CHEM 1315

Unit 3: Thermochemistry

Dr. Laura Clifford

Lecture notes available at https://learn.ou.edu

Learning Objective 3.1:

Utilize and convert different forms of energy

Readings 1.5, 6.1, 6.2, 6.3, 6.4

The nature of energy

Energy is the capacity to *do work* or to *transfer heat*.

Work: Energy used to cause an object with mass to move.

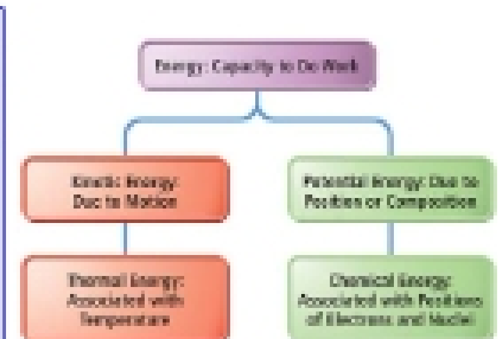
$$w = F \cdot d$$

Heat: Energy used to cause the temperature of an object to increase.

Heat flows from warmer objects to cooler ones.

The nature of energy

- Think of energy as a quantity an object can possess or as a collection of objects.
- Think of heat and work as the two different ways that an object can exchange energy with other objects.



Types 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.

The nature of energy

Chemical reactions are invariably accompanied by energy changes.

The two questions that we need to answer are:

1. *How does matter possess energy?*
   - kinetic energy: the energy an object possesses by virtue of its motion.
   - potential energy: the energy an object possesses as a result of its composition or its position.
2. *How is energy transferred?*
   - Law of conservation of energy

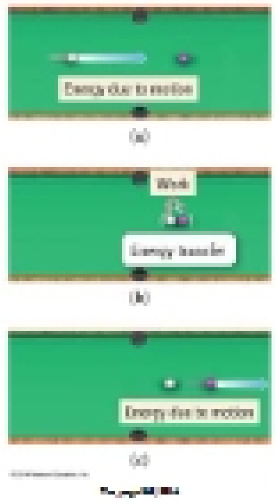
Kinetic Energy

Kinetic energy (KE) is the energy an object possesses by virtue of its motion or energy that is being transferred.

It takes *work* to move objects: Any object that is in motion may collide with another object and move it, thus has the capacity to do work.

The magnitude of the KE (E_k) of an object depends upon its mass (m) and velocity (v):

$$E_k = (½)\, mv^2$$



Thermal Energy

Thermal energy is the energy associated with temperature.

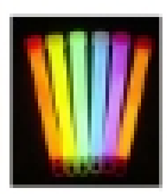
Thermal energy is a form of kinetic energy.

Energy and Energy Changes

How can we relate energy to chemistry?

Kinetic energy: Atoms and molecules have mass and are in motion, therefore they possess kinetic energy.

Potential energy: Chemical energy. Energy is stored in chemical bonds. Breaking bonds can release this stored energy as heat or light.

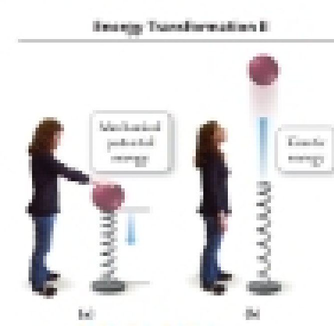


Energy is conserved in chemical reactions (law of conservation of energy)

- To understand the relationship between potential and kinetic energies, *units* are important.

The nature of energy

The law of conservation of energy states that energy cannot be created nor destroyed.



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.

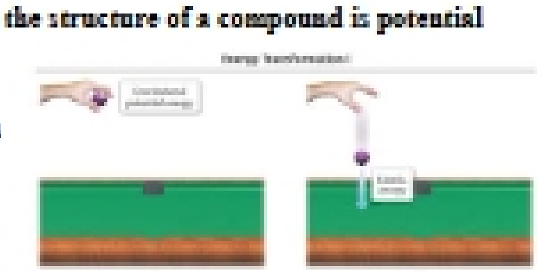
Potential Energy

Potential energy (PE): Potential energy is a retrievable (stored) form of energy that an object possesses by virtue of its position or state (composition).

