Announcements for Monday, 11NOV2024

- Exam 2 is now available for reviewing through ***Gradescope***
- Requests for Exam Question Regrades
  - Wednesday, 13NOV2024, 12:01 AM (EST) – Friday, 15NOV2024, 11:59 PM (EST)
  - MUST be submitted through ***Gradescope*** (do not email instructors)
  - See Canvas announcement regarding policies and procedure

ANY GENERAL QUESTIONS? Feel free to see me after class!

Try These On Your Own

Assign oxidation numbers to all species and determine if the reaction is a redox. If it is, identify the oxidizing agent and the reducing agent.

$$2\,\underset{\text{oxidizing agent}}{\overset{+2}{N}\overset{-2}{O}}(g) + 5\,\underset{\text{reducing agent}}{\overset{0}{H}_2}(g) \longrightarrow 2\,\overset{-3}{N}\overset{+1}{H}_3(g) + 2\,\overset{+1}{H}_2\overset{-2}{O}(g)$$

$$\overset{+5}{N}_2\overset{-2}{O}_5\,(aq) + \overset{+1}{H}_2\overset{-2}{O}(\ell) \longrightarrow 2\,\overset{+1}{H}\overset{+5}{N}\overset{-2}{O}_3(aq)$$ **Not a redox reaction**

$$5\,\underset{\text{reducing agent}}{\overset{+2}{Fe}^{2+}}(aq) + 8\,\overset{+1}{H}^{+}(aq) + \underset{\text{oxidizing agent}}{\overset{+7}{Mn}\overset{-2}{O}_4^{-}}(aq) \longrightarrow 5\,\overset{+3}{Fe}^{3+}(aq) + \overset{+2}{Mn}^{2+}(aq) + 4\,\overset{+1}{H}_2\overset{-2}{O}(\ell)$$

Chapter 9: Thermochemistry

Some questions we'll try to answer

- What is energy in general and what are some specific forms of energy?
- In what ways can energy transfer from one object to another?
- What kinds of energy changes accompany chemical processes?
- How can energy changes of chemical reactions be directly measured?
- How can energy changes of chemical reactions be indirectly measured or calculated?
- What is enthalpy and how can a change in enthalpy be used as a conversion factor?

Thermochemistry

- along with matter, energy is a major component of our physical universe
- in chemical processes, matter changes
  - energy changes as well
  - matter and energy interchange but are never created or destroyed
- **thermochemistry =** the study of the relationship between chemistry and energy
  - deals with the energy changes that occur during chemical processes
  - monitoring and quantifying energy exchanges/transfers between chemical reactions and their surroundings
  - direction of transfer is important and expressed using mathematical sign

Some Key Terms

- **energy =** capacity to do work
- **work =** a transfer of energy resulting from a force acting over a distance
    - pushing a box across a floor
- **heat =** a transfer of energy resulting from a temperature difference
    - a hot beverage sitting at room temperature
- matter contains energy but doesn’t contain work or heat
    - work and heat are ways matter ***exchanges*** energy

the law of conservation of energy = energy can neither be created or destroyed; it can be converted from one form to another

Some Forms of Energy

- **kinetic energy =** energy associated with motion
  - a bullet fired from a gun
- **thermal energy =** energy associated with the temperature of an object
  - due to the movement of atoms and molecules within an object
- **potential energy =** stored energy; energy associated with an object's position or composition
  - a compressed spring or drawn rubber band
- **chemical energy =** energy associated with the relative positions of electrons and nuclei in atoms and molecules
  - energy in bonds and interactions between atoms/molecules

