Chem 150, Spring 2015

Unit 3 - Chemical Reactions

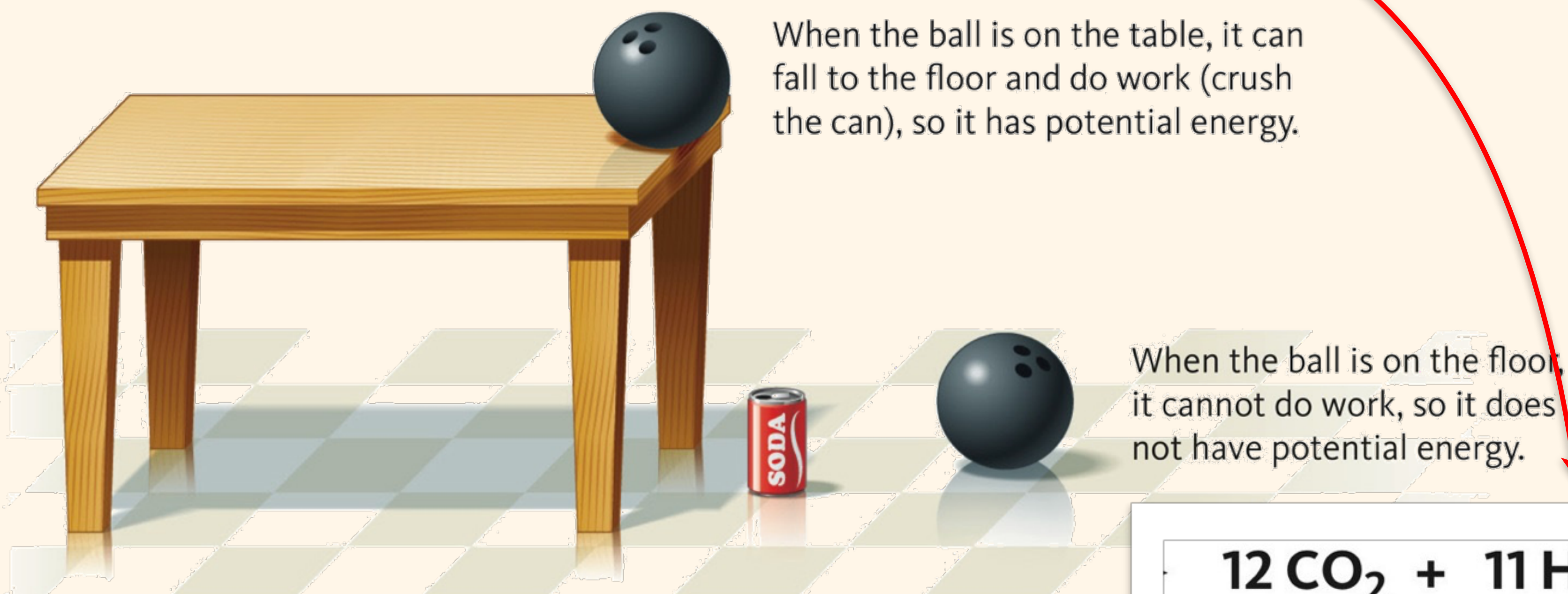
Introduction

- Reading Assignment
  - Chapter 6-4,5,6 & 7
- Unit 3 Mastery and Problem Assignments
  - Due 10. February
  - Deadline 17. February

- Favorable chemical reactions give up potential energy.

$C_{12}H_{22}O_{11} + 11\,O_2$

(High chemical energy)



$12\,CO_2 + 11\,H_2O$

(Low chemical energy)

6.4 Heats of Reaction

- Some reactions release heat energy (Exothermic Reactions)
- While others absorb heat energy (Endothermic Reactions)
- The burning (combustion) of 1 mole of sucrose is exothermic and releases 1,342 kcal of heat energy

$$C_{12}H_{22}O_{11} + 11\,O_2 \longrightarrow 12\,CO_2 + 11\,H_2O + \text{Thermal energy}$$

(High chemical energy) (Low chemical energy)

- The energy for a balanced chemical equation is called the heat of reaction (ΔH).

6.4 Heats of Reaction

- The reaction of bicarbonates with HCl is an example of an endothermic reaction.

$$NaHCO_3 + HCl + \text{Thermal energy} \longrightarrow NaCl + CO_2 + H_2O$$

(Low chemical energy)

ΔH = + 2.8 kcal/mol

(High chemical energy)

- Overall, free energy is released in the reaction, but it is accompanied by an absorption of heat energy.

Exothermic and Endothermic Reactions

TABLE 6.2 A Comparison of Exothermic and Endothermic Reactions

	Exothermic Reaction	Endothermic Reaction
Type of energy conversion	Converts chemical energy into thermal energy	Converts thermal energy into chemical energy
Effect of the reaction	Makes its surroundings warmer	Makes its surroundings cooler
Location of the heat in the balanced equation	Heat is on the right side: reactants → products + heat	Heat is on the left side: reactants + heat → products
Sign of ΔH	Negative	Positive

Nutritive Value of Food

- One gram of any carbohydrate supplies around 4 kcal of energy
- One gram of any fat supplies around 9 kcal of energy
- The word Calorie (Cal) is actually a kilocalorie (kcal)
  - Recall, a calorie is defined as the quality of heat energy needed to raise the temperature of 1 gm of water by 1°C.
- The Calorie content of food is determined by burning it and measuring how much heat energy is released.

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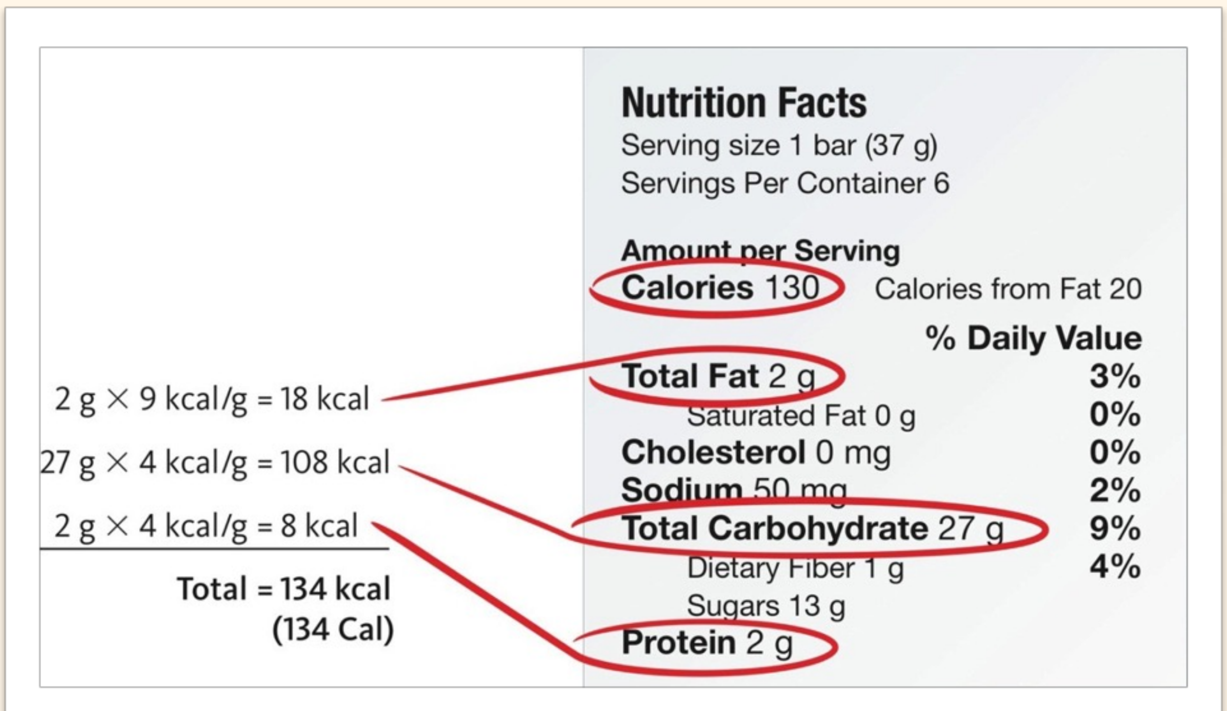
(High chemical energy) (Low chemical energy) ΔH = -1,342 kcal/mol

