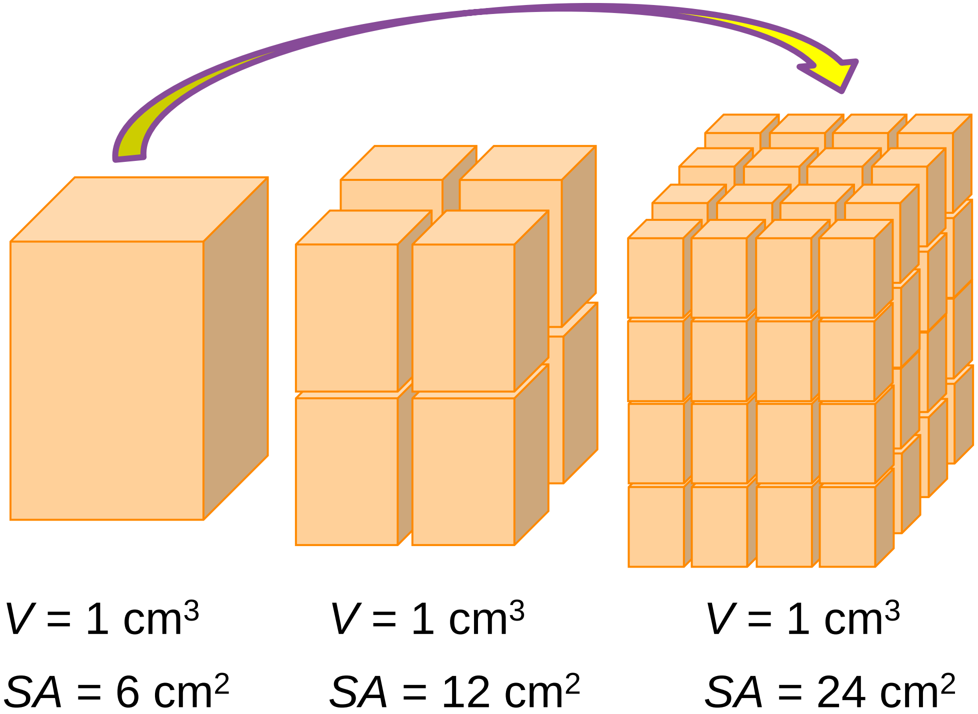


V = 1 cm³	V = 1 cm³	V = 1 cm³
SA = 6 cm²	SA = 12 cm²	SA = 24 cm²

Which group of cubes will react the fastest?

Effects of Surface Area on Reaction Rate

- The easiest and most common way to increase the surface area of a solid is to break it into smaller pieces.
- Although its total volume does not change, its surface area increases significantly.

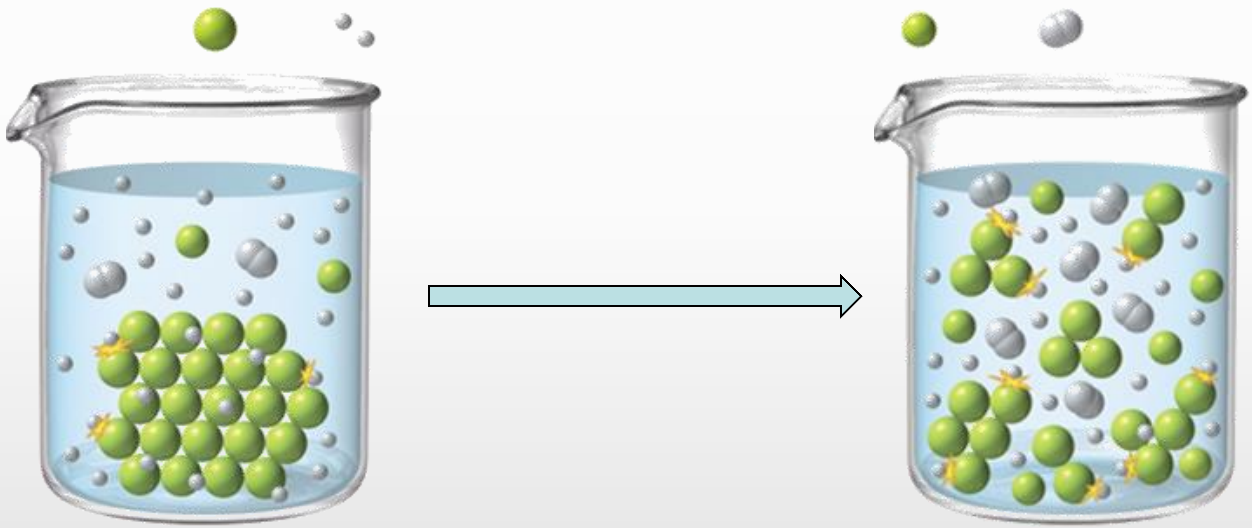


As the surface area of a solid reactant increases, reaction rate increases.

Surface Area Affecting Reaction Rates

When a piece of magnesium is placed in dilute acid, hydrogen ions can collide with magnesium atoms.

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$



Only atoms at the surface of the metal are available for reaction.

Dividing the metal into smaller pieces increases the surface area and the number of collisions.

Surface Area and Reaction Rate

Kindling burns faster than a large log:

This fire was a combustion reaction between grain dust and oxygen. The rate of combustion is very rapid due to the small particle size of the grain dust.

Effect of Concentration on Reaction Rate

Which highway will tend to have the most accidents and why?

Effect of Concentration on Reaction Rate

The higher the concentration of reactants, the more frequently reactant molecules collide and the faster the reaction proceeds to product(s).

The **concentration** (*number of particles in a given volume*) affects the rate at which reactions occur.

How are concentration and reaction rate related?

