THERMOCHEMISTRY

A Quick Review

Definitions #1

Energy: The capacity to do work or produce heat

Potential Energy: Energy due to position or composition

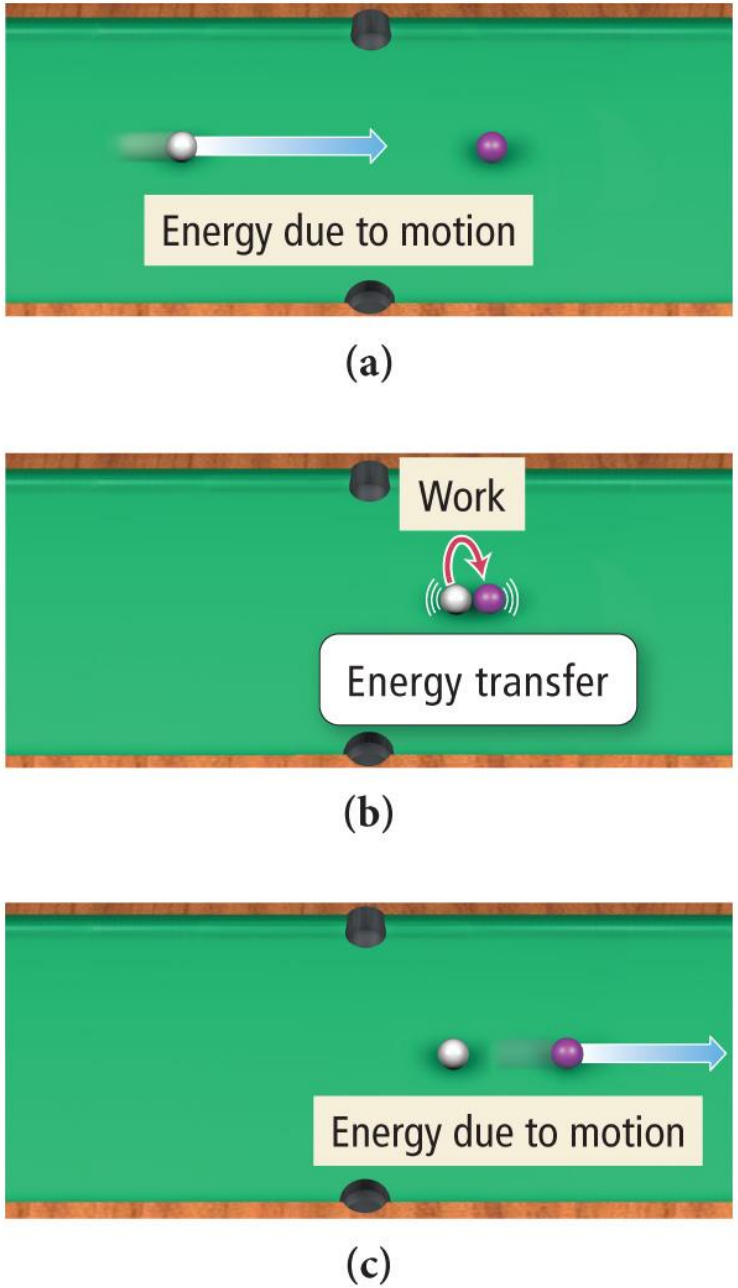
Kinetic Energy: Energy due to the motion of the object