Food Labels

- For 1 g of sucrose (a carbohydrate)

$$1\ \text{g}\left(\frac{1\ \text{mol}}{342.3\ \text{g}}\right)\left(\frac{1{,}342\ \text{kcal}}{\text{mol}}\right)\left(\frac{1\ \text{Cal}}{1\ \text{kcal}}\right) = 3.9\ \text{Cal}$$



6.5 Combustion Reactions and the Carbon Cycle

- Combustion Reactions are reactions of a chemical compound with oxygen to produce small oxygen containing compounds and heat energy.
- Carbon and hydrogen containing reactants are common:
  - CH_4 - methane (natural gas)
  - $CH_3CH_2CH_3$ - propane
  - $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ - octane (gasoline)
  - $C_{12}H_{22}O_{11}$ - sucrose (table sugar)

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- The combustion of butane ($CH_3CH_2CH_2CH_3$)

$$C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$$

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$$C_4H_{10} + \frac{13}{2} O_2 \rightarrow 4\ CO_2 + 5\ H_2O$$

$$2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$$

6.5 Combustion Reactions and the Carbon Cycle

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Question:

Write the balanced chemical equation for the combustion of propane ($CH_3CH_2CH_3$) to CO_2 and H_2O.

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Photosynthesis

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- It converts carbon dioxide and water (the products of combustion) into glucose ($C_6H_{12}O_6$) and oxygen by using light energy from the sun.

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- Animals eat plants and convert the carbon containing molecules back into CO_2 and H_2O in a process called respiration.

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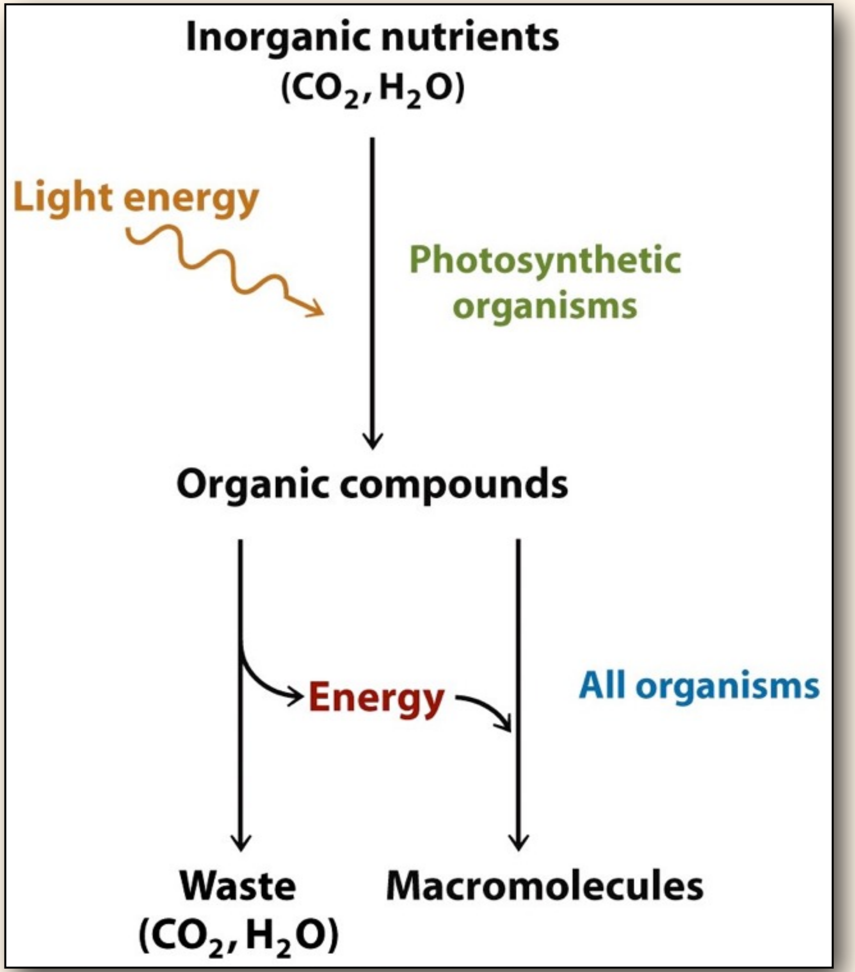
$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 686\ kcal$$

  - This releases the energy that was originally captured by the plants from the sun.