Effect of Concentration on Reaction Rate

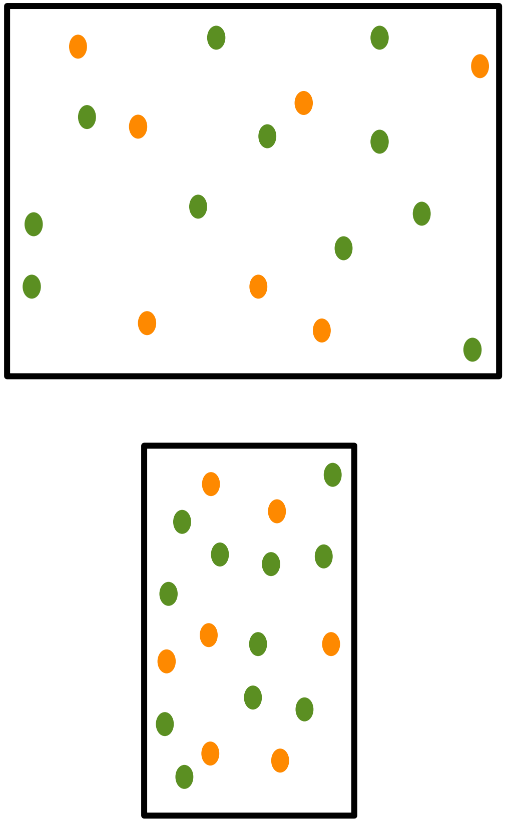
Cramming more particles into a fixed volume increases the concentration of reactants, and, thus, the frequency of collisions.

As concentration of reactants increases, reaction rate increases.

Effect of Concentration on Reaction Rate

Concentration can increase by:

- Decreasing volume
- Adding more reactants



Predict Reaction Rates

QUICK CHECK

Hydrogen peroxide (H_2O_2) readily decomposes to form water and oxygen gas:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Which concentration of hydrogen peroxide (1%, 5%, 30%) would produce the fastest reaction? Explain using kinetic theory.

A chemical engineer is developing a process for producing a new chemical. One step in the process involves reacting a solution of potassium hydroxide with a solid reactant. Which of the following actions would most likely increase the reaction rate for this step?

- using larger pieces of the solid reactant
- using a more concentrated potassium hydroxide solution
- adding water to the system

Predict Reaction Rates

QUICK CHECK

Hydrogen peroxide (H_2O_2) readily decomposes to form water and oxygen gas:

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

Which concentration of hydrogen peroxide (1%, 5%, **30%**) would produce the fastest reaction? Explain using kinetic theory.

Percentage by mass or volume of solute in the solution indicates concentration. Higher concentration means more frequent collisions & faster reaction.

A chemical engineer is developing a process for producing a new chemical. One step in the process involves reacting a solution of potassium hydroxide with a solid reactant. Which of the following actions would most likely increase the reaction rate for this step?

- **using a more concentrated potassium hydroxide solution**

Effect of Temperature on Reaction Rate

- Increasing temperature means that the average Kinetic Energy (KE) of the particles increases.
- Increasing the average KE (motion/energy) of the particles increases the **number** and **effectiveness** of collisions.

How are temperature and reaction rate related?

Effect of **Temperature** on Reaction Rate

General / Approximate Rule:

Reaction rate will double for every +10º C

- *Applying a cover to a cooking pan increases the potential temperature and cooks food faster.*
- *A pressure cooker at 110º C will cook food twice as fast as a pot at 100º C.*

As temperature increases, reaction rate increases.

Reaction rate will halve for every -10º C (refrigerator).

Effect of Temperature on Reaction Rates

Refrigeration decreases the temperature and slows the rate of food spoilage.

Food deteriorates four times as fast at room temperature (25º C) than in a refrigerator (5º C). Explain using kinetic theory.

On a camping trip at 2300 m elevation, you find that your water boils at 92°C instead of 100°C. You know this is due to the lower atmospheric pressure at higher altitudes. The question is, how will this affect your cooking times? Do you expect the time to boil your spaghetti noodles to be longer or shorter than at sea level?

Effect of Temperature on Reaction Rates

Refrigeration decreases the temperature and slows the rate of food spoilage.

Food deteriorates four times as fast at room temperature (25º C) than in a refrigerator (5º C). Explain using collision theory.

Lower temperature reduces molecular speeds and energy of motion, decreasing the number of effective collisions.

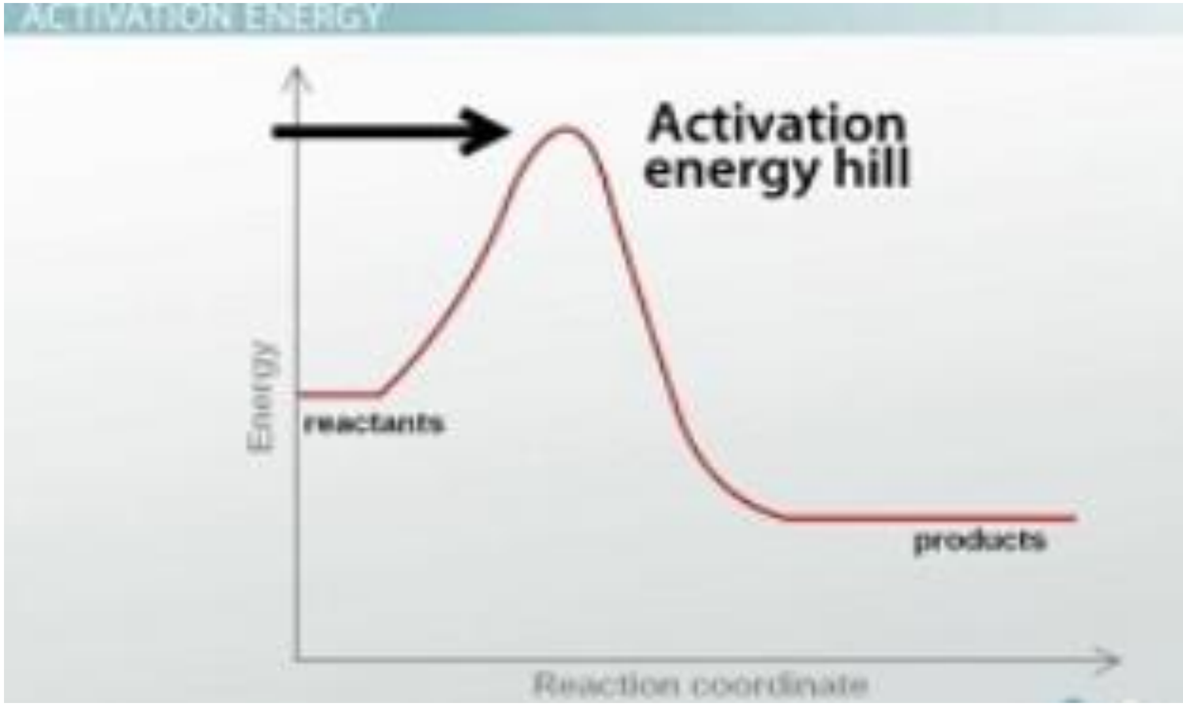
On a camping trip at 2300 m elevation, you find that your water boils at 92°C instead of 100°C. You know this is due to the lower atmospheric pressure at higher altitudes. The question is, how will this affect your cooking times? Do you expect the time to boil your spaghetti noodles to be longer or shorter than at sea level?