$$KE = \frac{1}{2}mv^2$$

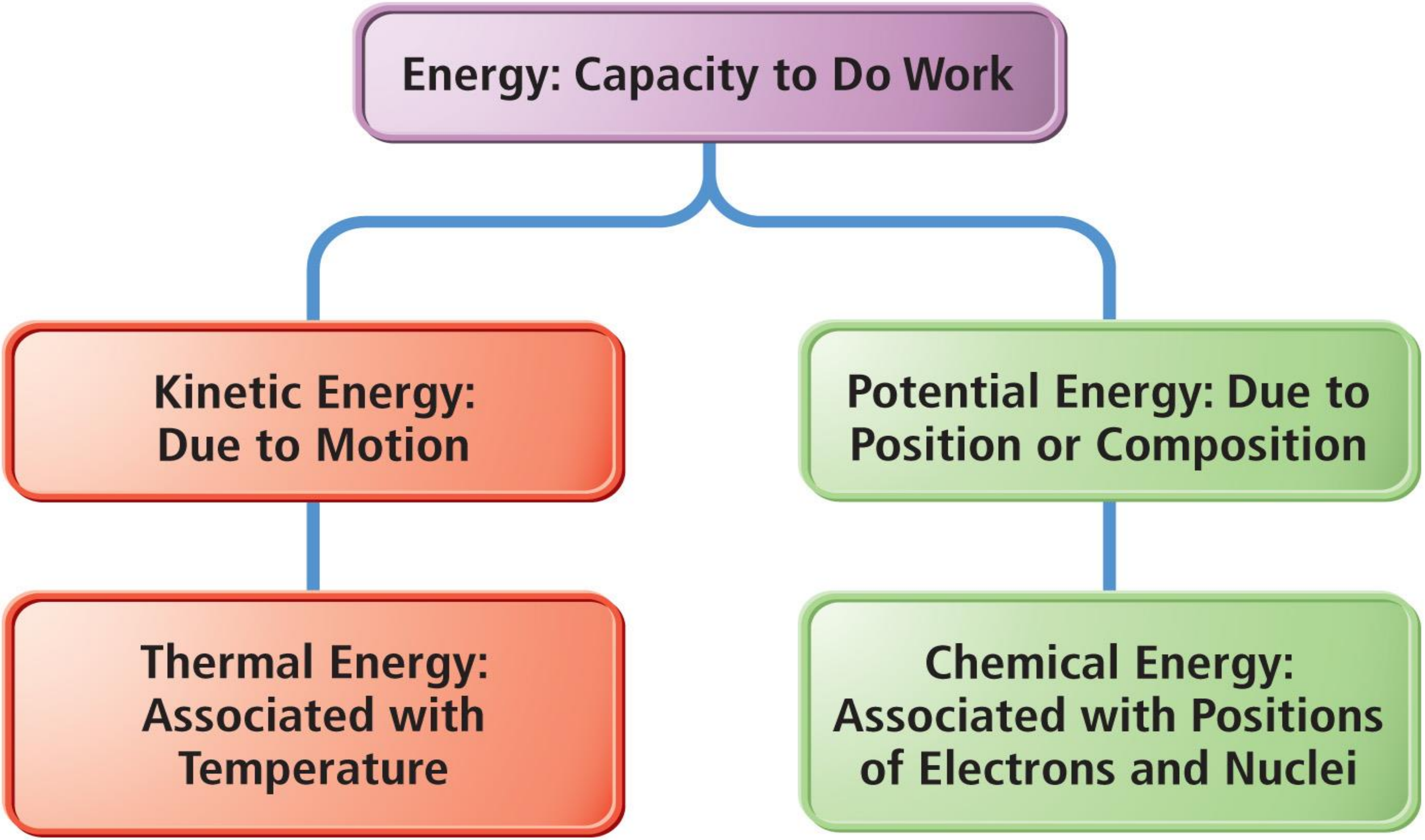
Classification of Energy

- **Kinetic energy** is energy of motion or energy that is being transferred.

- **Thermal energy** is the energy associated with temperature.
  - Thermal energy is a form of kinetic energy.