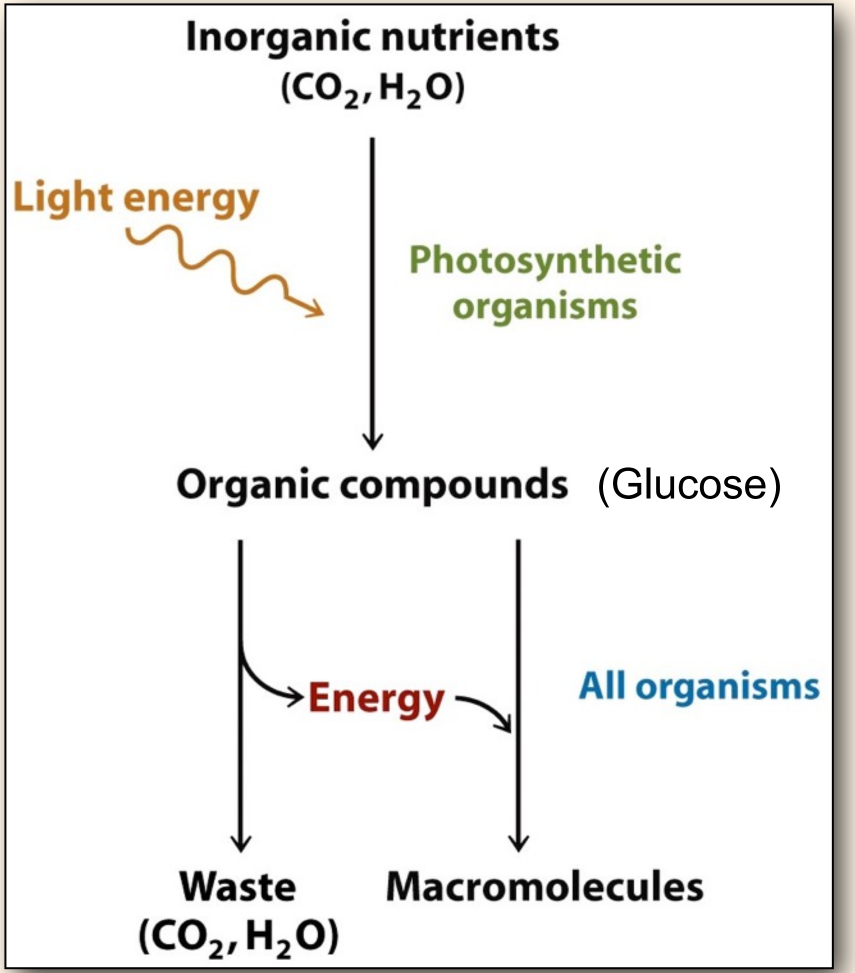
Photosynthesis

Photosynthesis



Photosynthesis

$6\ CO_2 + 6\ H_2O + 686\ \text{kcal} \rightarrow \text{Glucose} + 6\ O_2$



(Glucose)

Photosynthesis

$6\ CO_2 + 6\ H_2O + 686\ \text{kcal} \rightarrow \text{Glucose} + 6\ O_2$

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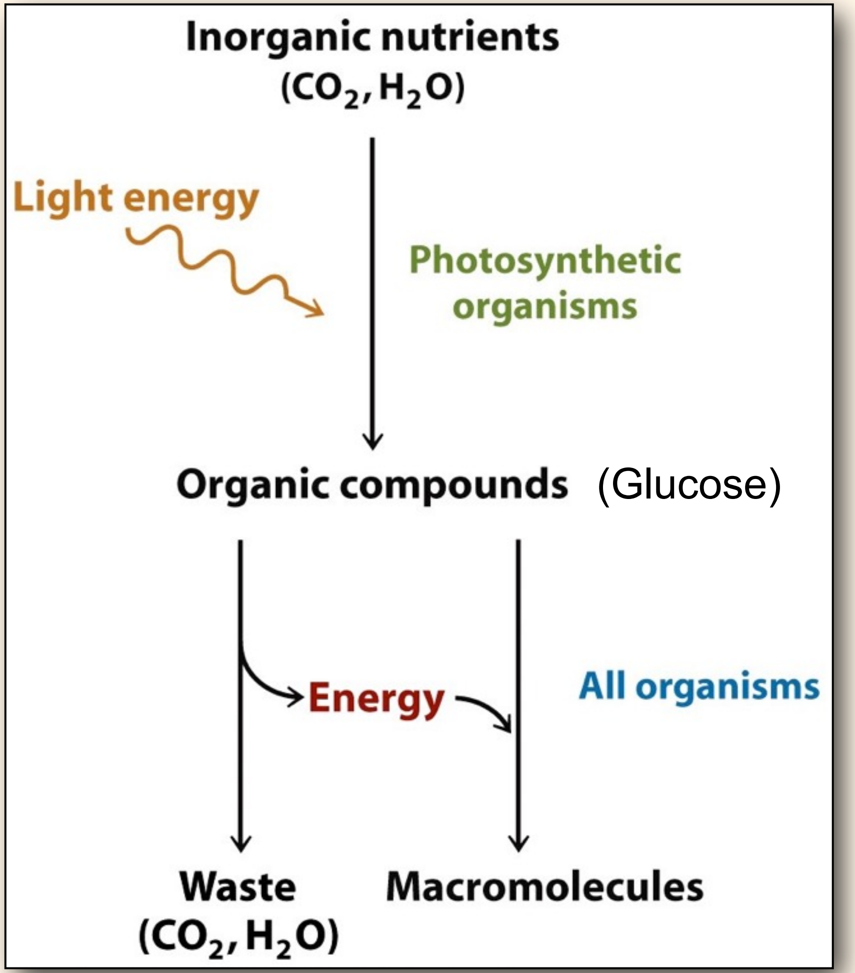

Respiration

- Respiration is not limited to glucose
  - The combustion of the carbohydrate glucose ($C_6H_{12}O_6$)

    $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 686\ \text{kcal}$
  - The combustion of the fat tristearin ($C_{57}H_{110}O_6$)

Respiration

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Question:

Write the balanced chemical equation for the combustion of tristearin ($C_{57}H_{110}O_6$) to CO_2 and H_2O.

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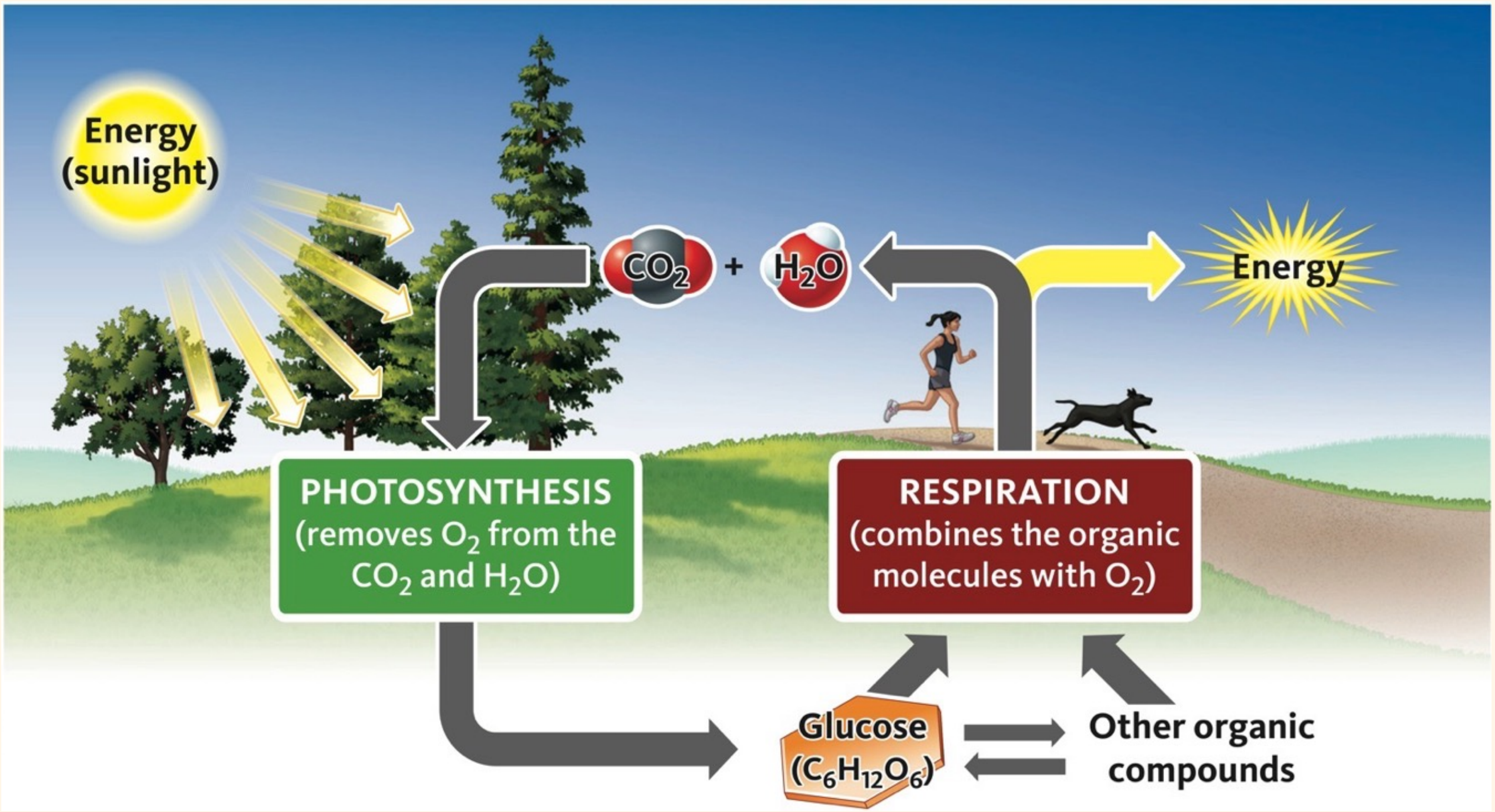
      $$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 686\ \text{kcal}$$