Boiling at a lower temperature means less heat energy is cooking the food. Therefore, less effective collisions & longer cooking time.

Effect of Temperature on Reaction Rates

Increasing temperature in essence lowers the activation energy of reaction.

Activation Energy, E_A, is the energy required to bring reactants to the point where they can rearrange to form products.



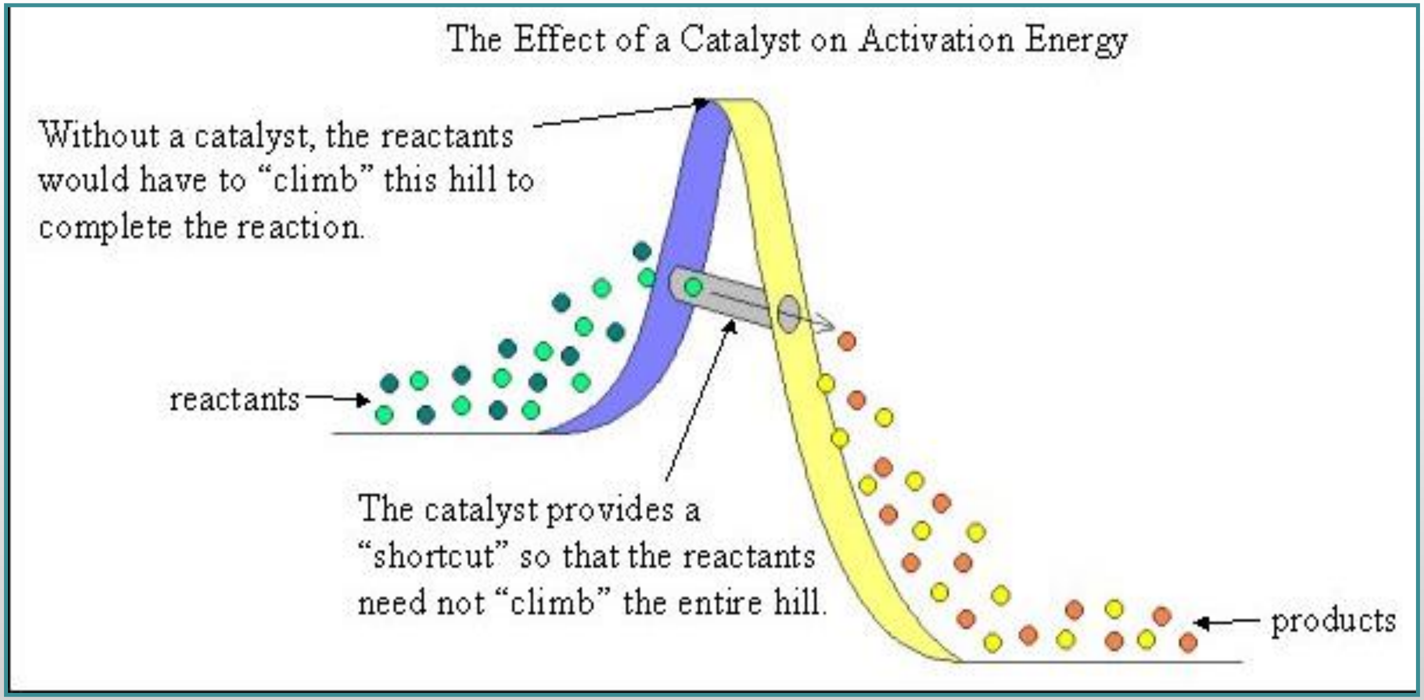
Effect of Stirring on Reaction Rates

Stirring reactants increases their exposure to each other and increases the rate of dissolving.

Catalysts

A catalyst is a substance that increases the rate of a reaction without being used up during the reaction.

Catalysts permit reactions to proceed along a lower energy path.



