Chapter 6: Thermochemistry

Thermochemistry: study of the relationships between chemistry and energy

Energy: capacity to do work

Work: result of a force acting over a certain distance, one way to transfer energy

Types of energy:

- **Kinetic energy**: energy of motion — motion of molecules
    - **Thermal energy:** energy associated with temperature, transferred by **heat**
- **Potential energy**: energy of position or composition
    - **Chemical energy**: energy associated with the composition of chemical compounds

Law of conservation of energy: energy cannot be created or destroyed, only transferred

- One object to another
- One type of energy to another

$W = 1\,J/s$

$\frac{J}{\cancel{s}} \cdot \underline{60\cancel{s}} \cdot 60 \cdot hr$

Units of energy:

- joule (J) = 1 kg · m^2 · s^{-2} (SI unit) $1\,kJ = 1000\,J$
- calorie (cal) = 4.184 J (heat 1 g H_2O · 1 ^oC)   English
- Calorie (Cal) = 1 kcal = 1000 cal (food labels)
- kilowatt-hour (kWh) = 3.60 x 10^6 J
- BTU

System and surroundings

The transfer of energy can be considered in terms of a system and its surroundings

- **System**: a specific place or substance — e.g. a chemical reaction itself
- **Surroundings**: everything outside of the system

In thermochemistry, the system is usually a **chemical reaction**, and it can use heat and work to transfer energy to or from its surroundings:

heat : transfer of energy

- Combustion of natural gas in a furnace

  system: $CH_4 + O_2 \rightarrow CO_2 + 2H_2O$

  sys $\rightarrow$ surr   chem. energy $\rightarrow$ thermal energy

- Combustion of gasoline in a car's engine

  sys $\rightarrow$ surr   chem energy $\xrightarrow{heat}$ thermal energy; chem energy $\xrightarrow{work}$ kinetic energy

- Chemical cold pack

  surr $\rightarrow$ sys   thermal $\rightarrow$ chemical

First law of thermodynamics

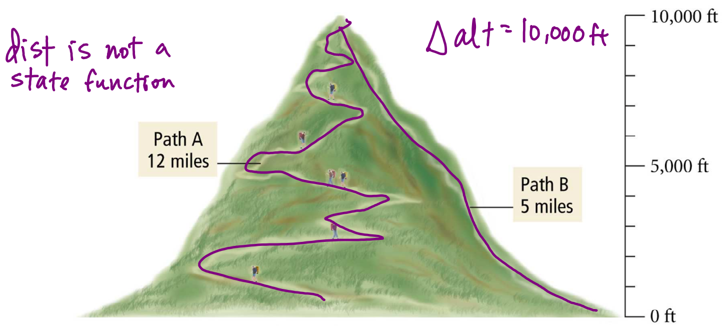
1st law: the total energy of the universe is constant

- law of conservation of energy
- perpetual motion? impossible

Internal energy *(E):* sum of all forms of kinetic and potential energy in a certain system

Internal energy is a state function: it depends **only** on the makeup of the system itself at one point in time, not its history (it doesn't add up over time)

A State Function
Change in altitude depends only on the difference between the initial and final values, not on the path taken.



The **change** in any state function can be considered:

$\Delta E = E_{final} - E_{initial}$

Work and heat

The change in a system's internal energy, ΔE, depends on how much work (w)was done and how much heat was transferred (q):

$\Delta E = q + w$ $(\Delta E = E_{final} - E_{initial})$

Signs are always considered from the system's perspective.

If energy flows **out of** the system, ΔE is: −
If energy flows **into** the system, ΔE is: +

If heat flows **out of** the system, q is: −
If heat flows **into** the system, q is: +

Measuring heat: Calculating the amount of heat transferred

Heat always transfers thermal energy from areas of high temperature to areas of low temperature

Heat capacity *(C)*: heat required to raise the temperature of an object by 1 °C
Units: J/°C

Specific heat capacity *(C_s or s)*: heat required to raise the temperature of **1 g of a substance** by 1 °C
our book
Units: J/g·°C

Calculating heat transfers

$\Delta t = t_{final} - t_{initial}$

For an object, $q = C \cdot \Delta t$

$(J) = (J/\cancel{°C}) \cdot (\cancel{°C})$

For a certain mass of a substance, $q = (C_s) \cdot m \cdot \Delta t$

$(J) = (J/g \cdot °C)(g)(°C)$

How much energy is required to heat 50.0 g water from 25.0 °C to 100.0 °C?

$q = (C_s)(m)(\Delta t)$

$= (4.18\ J/g \cdot °C)(50.0\ g)(75.0\ °C)$

$= 1.57 \times 10^4\ J$

$= \underline{15.7\ kJ}$

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.

How long will this take a 1000 W hotplate (assuming all of the heat is transferred to the water)? (1 W = 1 J/s)

$1.57 \times 10^4\ J \times \frac{1\ s}{1000\ J} = \underline{15.7\ s}$