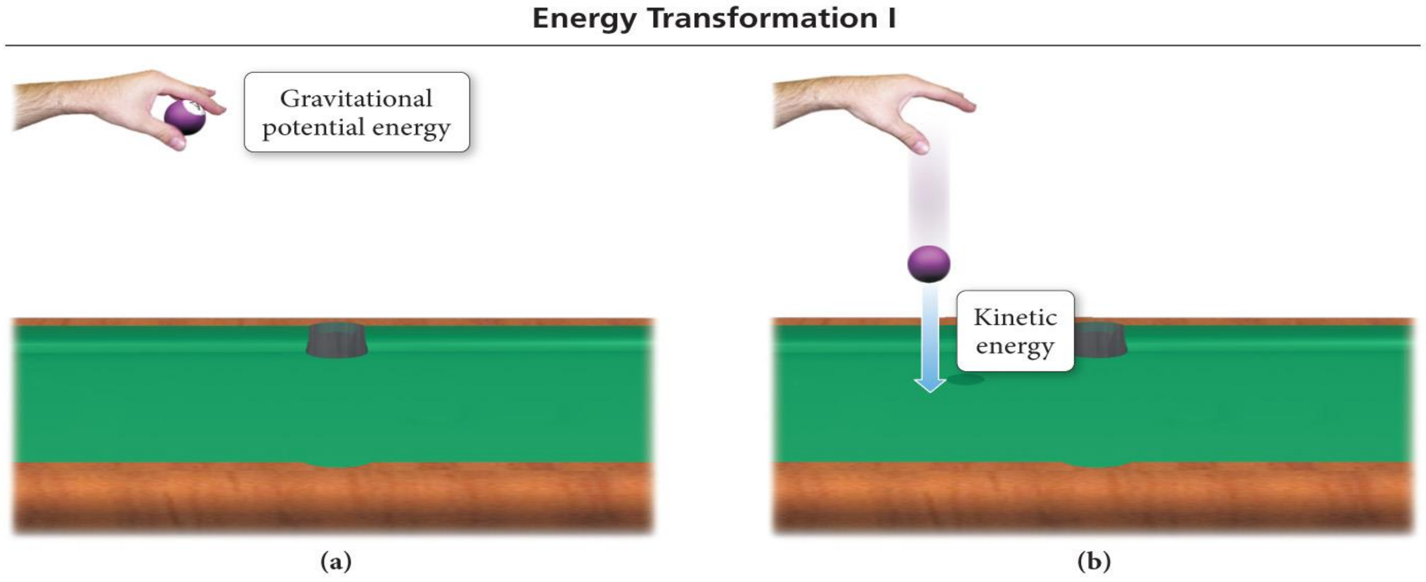


Manifestations of Energy



Classifications of Energy

- **Potential energy** is energy that is stored in an object, or energy associated with the composition and position of the object.
  - Energy stored in the structure of a compound is potential energy.

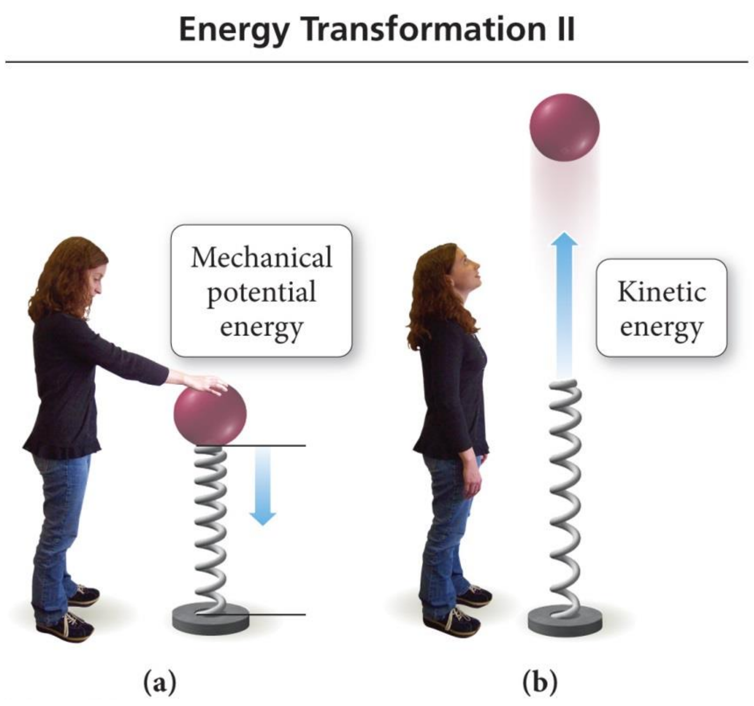


Some Forms of Energy

- **Electrical**
  - Kinetic energy associated with the flow of electrical charge
- **Heat or thermal energy**
  - Kinetic energy associated with molecular motion
- **Light or radiant energy**
  - Kinetic energy associated with energy transitions in an atom
- **Nuclear**
  - Potential energy in the nucleus of atoms
- **Chemical**
  - Potential energy due to the structure of the atoms, the attachment between atoms, the atoms' positions relative to each other in the molecule, or the molecules' relative positions in the structure

Definitions #2

- **Law of conservation of energy** states that energy cannot be created nor destroyed.
- **The First Law of Thermodynamics:** The total energy content of the universe is constant
- When energy is transferred between objects, or converted from one form to another, the total amount of energy present at the beginning must be present at the end.



The First Law of Thermodynamics: Law of Conservation of Energy

- **Thermodynamics** is the study of energy and its interconversions.