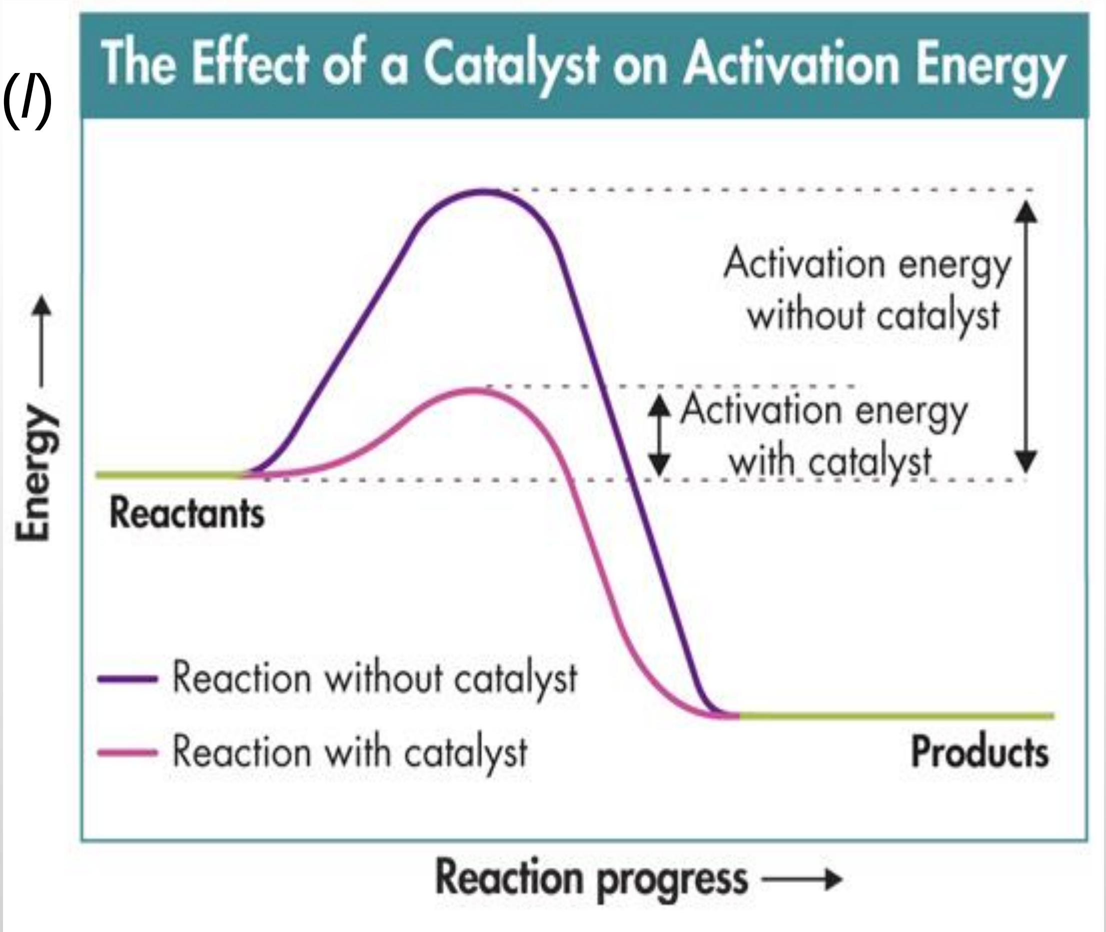
Catalysts

The rate of reaction of hydrogen and oxygen at room temperature is negligible. But with a small amount of platinum (Pt) as a catalyst, the reaction is rapid.

$$2H_2(g) + O_2(g) \xrightarrow{Pt} 2H_2O(l)$$

Pt is not consumed & therefore, is not a reactant in the chemical equation.

The catalyst is often written above the yield arrow.

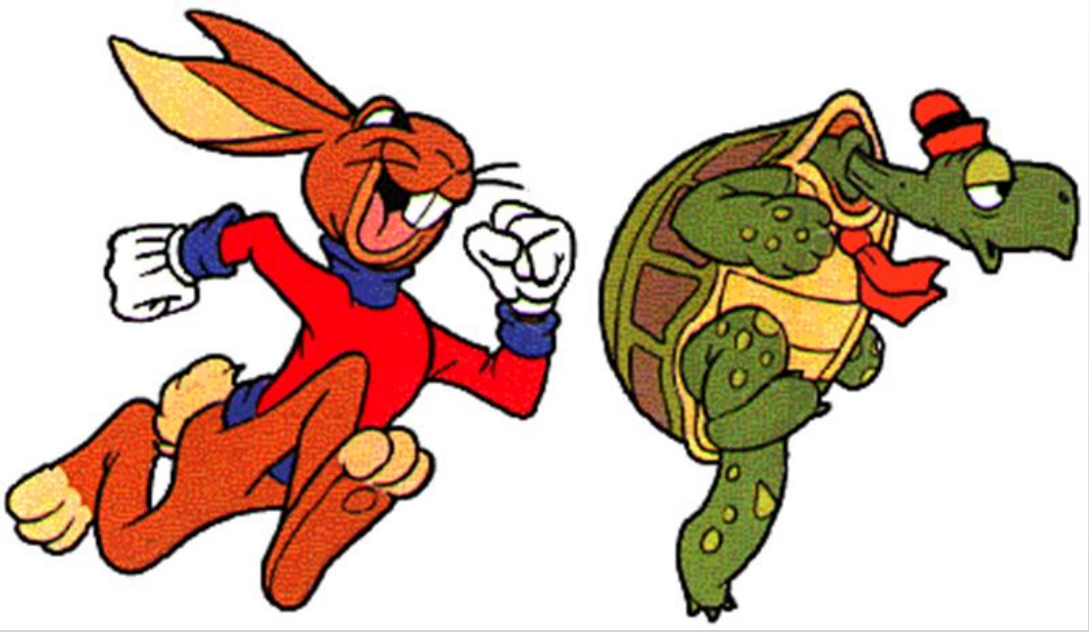


Inhibitors

are substances that interfere with the action of a catalyst. Some inhibitors work by reaction with, or “poisoning,” the catalyst itself.

Thus, the inhibitor reduces the amount of catalyst available for a reaction and are often called “negative catalysts”.

Reactions slow or even stop when a catalyst is inhibited.



