Thermochemistry

The study of energy transfers and chemical reactions

Energy

- Energy is the ability to do work
- Work = Force x distance
- SI unit is the Joule (J)
- 1000 J = 1 kJ
- other unit: calorie (cal)
- 1000 cal = 1 kcal = 1 Cal (food)
- 1 cal = 4.184 J

A few terms...

- System: what we are observing
  - beaker, battery, cell, atmosphere, etc.
- Surroundings: everything outside of the system
- Boundary: a separation between system and surroundings
  - (real or imaginary)

A few terms…

- If a system is prevented or hindered from transferring heat past the boundary, it is *insulated*

A few terms...

- the *state* of the system is its temperature (T), pressure (P), volume (V), concentration, phase (s,l,g,aq)

- a change in any of these (ΔT, ΔP, ΔV, *etc*.) is a change in the state of the system

There are many forms of energy

- Electrical
- electromagnetic
- nuclear
- heat
- chemical
- mechanical

- All are inter-convertible
- chemical reactions usually involve at least heat and chemical

There are two **types** of energy

- **Kinetic**
  - $KE = {}^{1}/_{2}mv^{2}$
  - energy due to *motion*
  - ***HEAT***
- **Potential**
  - depends on position or *composition*
  - ***ATTRACTIVE FORCES***

Potential Energy

- The **attraction** between two objects may be gravitational, electrostatic, magnetic, or in the nucleus, the "strong" force
- PE is the energy added to the system whenever work must be done to change the distance between two objects

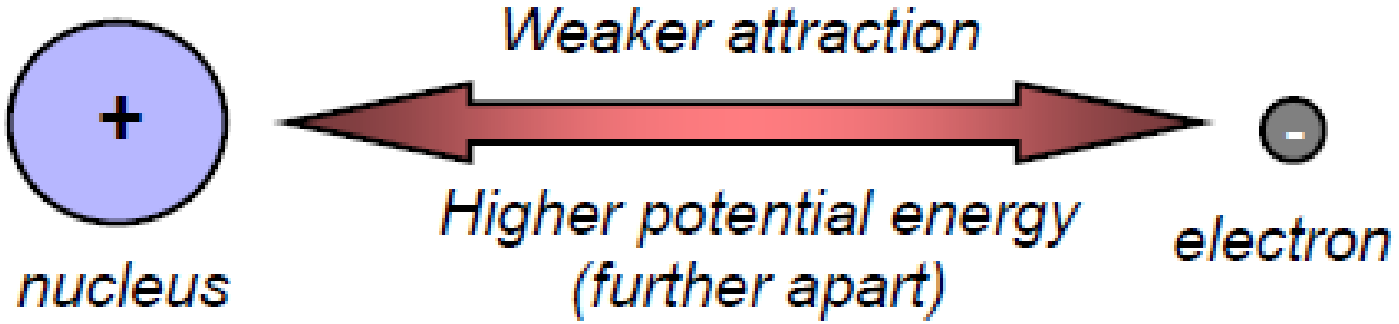
Potential Energy

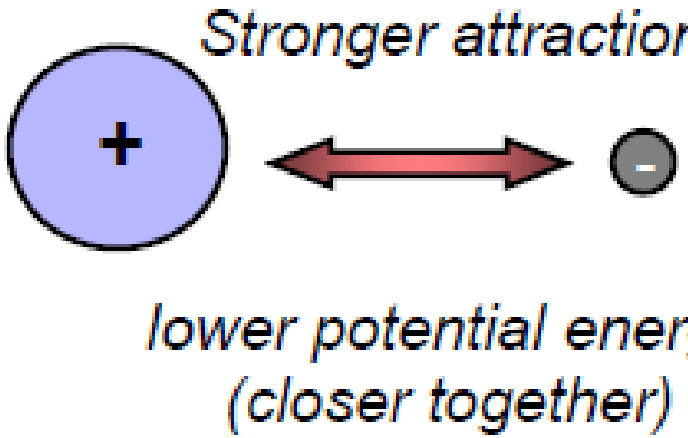
- Whenever attractions are allowed to **form**, energy is **RELEASED**
  - A decrease in PE

- Whenever attractions are **broken**, energy must be **ABSORBED**
  - An increase in PE

Potential Energy in Atoms and Molecules

electron-proton attraction





Coulomb's Law:

$$F = k\, q_1 q_2 / d^2$$

There are three forms of Potential Energy

- gravitational
  - Depends on your position
- elastic
  - Based on the degree of compression
- **chemical**
  - Based on the arrangement of atoms within a compound