    - The combustion of the fat tristearin ($C_{57}H_{110}O_6$)

      $$2\ C_{57}H_{110}O_6 + 163\ O_2 \rightarrow 114\ CO_2 + 110\ H_2O + 17{,}116\ \text{kcal}$$

Carbon Cycle

- Respiration and photosynthesis combine to create the carbon cycle.



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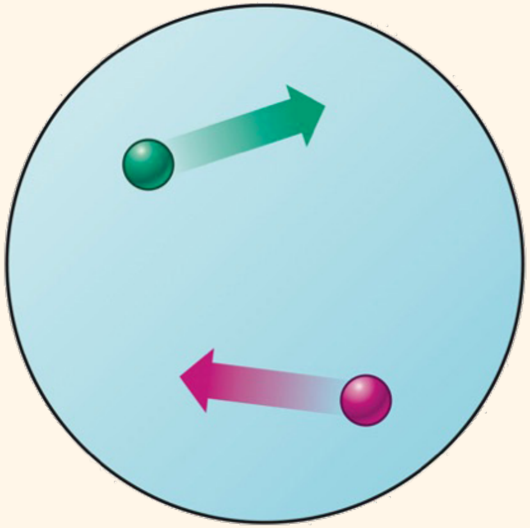
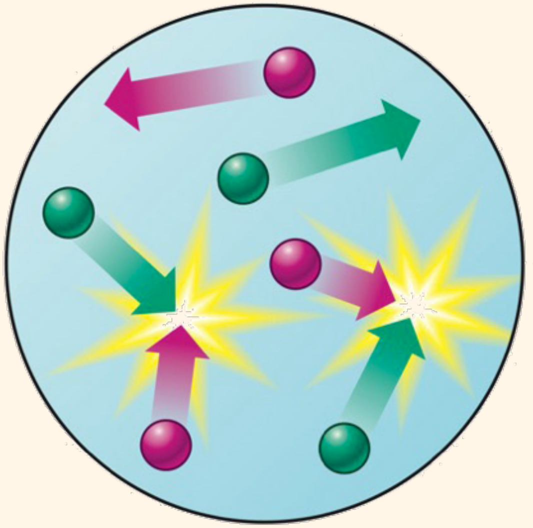
- Reaction Rate is the speed of the reaction
  - Fast reactions: Consume reactants quickly
- Three main factors effect the rate of reaction
  - How often the reactant molecules collide with each other.
  - How much kinetic energy the molecules have when they do collide.
  - How much energy the molecules need in order to react with each other.

Frequency of collision

- Molecules can't react unless they collide. The higher the concentration of reactants present, the more likely a collision and a reaction will occur:



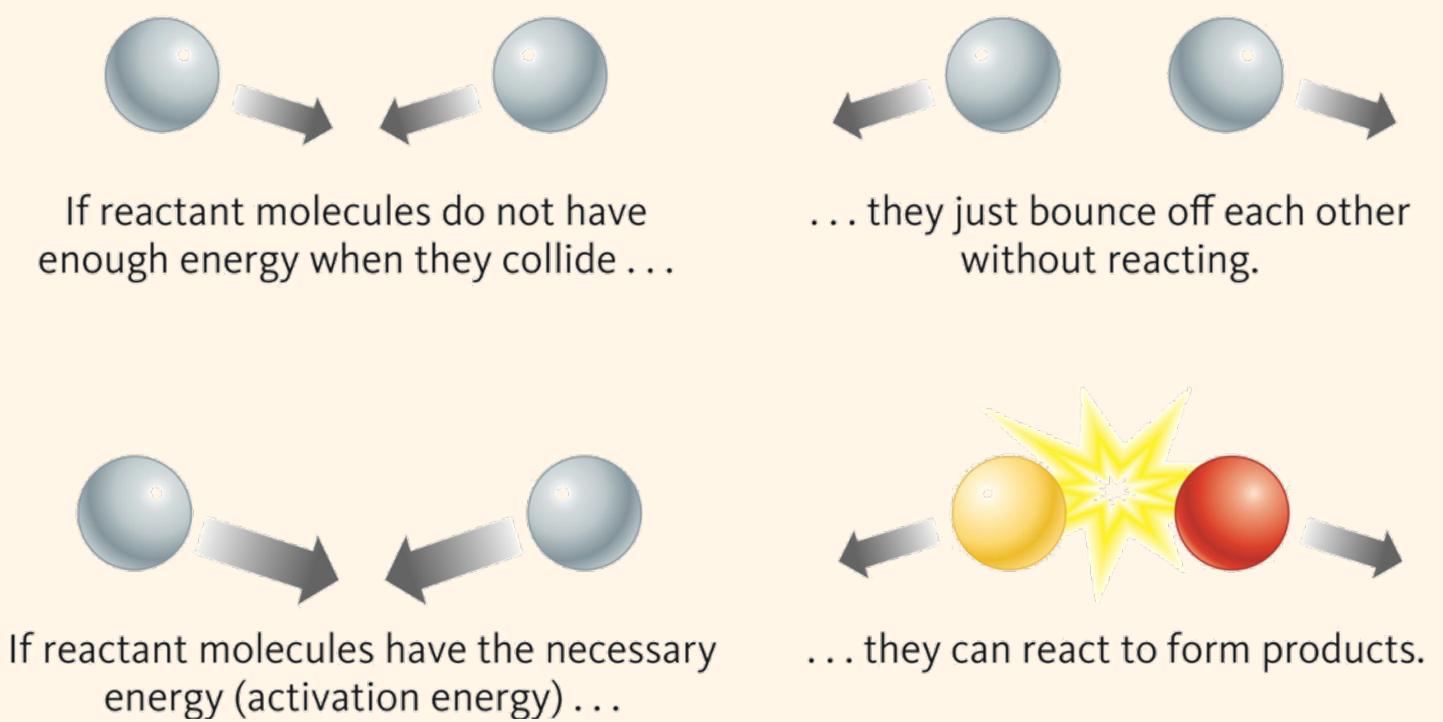
When the reactant concentrations are low, the reaction is slow because the molecules do not collide often.