- The first law of thermodynamics is the law of conservation of energy.
  - This means that the total amount of energy in the universe is constant.

- Therefore, you can never design a system that will continue to produce energy without some source of energy.

State Functions

Depend ONLY on the present state of the system

ENERGY <u>IS</u> A STATE FUNCTION

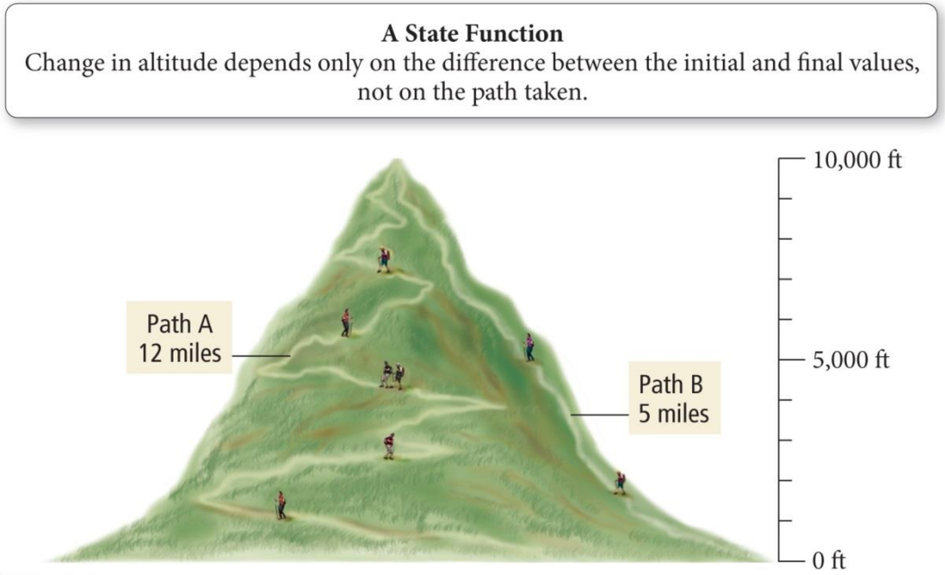
A person standing at the top of Mt. Everest has the same potential energy whether they got there by hiking up, or by falling down from a plane!

WORK <u>IS NOT</u> A STATE FUNCTION

State Function

To reach the top of the mountain there are two trails:

1. Long and winding
2. Short but steep



Regardless of the trail, when you reach the top you will be 10,000 ft above the base.

The distance from the base to the peak of the mountain is a state function. It depends only on the difference in elevation between the base and the peak, not on how you arrive there!

Energy Change in Chemical Processes

Endothermic:

Rxns in which energy flows into the system as the rxn proceeds.

$+ q_{system}$ $- q_{surroundings}$

Exothermic:

Rxns in which energy flows out of system as the rxn proceeds.