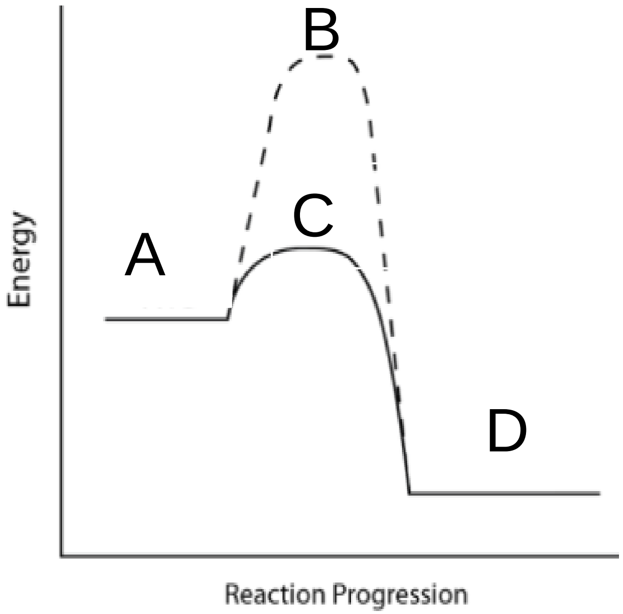
Inhibitors

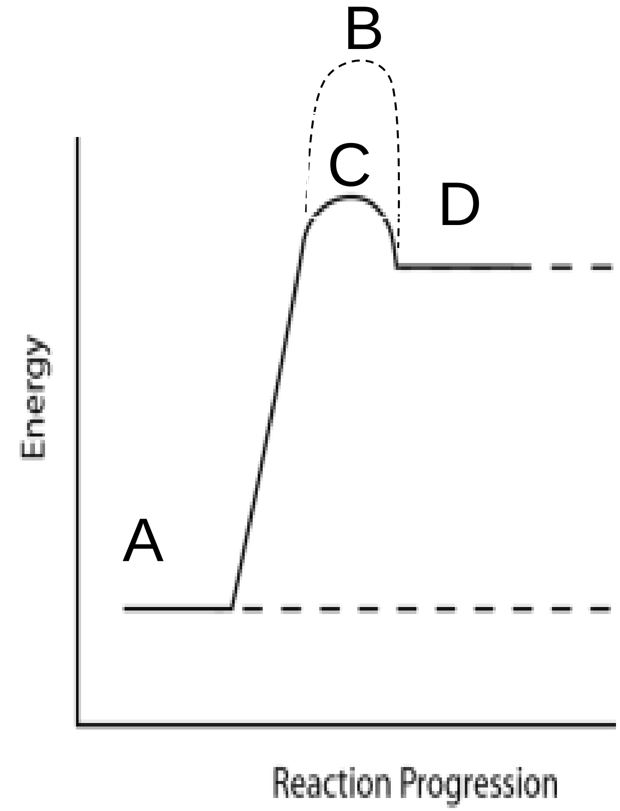
Examples of Enzyme inhibitors used in various human disease states:

CLINICAL USE	ENZYME INHIBITED	INHIBITOR
Epilepsy	GABA transaminase	Gama- vinyl GABA
Antidepressant	MAO	Tranylcypromine , phenelzine
Antihypertensive	ACE	Captopril, enalaprilat
Cardiac disorders	-ATPase	Cardiac glycosides
Gout	Xanthine oxidase	Allopurinol
Ulcer	, - ATPase	omeprazole

Biocides are chemicals that can kill a living organism, and are commonly used in agriculture, the food industry and medicine. Many are enzyme inhibitors. Triclosan is an **antibacterial/antifungal** disinfectant that inhibits an enzyme involved in fatty acid synthesis. It is used in toothpaste, soaps and other cleaning products.

Labeling Energy Diagrams





Activation energy of forward reaction ____

Activation energy with catalyst ____

Energy of products ____

Energy of reactants ____

Reaction type ________

E_A of forward reaction ____

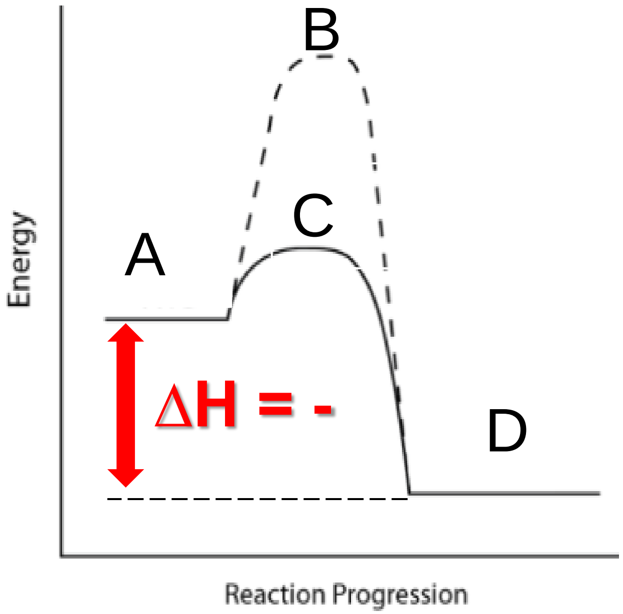
E_A with catalyst ____

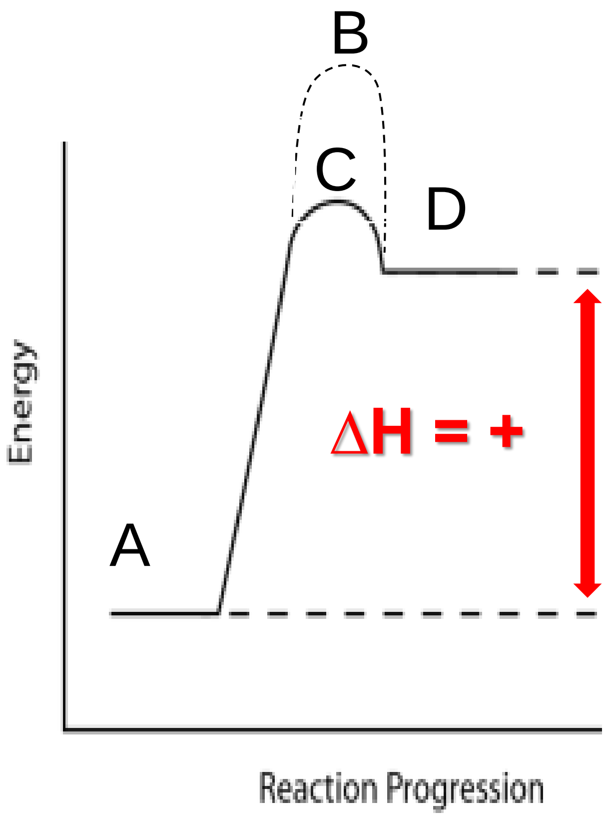
Energy of products ____

Energy of reactants ____

Reaction type ________

Labeling Energy Diagrams





activation energy of forward reaction **B**

activation energy with catalyst **C**

energy of products **D**

energy of reactants **A**

Reaction type **EXOthermic**

E_A of forward reaction A→**B**

E_A with catalyst A→**C**

Energy of products **D**

Energy of reactants **A**

Reaction type **ENDOthermic**

Reversible Reactions

- Up until now, you may have assumed that any chemical equation we write represents a reaction that proceeds from reactants to products only.