When the reactant concentrations are high, the reaction is fast because the molecules collide frequently.

Energy of Collision

- Breaking bonds requires energy, so collisions must have a high enough energy to allow for the formation of products.



- The minimum energy necessary for reaction is the activation energy.

Energy of Collision

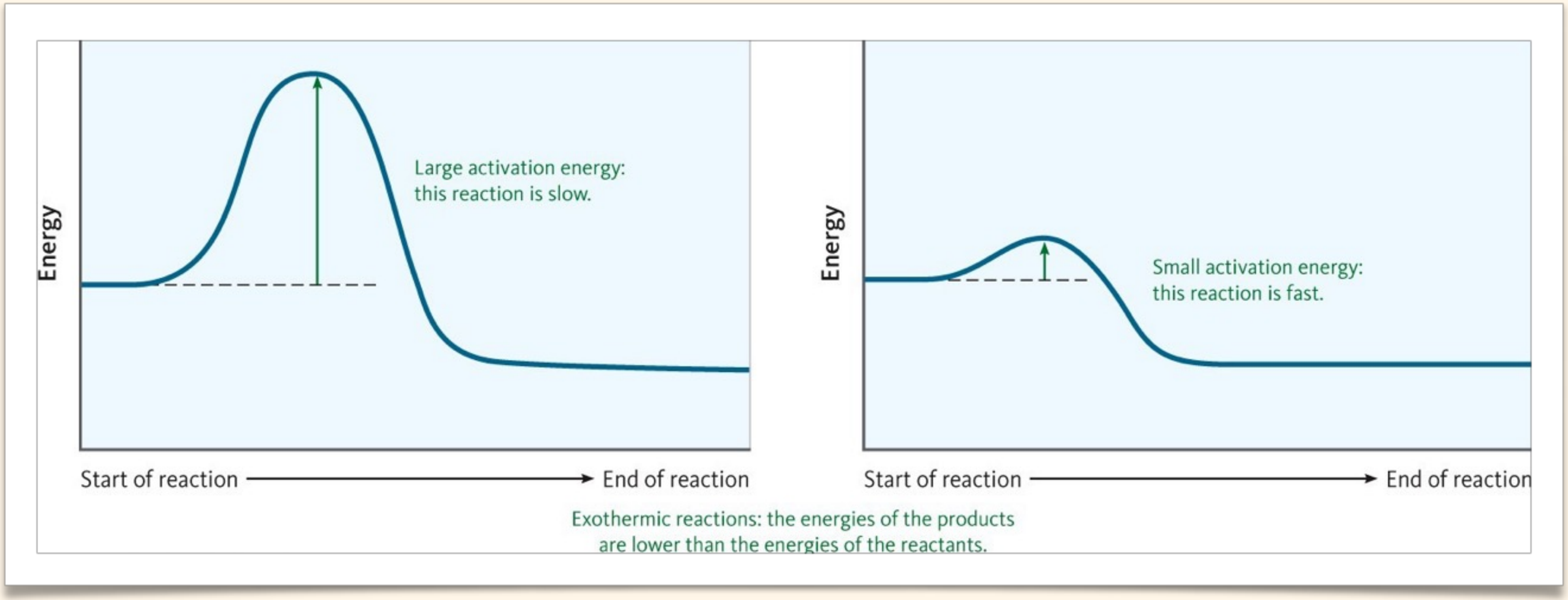
Question:

How might the kinetic energy of the reactants in a reaction be increased?

The Nature of the Reaction

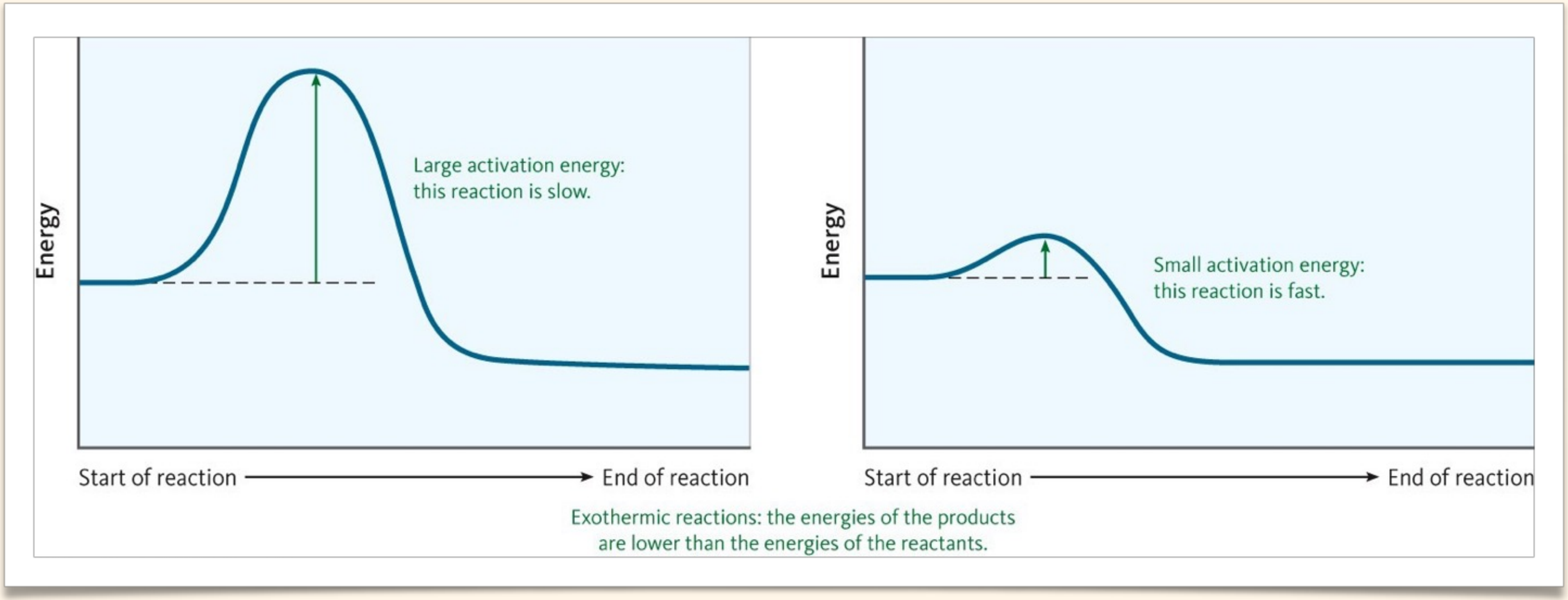
- The activation energy is the minimum amount of energy input required for molecules to react.
  - The smaller the activation energy, the faster the rate of reaction

Energy Diagrams allow this to be observed graphically



Exothermic Reactions

- Energy of the reactant is higher than the energy of product.
- The reaction releases heat (it converts potential energy into thermal energy)