$- q_{system}$ $+ q_{surroundings}$

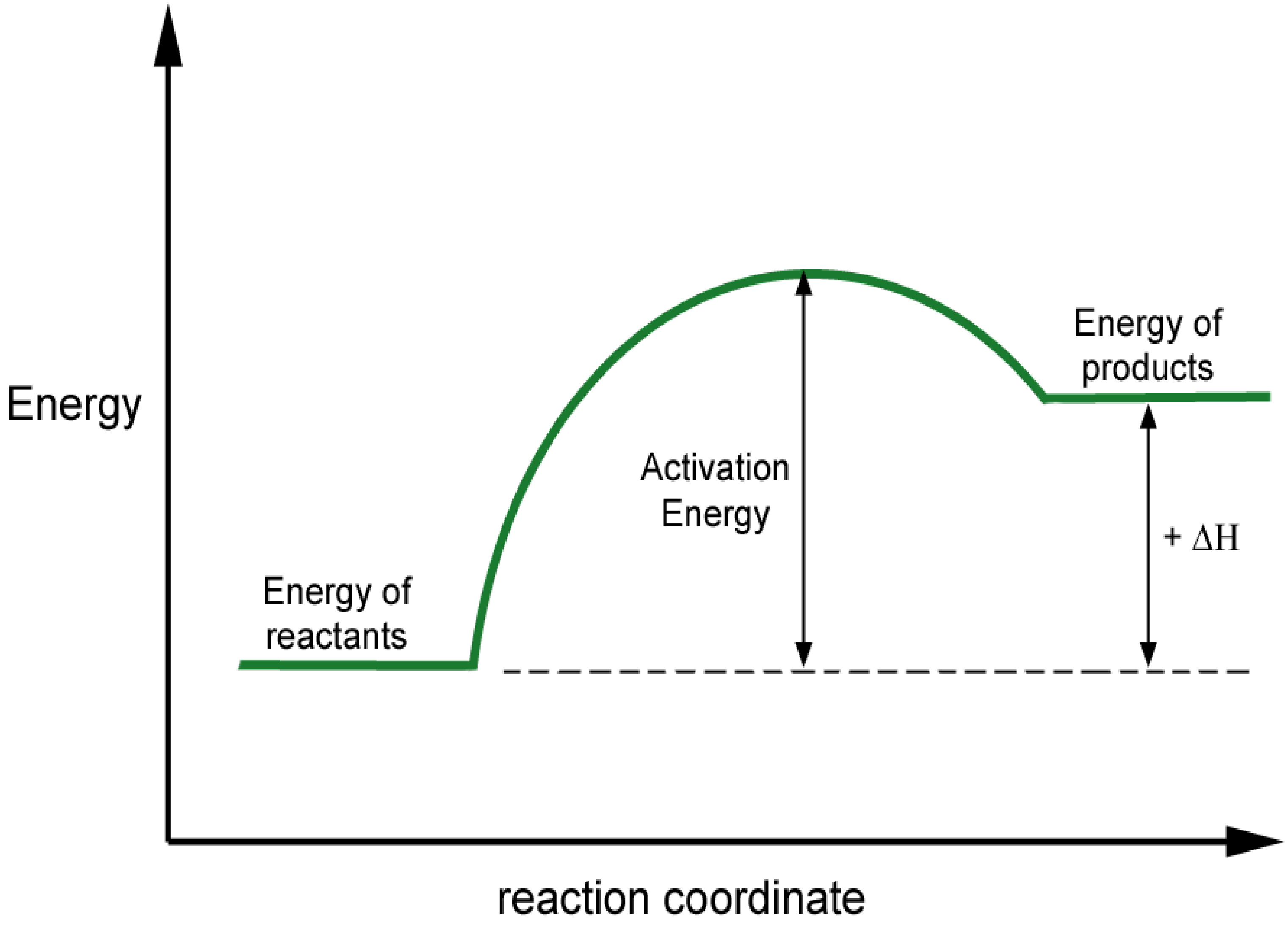
System and Surroundings

- **System -** the material or process which we are studying the energy changes within.