This is true of: $2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{\,(g)}$.

- In principle, however, almost all reactions are reversible to some extent under the right conditions.

Forward Reaction: $CO_{2(aq)} + H_2O_{(l)} \rightarrow H_2CO_{3(aq)}$

Reverse Reaction: $H_2CO_{3(aq)} \rightarrow CO_{2(aq)} + H_2O_{(l)}$

Reversible Reactions

- Reactions that can proceed in both directions (forward and reverse) use a double arrow system:

$$CO_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)}$$

- *The* ***length of each arrow*** *is significant, indicating whether the forward or reverse reaction is favored.*

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

- In the reaction, the reactants change into products just as fast as the products change back into reactants.

Equilibrium

When a chemical reaction does not go to completion, a chemical equilibrium is established between the forward and reverse reactions.

Irreversible reactions that go to completion:

Explosions are nonreversible reactions and to go to completion.

$$CH_4 + O_2 \dashrightarrow CO_2 + 2\,H_2O$$

When no reactants can be detected, you can say that the reaction has gone to completion, or is irreversible.

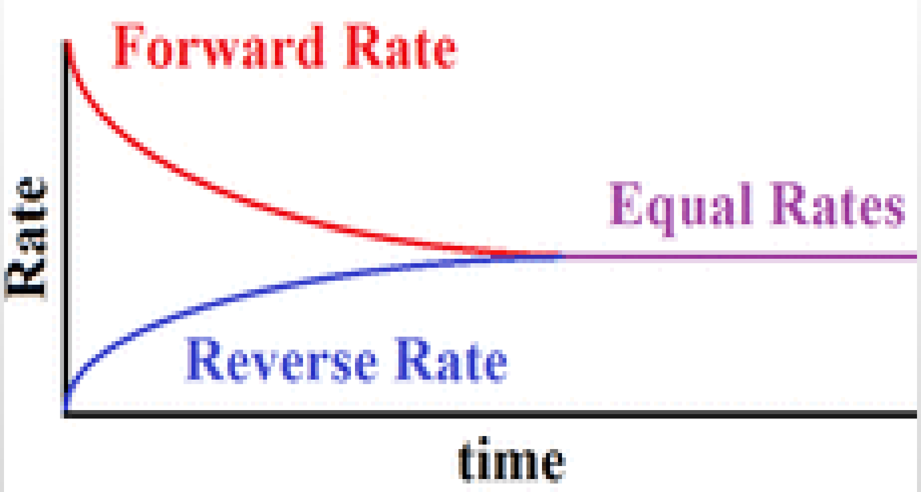
Equilibrium

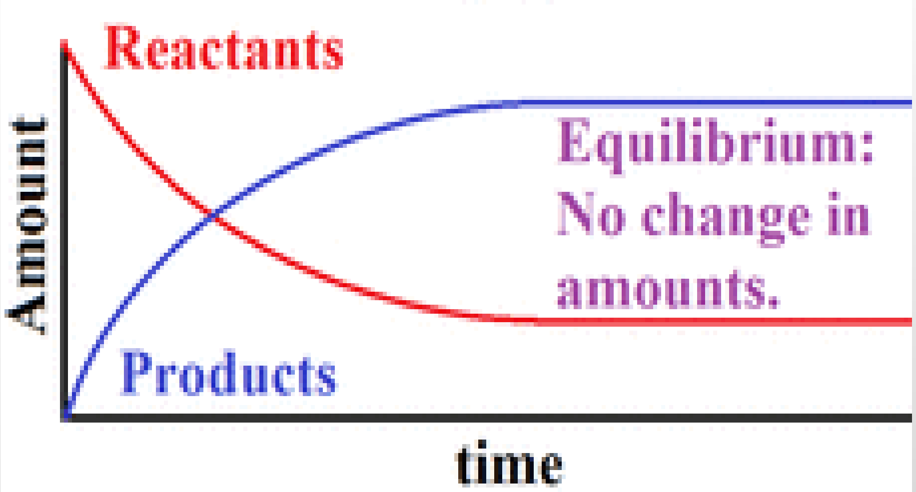
Both reactants and products coexist.

Equilibrium

Chemical equilibrium is the state in which both reactants and products are present in concentrations which have no further tendency to change with time.

Usually, this state results when the forward reaction proceeds at the same rate as the reverse reaction and concentrations of the reaction components no longer change.