Endothermic Reactions

- Energy of the reactant is lower than the energy of product.
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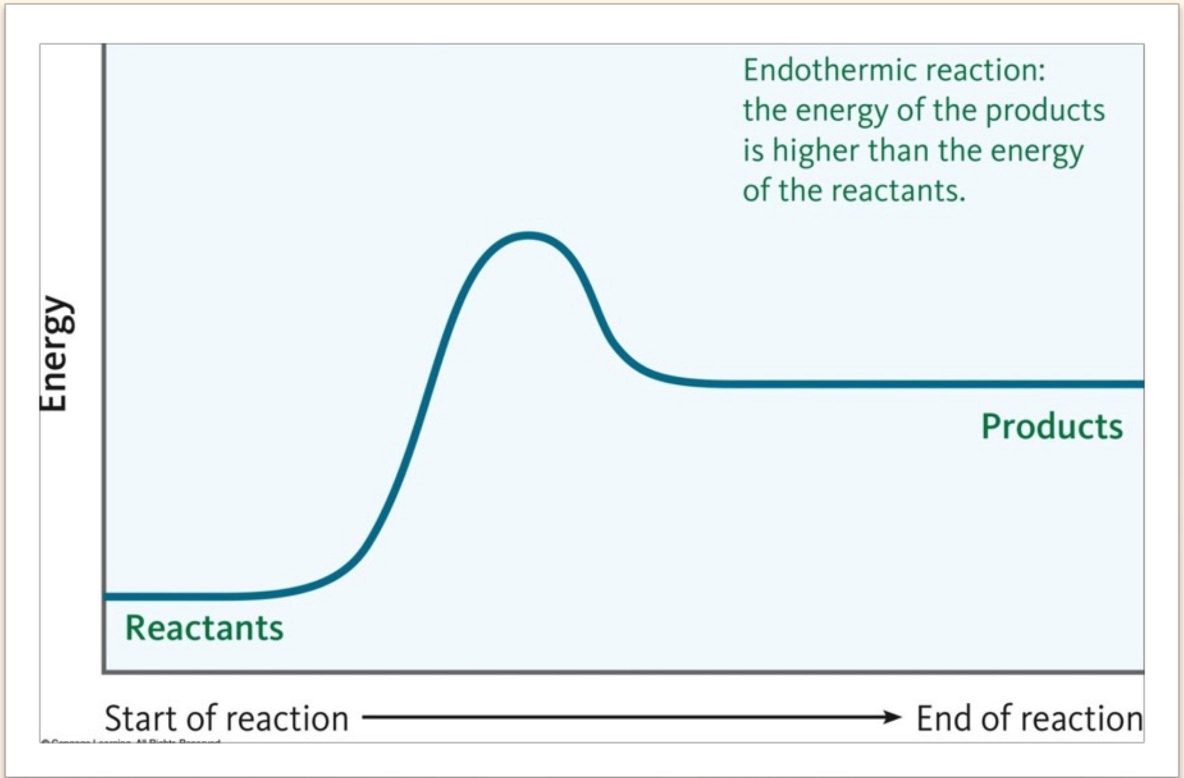

Endothermic Reactions

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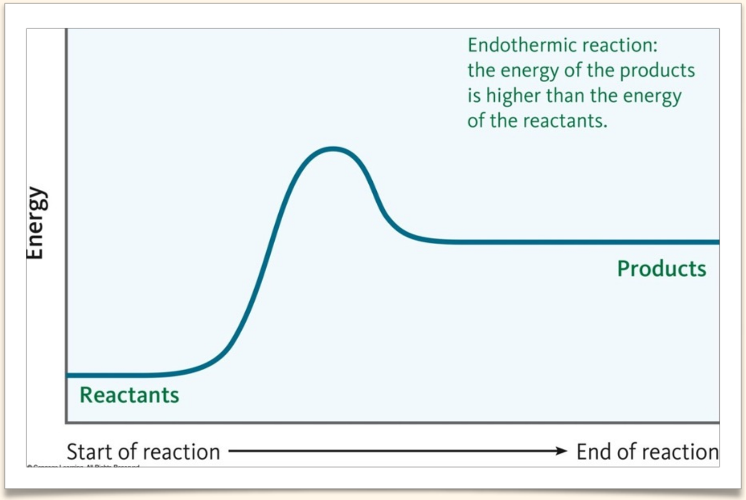
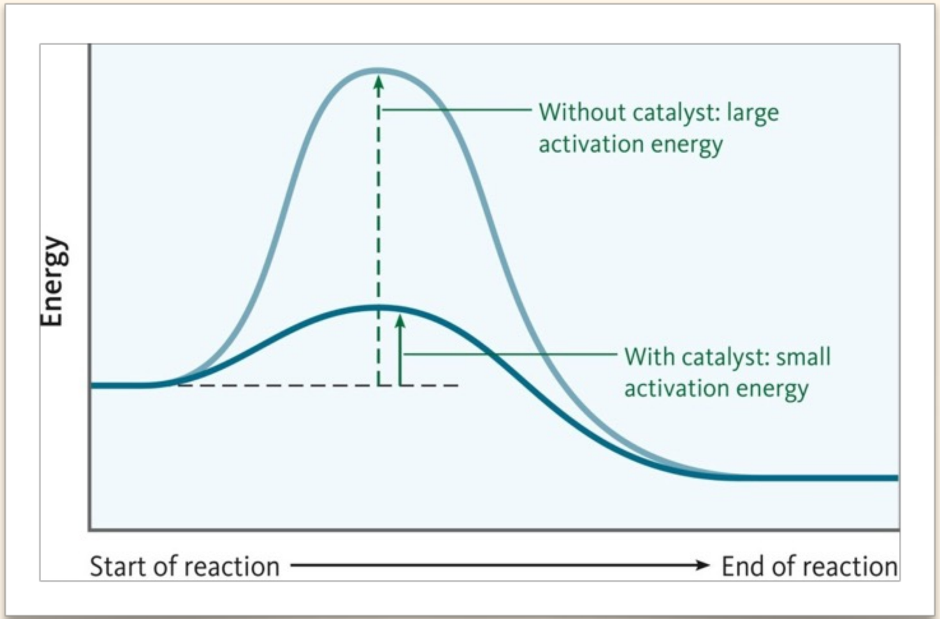
It is important to realize that your text book is considering only the heat of the reaction (ΔH) when describing the energy diagrams. Other sources instead consider free energy (ΔG). The distinction is an important one.



Catalysts

- Catalysts
  - A Catalyst increases the rate of reaction without itself being consumed in the reaction.
  - Biological catalysts are proteins called enzymes
  - Catalysts lower the amount of energy required for a reaction to take place (activation energy)



Factors that affect the rate of reaction

TABLE 6.4 Factors that affect the rate of a reaction

Factor	Effect	Reason
Concentration of reactants	Raising the concentration increases the reaction rate.	Reactant molecules collide more frequently.
Surface area of solids and liquids	Stirring and breaking up solids increases the reaction rate.	The surface area is increased, exposing more reactant molecules.
Temperature	Raising the temperature increases the reaction rate.	More molecules have enough energy to react (activation energy).
Catalyst	Adding a catalyst increases the reaction rate.	The catalyst lowers the activation energy.