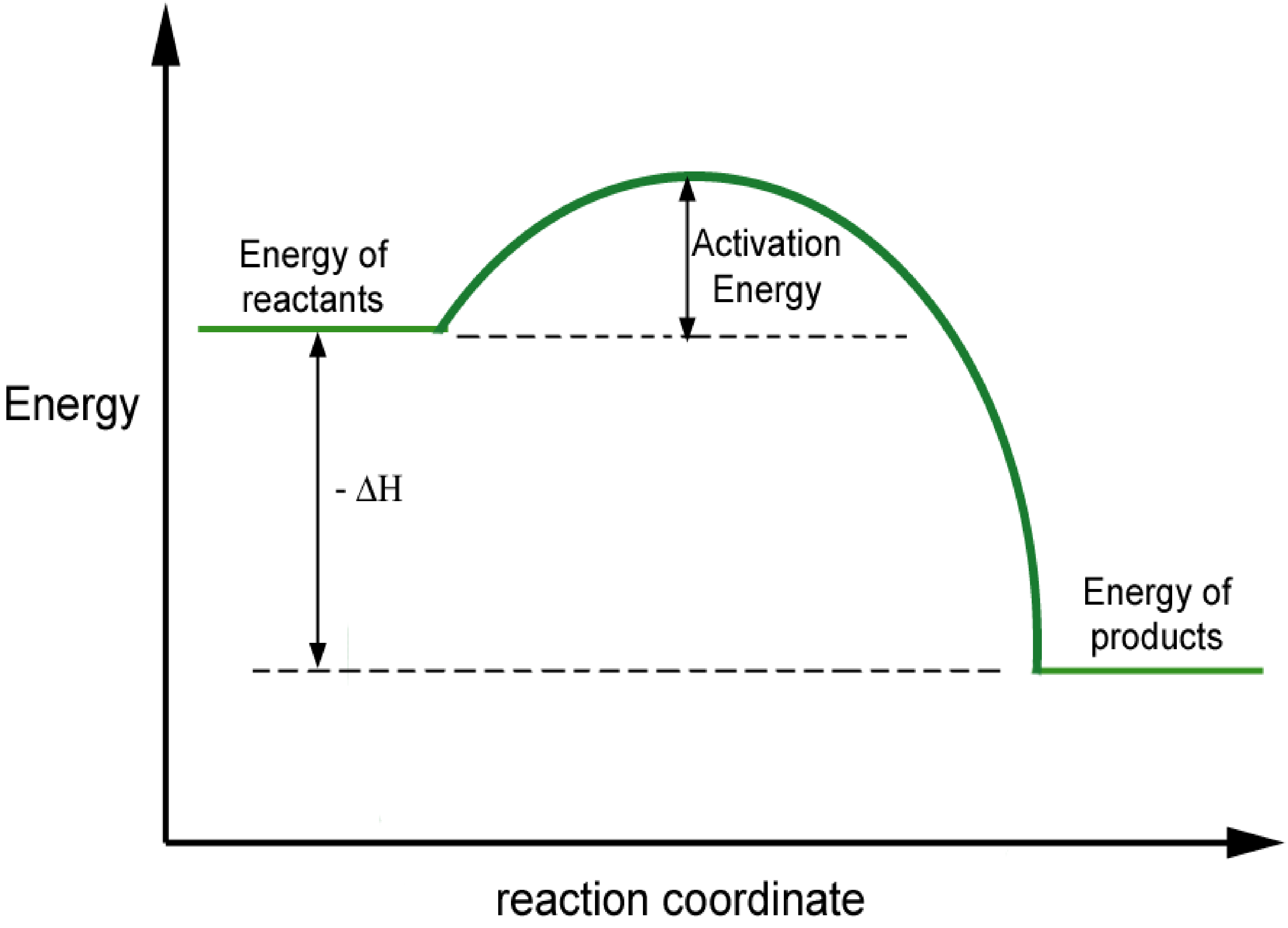
- **Surroundings -** everything else with which the system can exchange energy.

- What we study is the exchange of energy between the system and the surroundings.

Endothermic Reactions



Exothermic Reactions



Calorimetry

The amount of heat absorbed or released during a physical or chemical change can be measured…

…usually by the change in temperature of a known quantity of water

1 calorie is the heat required to raise the temp of 1 gram of water by 1 °C

1 BTU is the heat required to raise the temp of 1 pound of water by 1 °F

Units of Energy

- The amount of kinetic energy an object has is directly proportional to its mass and velocity.

$$\mathbf{KE = \tfrac{1}{2}\mathit{mv}^2}$$

- When the mass is in kg and velocity is in m/s, the unit for kinetic energy is $\dfrac{\boldsymbol{kg \bullet m^2}}{\boldsymbol{s^2}}$

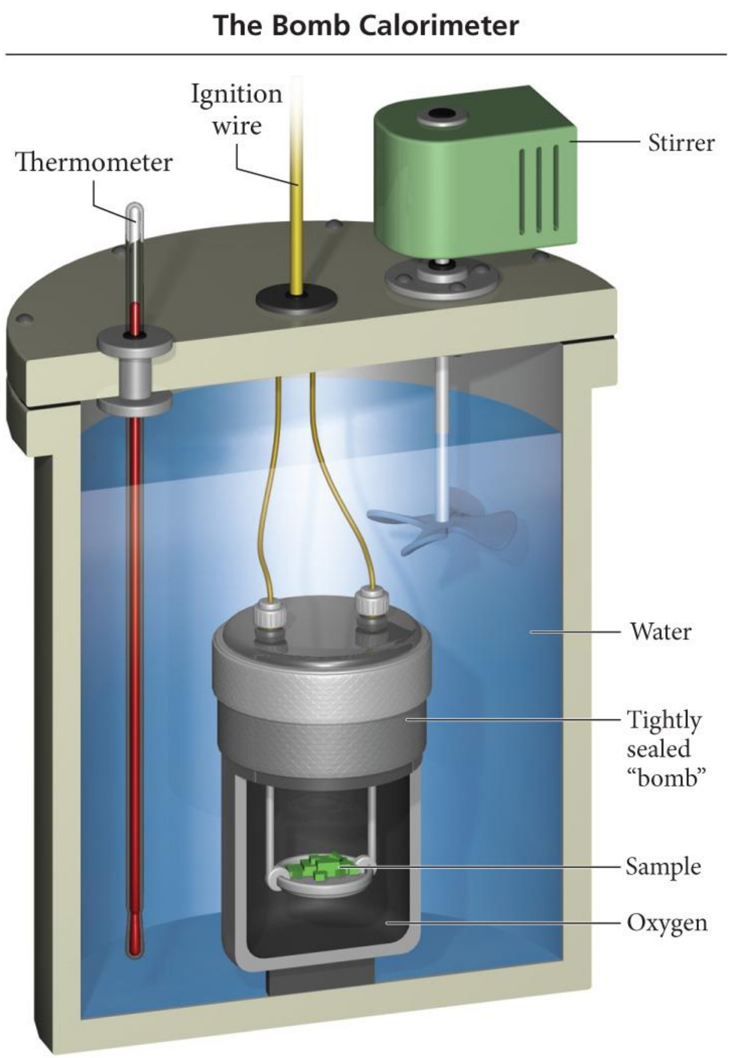
- 1 joule of energy is the amount of energy needed to move a 1 kg mass at a speed of 1 m/s.

