Module 5: Energy and Chemistry
The Nature of Energy; Energy Units

Fundamentals of Chemistry Open Course

Learning Objectives | Module 5

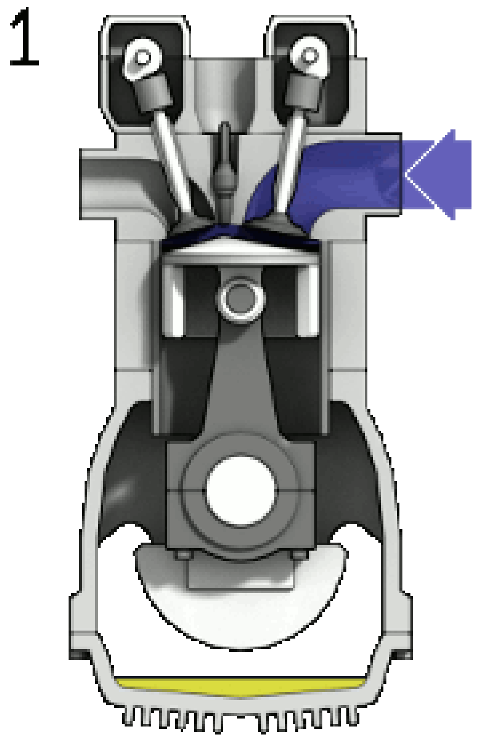
1. Recognize and define energy and the various forms of energy.
2. Recognize and convert between the most common units of energy in chemistry.
3. Conceptualize problems in thermodynamics by properly defining the system and surroundings.
4. Distinguish between open, closed, and isolated thermodynamic systems.
5. Define and apply the first law of thermodynamics.
6. Provide technical definitions for heat and work and distinguish between them.

- **Energy** is the quantitative property of a physical system "recognizable in the performance of work and in the form of heat and light." (source)

- We know energy when we see it: a system with the capacity to do work or transfer heat "has energy."

- **Thermodynamics** is the study of the laws and principles that govern the transfer of energy between physical systems.

- **Thermochemistry** refers specifically to the study of heat transfers associated with chemical reactions or phase transitions.



- We classify energy based on (a) whether it is the result of effects inside or outside a physical system and (b) whether it is the result of motion or position.
  - **External energy** is due to the motion or position of a system with respect to an external reference frame.
  - **Internal energy** is due to the motion or position of particles within a system.
  - **Kinetic energy** is due to the motion of a system or the particles within it.
  - **Potential energy** is due to the relative positions of particles and distance-dependent effects such as gravity and electrical charges.
- What counts as internal or external energy depends on how we define the system—more on this soon.

Units of Energy | 1 of 3

- Energy *manifests* as heat or work; thus, all three quantities share the same units.

- **Work (w)** is the movement of a force through a distance and is defined quantitatively as the product of force and displacement (or an integral over a trajectory, for a position-dependent force).

- Work is commonly expressed in units of Newton-meters or **Joules (J)**.

Joules (kilogram-meters squared per second squared)

$$w = F\Delta x \qquad\qquad w = \int F(x)\,dx$$

Newtons (kilogram-meters per second squared)

meters

- Electrical work is defined analogously as the movement of a charge through an electric potential difference (voltage). The product of charge and voltage has units of energy.

- **Electron-volt (eV):** the elementary charge *e* times one Volt. This is a convenient unit for energy on the submicroscopic level.

Units of Energy | 2 of 3

- Energy *manifests* as heat or work; thus, all three quantities share the same units.

- **Work (*w*)** is the movement of a force through a distance and is defined quantitatively as the product of force and displacement (or an integral over a trajectory, for a position-dependent force).

- **Pressure-volume (*PV*) work** of a gas involves expansion or compression of a gas against a pressure *P*.

Joules (kilogram-meters squared per second squared)

$$w = -P\Delta V \qquad w = -\int P(V)\,dV$$

Pascals (Newtons per meter squared)

meters cubed

- Thus, energy can also be expressed in units of pressure times volume, such as **liter-atmospheres (L·atm)**.

Units of Energy | 3 of 3

- Energy *manifests* as heat or work; thus, all three quantities share the same units.

- **Heat (*q*)** is the transfer of thermal energy. Heat is also commonly expressed in Joules. The **heat capacity (*C*)** of a system relates heat to a change in temperature.

degrees Celsius

Joules

$$q = C\Delta T$$

Joules per degree Celsius

$$q = \int C(T)\, dT$$

- Units of heat may also be defined with respect to a standard process, such as heating liquid water.

- **Calorie (cal):** the heat required to raise the temperature of 1 g of $H_2O(\ell)$ by 1 °C.