- Energy stored in the structure of a compound is potential energy.

The magnitude of the PE (E_p) of an object depends upon:

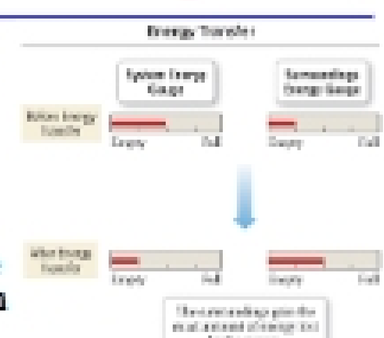
$$E_p = m\cdot g\cdot h$$



m = mass g = gravitational constant (9.8 m/s^2) h = height

System and Surroundings

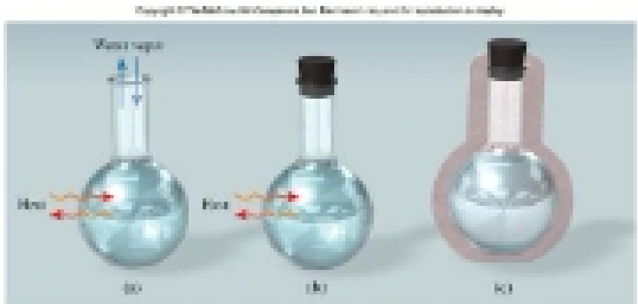
- The system is defined as the material or process within which we are studying the energy changes within.
- The surroundings are defined as everything else with which the system can exchange energy.



Conservation of energy means that the amount of energy gained or lost by the system has to be equal to the amount of energy lost or gained by the surroundings.

Open and Closed systems

Open system (a): exchange of both energy and matter
Closed system (b): exchange of only energy, not matter
Isolated system (c): no exchange of energy or matter



Open and Closed systems – reactions

This system includes the molecules we want to study (hydrogen, oxygen, and water).

The surroundings would be anything else (cylinder and piston).

Matter is not exchanged in a closed system, but energy is.

Energy is exchanged in the form of work and heat.

$$2H_2\ (g) + O_2\ (g) \longrightarrow 2H_2O\ (g) + \text{energy}$$

Units of Energy

A joule (J) is the amount of energy needed to move a 1 kg mass a distance of 1 meter.

- $1\ J = 1\ N \cdot m = 1\ kg \cdot m^2/s^2$

A calorie (cal) is the amount of energy needed to raise the temperature of one gram of water 1 °C.

- kcal = energy needed to raise 1000 g of water 1 °C

TABLE 6.1 Energy Conversion Factors*

1 calorie (cal)	= 4.184 joules (J)
1 Calorie (Cal) or kilocalorie (kcal)	= 1000 cal = 4184 J
1 kilowatt-hour (kWh)	= 3.60×10^6 J

*All conversion factors in this table are exact.

Units of Energy

The SI unit for energy is the joule.

$1\ J = 1\ kg \cdot m^2/s^2$

The calorie content listed in nutritional labels is actually the kcal, or Cal:

1 kCal = 1 Cal = 1000 cal

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.

- The total amount of energy in the universe is constant.
- The sum of the energy changes in the system and the surroundings must be zero.

$$\Delta Energy_{universe} = 0 = \Delta Energy_{system} + \Delta Energy_{surroundings}$$

Δ means change: Final amount − initial amount

Internal Energy

The internal energy is the sum of the kinetic and potential energies of all of the particles that compose the system.

- The change in the internal energy of a system only depends on the amount of energy in the system at the beginning and end.

A state function is a mathematical function whose result only depends on the initial and final conditions, not on the process used.