$$\mathbf{1\,\mathit{J} = 1\,\dfrac{\mathit{kg} \bullet \mathit{m}^2}{\mathit{s}^2}}$$

Bomb Calorimeter

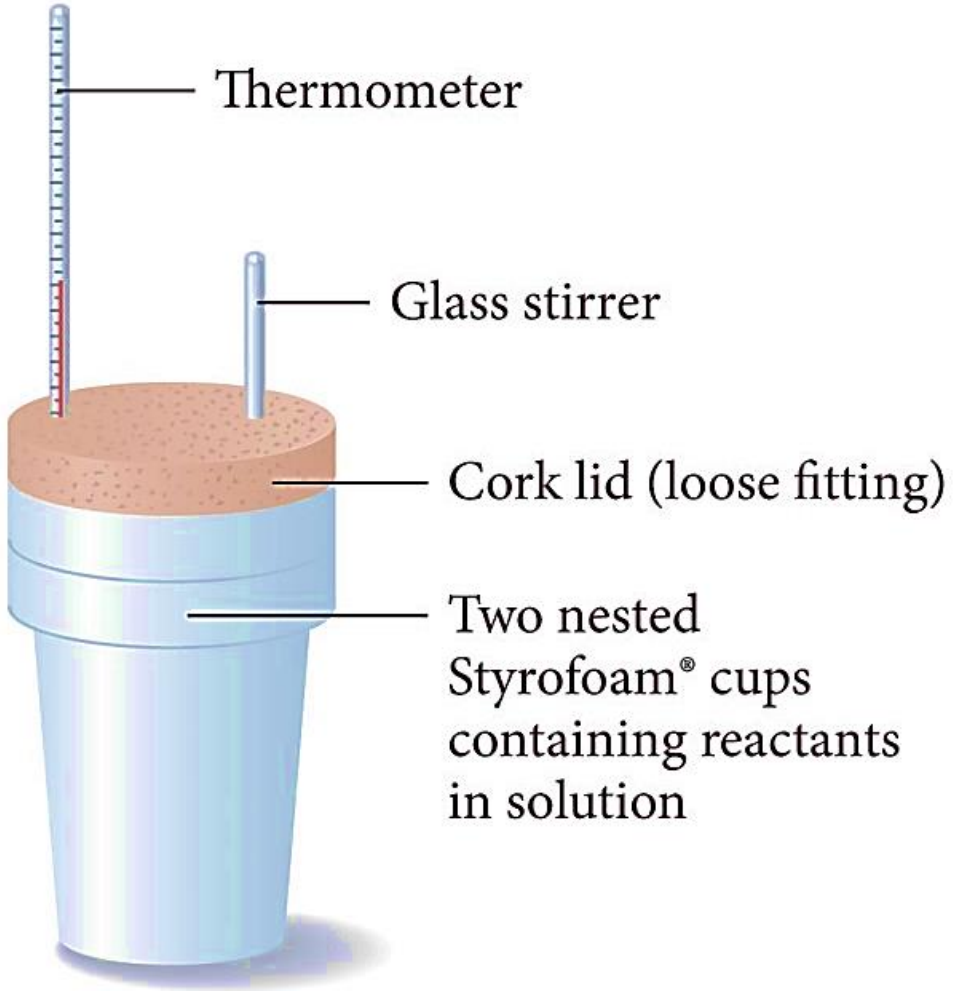
- It is used to measure ΔE because it is a constant volume system.