Kinetic Energy

- Heat energy is a form of kinetic energy
  - hotter ≈ faster

How Atoms and Molecules Possess Energy

***Kinetic Energy* - in any substance, whether it's a solid, liquid, or gas, the individual particles are in constant, random, motion**

Gas = "bouncing" around

Liquids = "sliding" around

Solids = vibrations

The average Kinetic Energy is directly proportional to the absolute Kelvin temperature

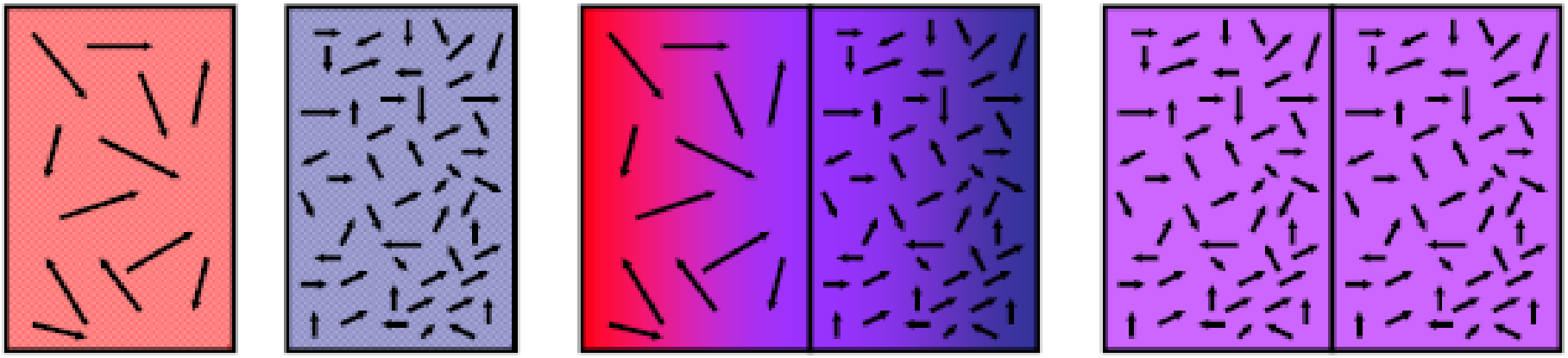
Heat flow

- Heat: the Energy that flows between any two objects at different temperatures that are in contact with each other.
  - From the higher T object to the lower T object
- Two objects at the same T are said to be at “thermal equilibrium”.

Heat = Kinetic Energy

→ = High KE

- = Low KE



HOT **COLD**

When brought into contact...

Collisions transfer KE from hot to cold until equalized

Heat "flows" from the hot object to the cold

What is heat, anyway?

- The *amount* of heat is equal to the total KE of all the molecules of a system

- the *degree* of heat, or the temperature, is related to the average KE of the molecules of a system

- All forms of energy are interconvertible
- because heat is easy to measure, ΔE is usually considered to be heat lost or gained by a system
- the symbol for heat is q

Energy Changes in Chemical Reactions

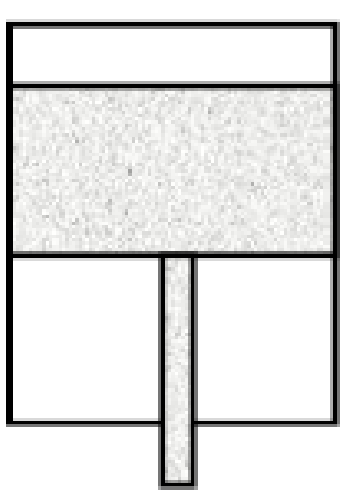
In virtually every chemical reaction, heat is either lost or gained. How can we think of this in terms of kinetic and potential energy?