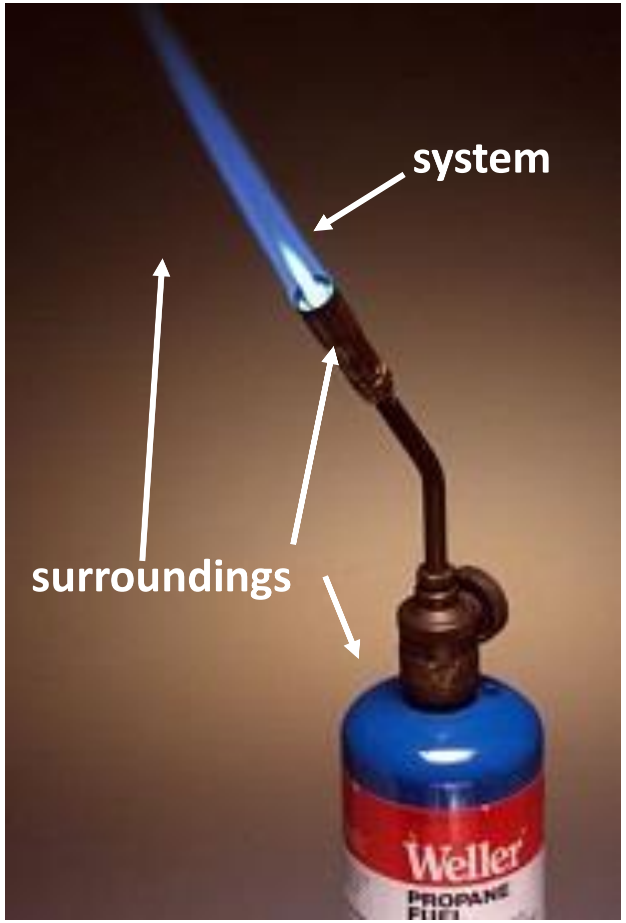
<u>common energy units</u>

- in SI units: $kg{\cdot}m^2/s^2$
- joule (J), kilojoule (kJ), calorie (cal), kilocalorie (kcal or Cal), liter-atmosphere (L·atm)

System vs Surroundings

<u>energy transfers always occur between two frames of reference</u>

- **system =** the objects (atoms/molecules) directly under investigation
- **surroundings =** everything else that can interact with and transfer energy with the system



- example: combustion of propane
- $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$
- system: the molecules of C_3H_8, O_2, CO_2, and H_2O involved in the reaction
- surroundings: the surrounding air, the metal torch…everything else
- energy transfers always occur between system and surroundings
- specifically defining or identifying the system is an important step in many thermochemical problems

Internal Energy (E)

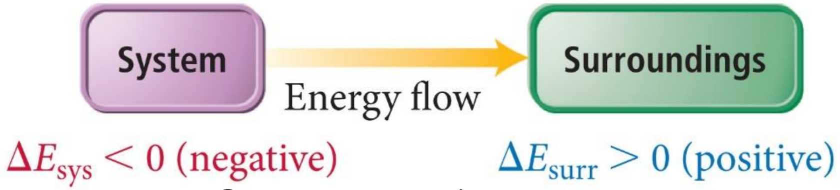
- **thermodynamics =** the study of energy and its interconversions
- The first law of thermodynamics: the total energy of the universe is constant
- **internal energy of a system (E) =** the total energy of a system
  - it is the sum of the kinetic and potential energies of all particles making up a system
- it is a **state function**
  - its value only depends on the current state of the system and NOT how the system arrived at that state
  - the state of a chemical system is specified by certain parameters such as temperature, pressure, concentration, physical state, etc.
  - **path function =** DOES depend on the path that the system goes to achieve a certain state
- the internal energy of a system can be changed by exchanging energy with the surroundings

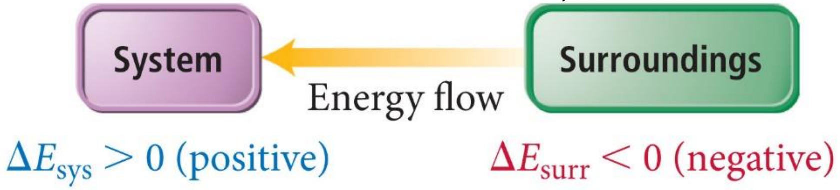
Internal Energy Change (ΔE)