- The heat capacity of the calorimeter is the amount of heat absorbed by the calorimeter for each degree rise in temperature and is called the **calorimeter constant**.
  - **C_{cal}, kJ/ºC**



Notice how the Ccal has different units! It isn't J/g°C – there is no mass portion! So not Q = mCΔT, just Q = CΔT !

A Cheaper Calorimeter – Coffee Cup!



Specific Heat Capacity

- Measure of a substance's ***intrinsic*** ability to absorb heat.

- **Specific heat capacity** - the amount of heat energy required to raise the temp of one gram of a substance 1 °C.
    - C_s Units J/(g · °C)

- **Molar heat capacity** - the amount of heat energy required to raise the temp of one mole of a substance 1 °C.

TABLE 6.4 Specific Heat Capacities of Some Common Substances

Substance	Specific Heat Capacity, C_s (J/g · °C)*
Elements	
Lead	0.128
Gold	0.128
Silver	0.235
Copper	0.385
Iron	0.449
Aluminum	0.903
Compounds	
Ethanol	2.42
Water	4.18
Materials	
Glass (Pyrex)	0.75
Granite	0.79
Sand	0.84

*At 298 K.

Identical amounts of heat are applied to 50 g blocks of lead, silver, and copper, all at an initial temp of 25°C. Which block will have the largest increase in temp?

A Lead

B Silver

C Copper

D None, all will be at the same temp

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C Copper

D None, all will be at the same temp

$$Q = mC\Delta T$$

$$\Delta T = \frac{Q}{mC}$$

Smallest C gives you largest ΔT

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Calculations Involving Specific Heat

$$q = m \cdot c \cdot \Delta T$$

OR

$$c = \frac{q}{m \cdot \Delta T}$$

c = Specific Heat Capacity

q = Heat lost or gained

ΔT = Temperature change

Thermal Energy Transfer

- A block of metal at 55 °C is added to water at 25 °C.
- Thermal energy transfers heat from the metal to the water.
- The exact temperature change depends on the following:
  - The mass of the metal
  - The mass of water
  - Specific heat capacities of the metal and of water

$$q_{\text{metal}} = -q_{\text{water}}$$

$$m_{\text{metal}} \times C_{\text{s, metal}} \times \Delta T_{\text{metal}} = -m_{\text{water}} \times C_{\text{s, water}} \times \Delta T_{\text{water}}$$

The temperature of a 700.0-g bar of iron decreases by 10.0°C when the iron is plunged into 500.0 g of water. What is the temperature increase of the water, assuming that no heat is lost in the transfer? (C_{Fe} = 0.45 J/g°C)

- A 3.0°C
- B 1.5°C
- C 1.7°C
- D 1.3°C
- E None of the above

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- B **1.5°C**
- C 1.7°C
- D 1.3°C
- E None of the above

$$Qwater = -Qmetal$$

$$mC\Delta T = -mC\Delta T$$

$$(500)(4.18)(\Delta T) = -(700)(0.45)(-10)$$

$$\Delta T = 1.51\ ℃$$

50.0 g of water at 22 °C is mixed with 125 g of water initially at 36 ° C. What is the final temperature of the water after mixing, assuming no heat is lost to the surroundings?

- A 29°C
- B 42°C
- C 32°C
- D 30°C
- E None of the above

50.0 g of water at 22 °C is mixed with 125 g of water initially at 36 ° C. What is the final temperature of the water after mixing, assuming no heat is lost to the surroundings?

<u>*THINK* - Use this to check your work!</u>

50g @ 22°C and 125g @ 36°C with same C…

Won't end exactly halfway. Will end closer to 36°C than 22°C. Cant end at 36°C or higher than 36°C…

A 29°C

B 42°C

C **32°C**

D 30°C

E None of the above

$$Q1 = -Q2$$

$$mC\Delta T = -mC\Delta T$$

$$(50)(4.18)(Tf - 22℃) = -(125)(4.18)(Tf - 36)$$

$$Tf = 32\ ℃$$