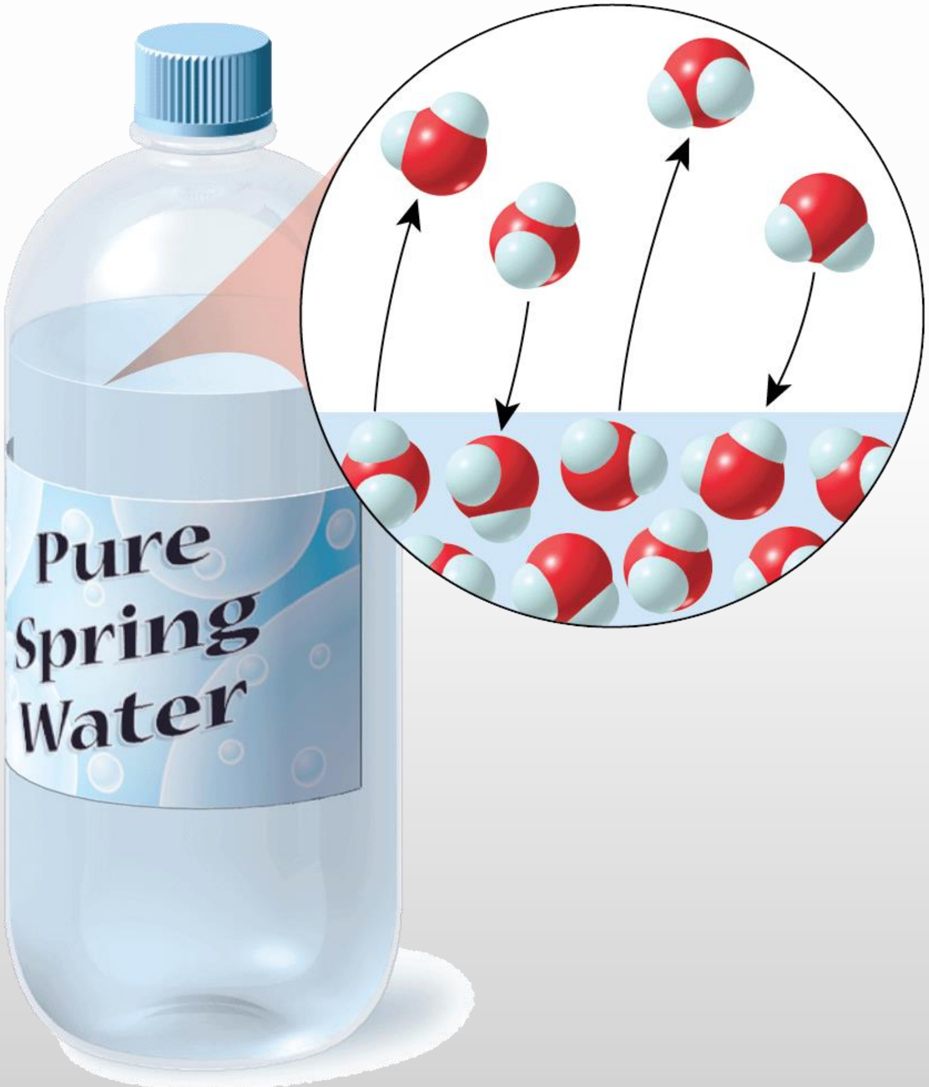




Equilibrium

Physical Equilibrium

Liquid water left in a closed container eventually reaches equilibrium with its vapor when the rate of evaporation equals the rate of condensation.

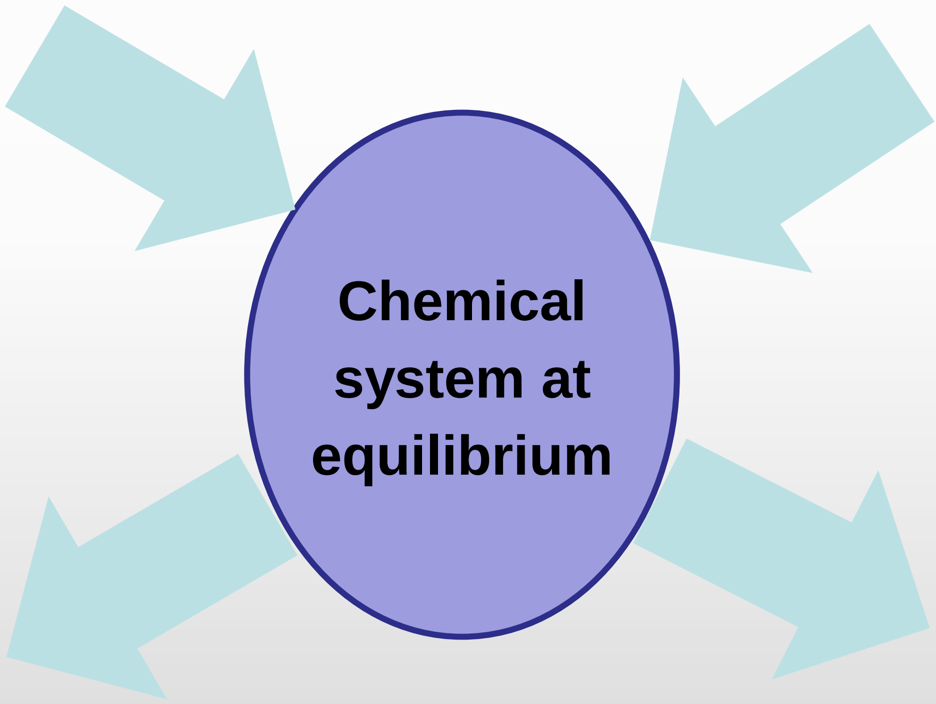


Stresses to Chemical System

External changes called **stresses** can disrupt chemical equilibrium.

Stresses include:

- Change in **concentration**
- Change in **pressure**
- Change in **temperature**



Le Chatelier's Principle

Le Chatelier's principle:
If a **stress** is applied to a chemical system at equilibrium, the system will respond by shifting in a direction to counteract the stress and a new equilibrium will be established.

Predicting Equilibrium Shift due to Concentration

QUICK CHECK

$$SO_{2\,(g)} + NO_{2\,(g)} \rightleftharpoons SO_{3\,(g)} + NO_{(g)}$$

For the equilibrium system described by the equation above, what will happen if SO_3 is removed?

- O equilibrium shifts right
- O equilibrium shifts left

What will happen if NO is added?

- O equilibrium shifts right
- O equilibrium shifts left

For the equilibrium system described by the equation above, what will happen if SO_2 is removed?

- O equilibrium shifts right
- O equilibrium shifts left

What will happen if NO_2 is added?

- O equilibrium shifts right
- O equilibrium shifts left

Predicting Equilibrium Shift due to Concentration

QUICK CHECK

$$SO_{2\,(g)} + NO_{2\,(g)} \rightleftharpoons SO_{3\,(g)} + NO_{(g)}$$

For the equilibrium system described by the equation above, what will happen if SO_3 is removed?

- The equilibrium shifts to the right (to replace product). Favors **forward** reaction.

What will happen if NO is added?

- The equilibrium shifts to the left (to remove product). Favors **reverse** reaction.

For the equilibrium system described by the equation above, what will happen if SO_2 is removed?

- The equilibrium shifts to the left (to replace the reactant). Favors **reverse** reaction.

What will happen if NO_2 is added?

- The equilibrium shifts to the right (to remove reactant). Favors **forward** reaction.

Stressing the system by Temperature causes a shift in equilibrium based on how heat flows.

Exothermic reaction

reactants → products + **heat**

- Adding heat causes shift to LEFT (*favors reverse reaction to relieve the stress of high energy products*)
- Removing heat causes shift to RIGHT

$2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

Brown Colorless

Stressing the system by Temperature causes a shift in equilibrium based on how heat flows.