6.7 Chemical Equilibria

- In theory, any reaction can go either forwards and backwards.
- For example, beverages are carbonated by bubbling CO_2 through the liquid and then sealing it off.
  - The CO_2 reacts with the water to produce carbonic acid, H_2CO_3:

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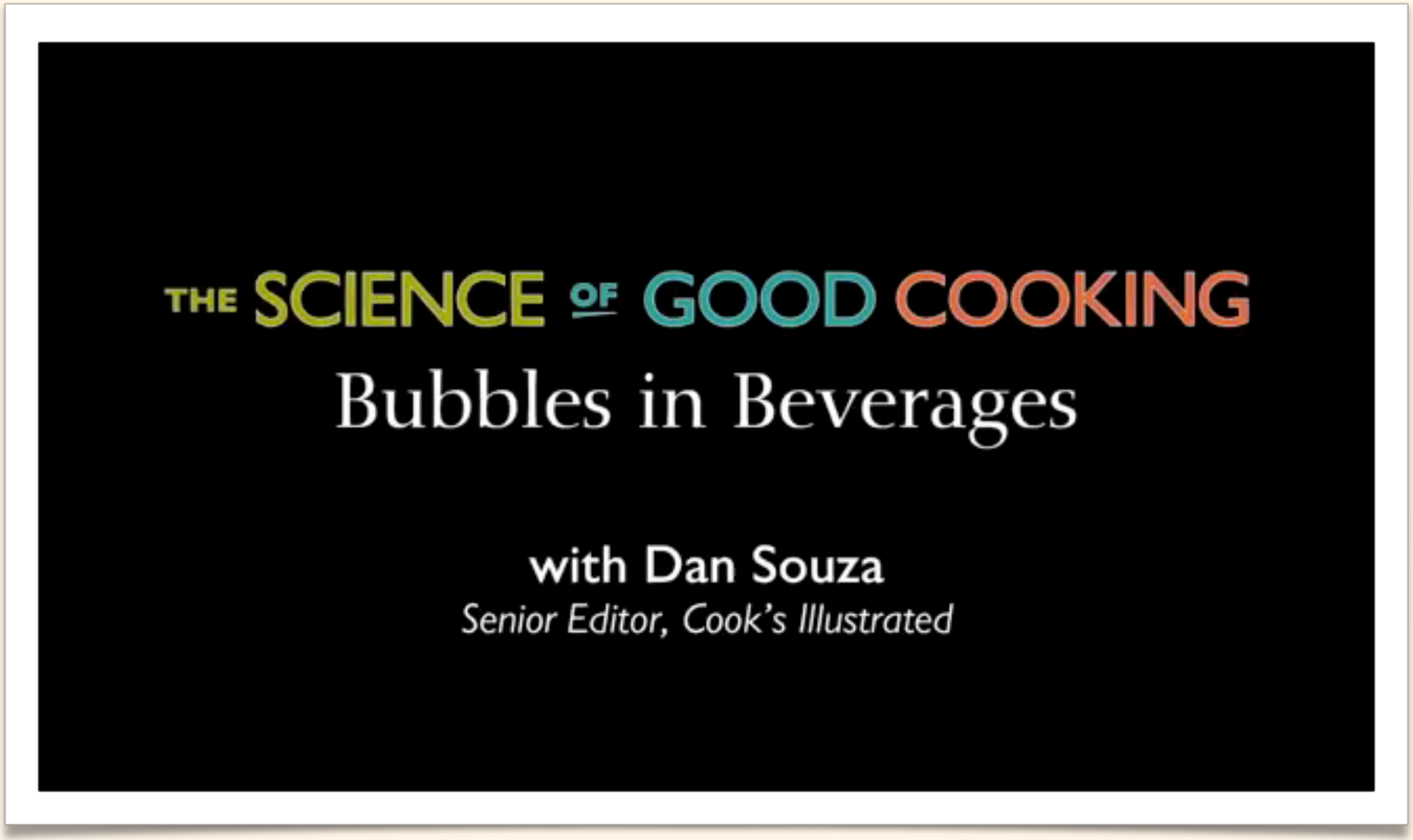
- When the cap is removed, the reverse reaction occurs, producing the effervescence:

$$CO_2 + H_2O \leftarrow H_2CO_3$$

6.7 Chemical Equilibria

- When a reversible reaction occurs at the same rate in both directions, it has reached equilibrium:



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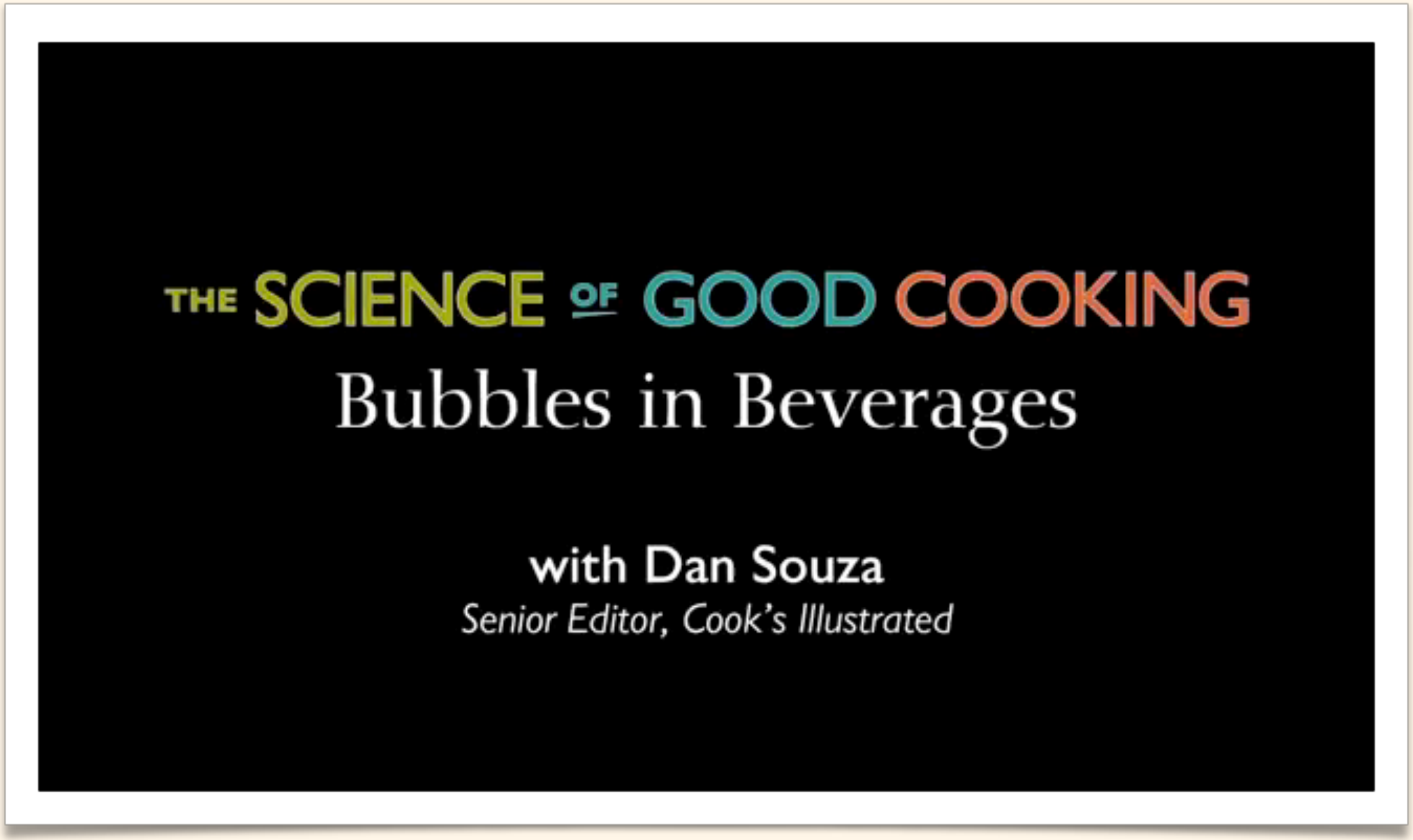