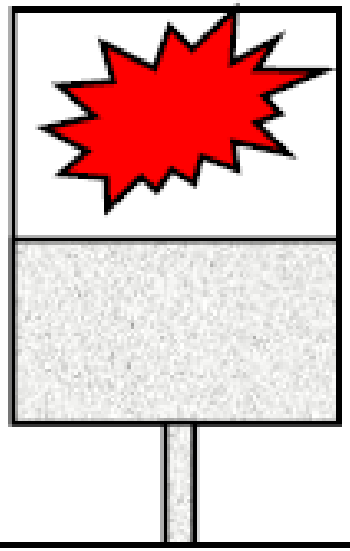
gasoline

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O + \text{heat}$$

high PE, low KE

Low PE, high KE

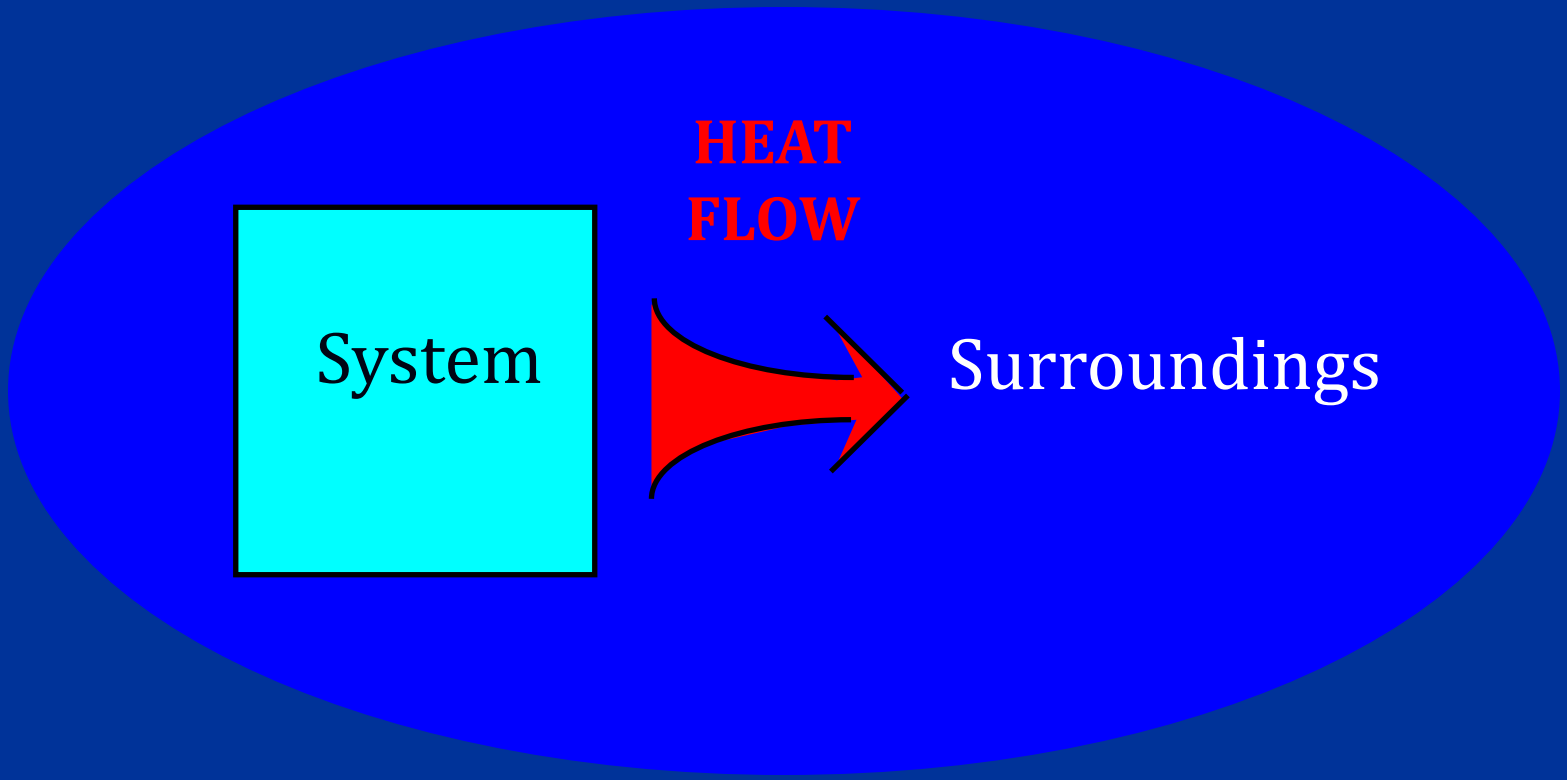




Exothermic reactions

- Reactions that involve the release of energy are called exothermic
- energy (heat) flows *from* the **system** *to* the **surroundings**
  - ex. combustion, luminescence
- may feel "hot", because your hand is part of the surroundings