Endothermic reaction

reactants + **heat** → products

- Adding heat causes shift to RIGHT (*favors forward reaction to relieve the stress of high energy reactants*)
- Removing heat causes shift to LEFT

$2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

Brown Colorless

Predicting Equilibrium Shift due to Temperature

QUICK CHECK

$$2POCl_{3\,(g)} + heat \rightleftharpoons 2PCl_{3\,(g)} + O_{2\,(g)}$$

For the equilibrium system described by the equation above, what happens if temperature is decreased?

O equilibrium shifts right

O equilibrium shifts left

What happens if temperature is increased?

O equilibrium shifts right

O equilibrium shifts left

$$2CO_{(g)} \rightleftharpoons CO_{2\,(g)} + C_{(s)} + heat$$

For the equilibrium system described by the equation above, what happens if temperature is increased?

O equilibrium shifts right

O equilibrium shifts left

What happens if temperature is decreased?

O equilibrium shifts right

O equilibrium shifts left

Predicting Equilibrium Shift due to Temperature

QUICK CHECK

$$2POCl_{3\,(g)} + heat \rightleftharpoons 2PCl_{3\,(g)} + O_{2\,(g)}$$

For the equilibrium system described by the equation above, what happens if temperature is decreased?

Equilibrium shifts left to restore the heat that was lost. Favors **reverse** reaction.

What happens if temperature is increased?

Equilibrium shifts right to absorb the excess heat added. Favors **forward** reaction.

$$2CO_{(g)} \rightleftharpoons CO_{2\,(g)} + C_{(s)} + heat$$

For the equilibrium system described by the equation above, what happens if temperature is increased?

Equilibrium shifts left to absorb the excess heat added. Favors **reverse** reaction.

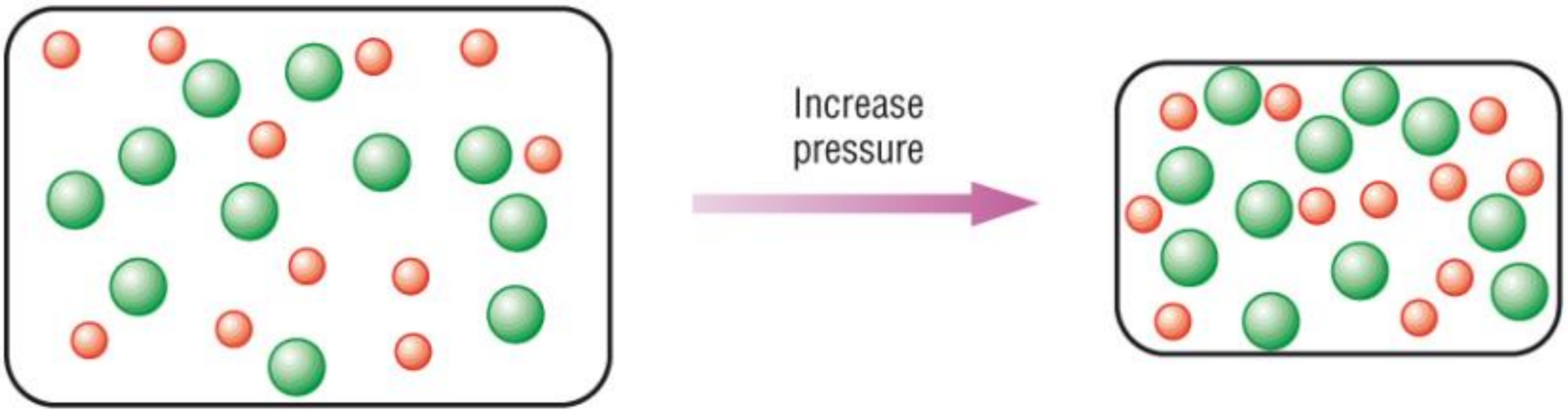
What happens if temperature is decreased?

Equilibrium shifts right to restore the heat that was lost. Favors **forward** reaction.

Effect of **Pressure** on Equilibrium

Pressure affects **GASES**:

- Increasing **pressure** increases the number of collisions, which stresses equilibrium.



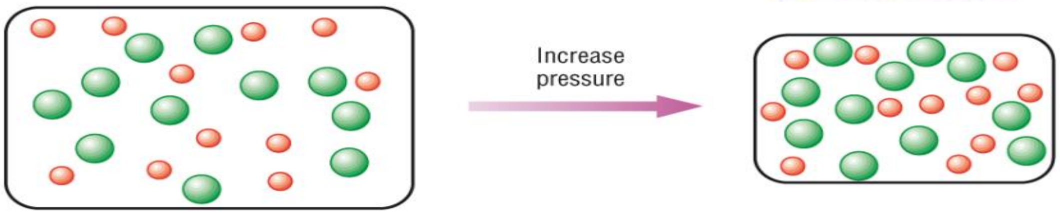
Effect of Pressure on Equilibrium

Pressure affects gases … Solids & liquids are generally insensitive to pressure.

$$1N_2(g) + 3H_2(g) = 2NH_3(g)$$

The balanced equation contains four moles of gas among the reactants....

....and only two moles of gas among the products.



There are more moles of reactant gas than products. Increasing pressure shifts equilibrium to the RIGHT.

Effect of Pressure on Equilibrium

TRY IT

Predict the shift in equilibrium when there is an increase in pressure for each of the following reactions.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

$$SnO_2(s) + 2H_2(g) \rightarrow Sn(s) + 2H_2O(g)$$

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + H_2O(l) + 2NaCl(aq)$$

Effect of Pressure on Equilibrium

TRY IT

Predict the effects of an increase in pressure for each of the following reactions.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

More moles of REACTANT gas so equilibrium will shift RIGHT to relieve the pressure (more collisions between reactants).

$$SnO_2(s) + 2H_2(g) \rightarrow Sn(s) + 2H_2O(g)$$

no change in equilibrium … equal number of moles of GAS on each side of reaction (same number of collisions).

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + H_2O(l) + 2NaCl(aq)$$

More moles of PRODUCT gas so equilibrium will shift LEFT to relieve the pressure (more collisions between products).