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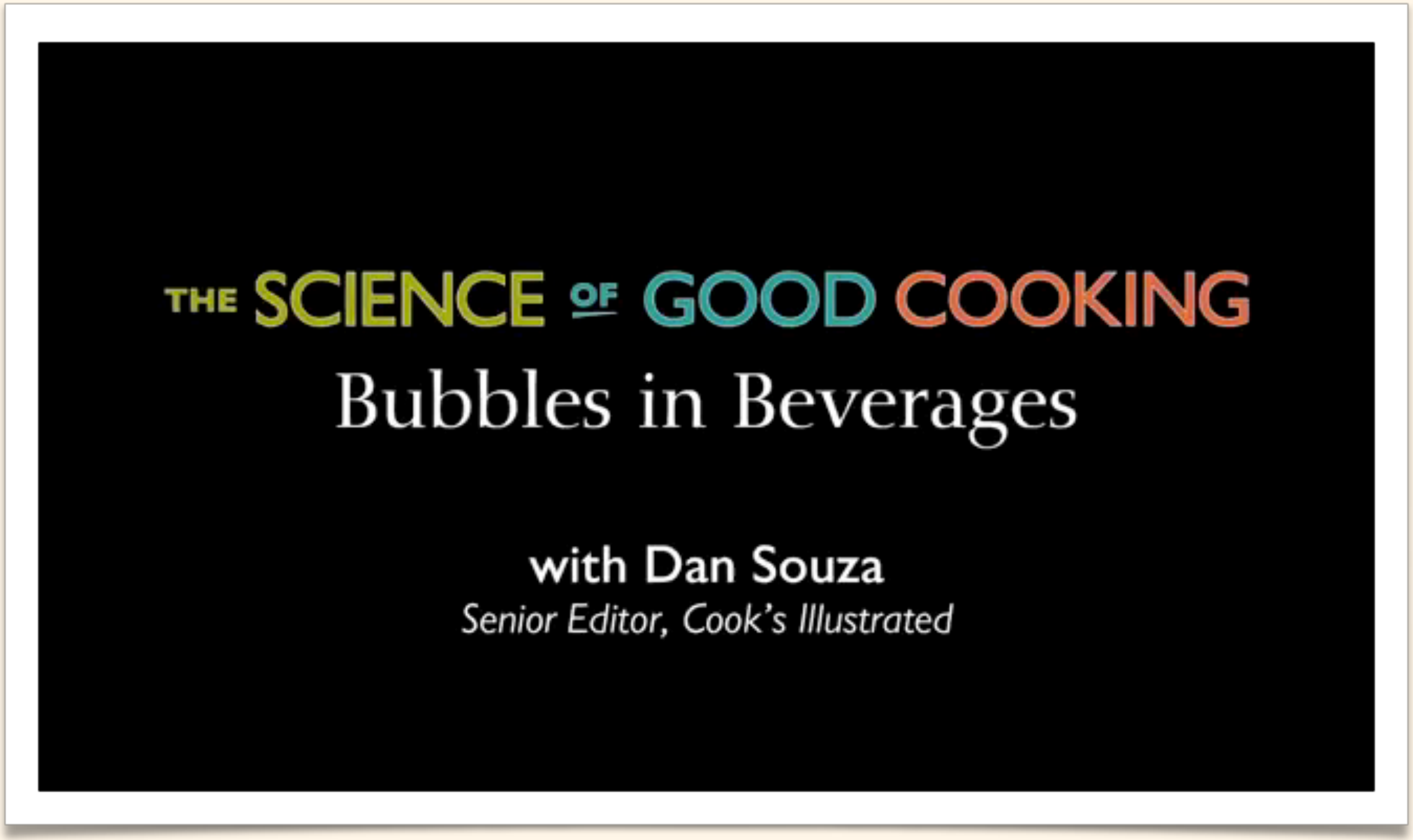
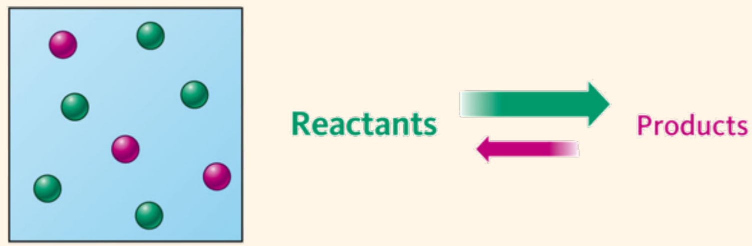


Equilibrium Mixture

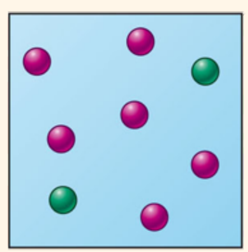
- In the equilibrium mixture, the forward and reverse reactions occur at the same rate.
  - Therefore the number of molecules of each component remains the same.
  - The number of reactant and product molecules will rarely be equal (not 50:50).
  - Each reaction will establish its own equilibrium.

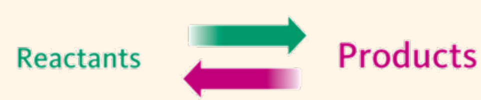
Equilibrium Mixture

At the start, the mixture contains only reactants, so the reaction can only go forward.



After a while, the mixture contains both reactants and products, but the forward reaction is still faster than the reverse reaction.





Chemical equilibrium: the forward and reverse reactions occur at the same rate.

Note that the rates of the two reactions are equal in an equilibrium mixture but the amounts of reactants and products are not.

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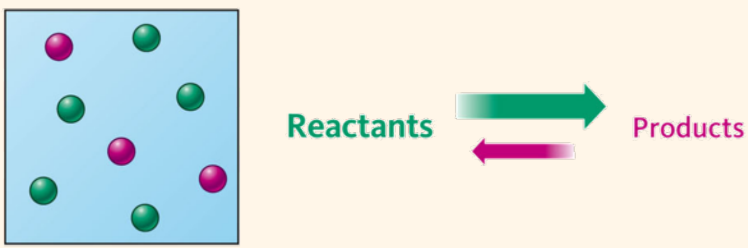

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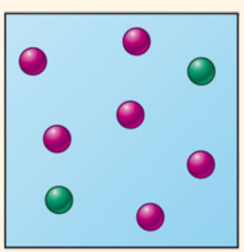

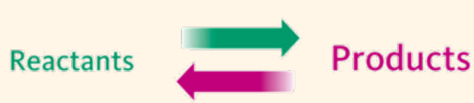

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If you started with only **Products** present, you would reach the equilibrium

Next Up

- Unit 4 - Acids and Bases
    - Reading Assignment: Chapter 7
    - Mastery Assignment due Feb. 17
    - Problem Assignment due Feb. 17