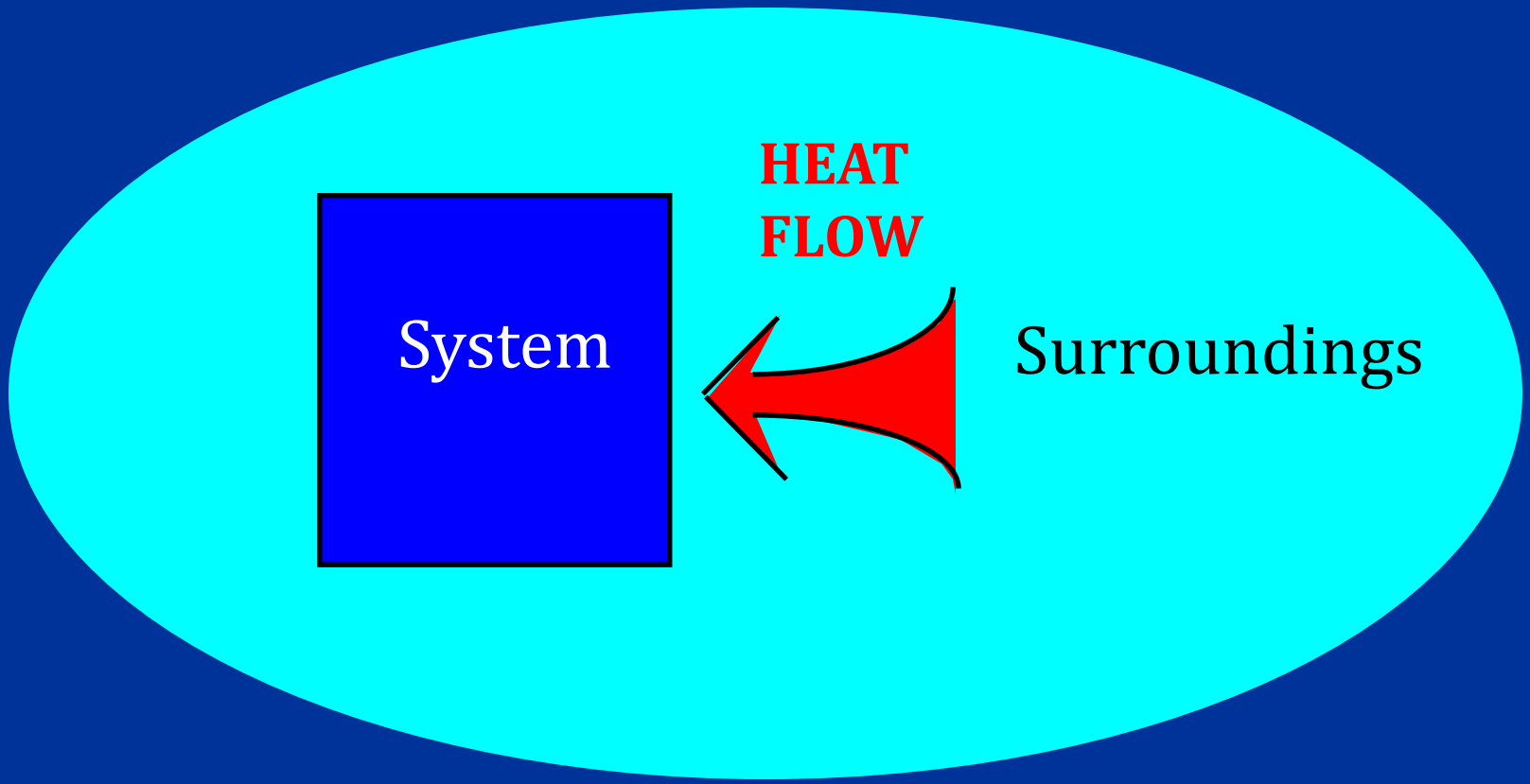
Exothermic reactions



Endothermic reactions

- Reactions that absorb energy are called endothermic
- energy (heat) flows *from* the **surroundings** *to* the **system**
  - cold packs, photosynthesis
- may feel "cold", because your hand, part of the surroundings, is losing heat to the system

Endothermic reactions



Heat Flow

- Molecules that compose matter are in constant motion
  - Translational
  - Rotational
  - vibrational
- Energy may be transferred from one object to another during collisions between the molecules

Heat flow

- There are three possible methods for heat transfer:

1. Conduction
2. Convection
3. Radiation

Conduction

- The transfer of heat by collisions between the particles in a substance (especially a solid)
- Solids made of particles with loosely held electrons are good conductors

  ex: metals

Convection

- The transfer of heat in a fluid (gas or liquid) by means of currents in the heated fluid.
- As the more energetic (“hotter”) molecules move throughout the fluid, they transfer heat to surrounding molecules via collisions
- Ex: water in a pot, warm air in a room

Radiation

- The transfer of heat by way of electromagnetic radiation
- Also known as “radiant energy”
- Ex: energy from the sun or a heat lamp
- Often in the infra-red part of the spectrum
- *NOT* nuclear radiation

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