- change in internal energy (ΔE) = the difference between the initial state and the final state
- $\Delta E = E_{final} - E_{initial}$
  - ALWAYS FINAL – INITIAL; NEVER THE OPPOSITE!
- in a chemical system: $\Delta E = E_{products} - E_{reactants}$
- we can monitor either the change of energy of the system (ΔE_{sys} or ΔE) or of the surroundings (ΔE_{surr})
  - unless stated by a subscript, ΔE is always from the point of view of the system

<u>possible signs of ΔE</u>

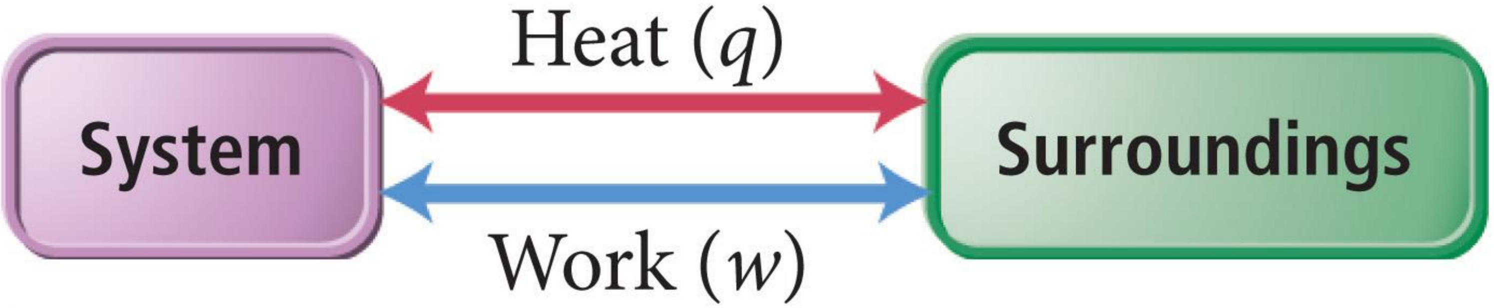
- ΔE (–): $E_{final} < E_{initial}$
  - energy **released by the system** *into the surroundings*
  - ***exo****thermic*
- ΔE (+): $E_{final} > E_{initial}$
  - energy **absorbed by the system** *from the surroundings*
  - ***endo****thermic*





Changing the Internal Energy of a System

the internal energy of a system can be changed through energy transfers with the surroundings by 2 main mechanisms:



<u>energy transfers through heat (q)</u>

(+) q: **system ABSORBS** heat **FROM the surroundings**

(–) q: **system RELEASES** heat **INTO the surroundings**

<u>energy transfers through work (w)</u>

(+) w: work is done **ON the system BY the surroundings**

(–) w: work is done **BY the system ON the surroundings**

Changing the Internal Energy of a System (continued)

★ a mathematical representation of the first law of thermodynamics

$$\mathbf{\Delta E = \mathit{q} + \mathit{w}}$$

A cylinder and piston assembly is heated, causing the contents of the cylinder to expand. If the cylinder absorbed 559 J of heat and performed 488 J of work, calculate the value of ΔE. **+71 J**

Quantifying Heat (q)

- the thermal energy of a system can be changed by transferring energy as heat
  - adding or removing heat will lead to a change in temperature
- when a system absorbs heat, q is (+) and the temperature of the system goes up
  - for the system: $\Delta T = T_{final} - T_{initial}$ = (+) when q (+)
- when a system releases heat, q is (–) and the temperature of the system goes down
  - for the system: $\Delta T = T_{final} - T_{initial}$ = (–) when q (–)
- we can see that $\Delta T \propto q$
- upon absorbing or releasing heat, the magnitude of ΔT will also depend on the amount of matter within the system and the intrinsic of the capability of the matter to absorb heat
  - more matter requires more heat to bring about a given temperature change
  - some matter absorbs heat more readily than other matter
    - this property is called heat capacity