# Thermochemistry

The study of energy transfers and chemical reactions

# 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 flow

- A + or - sign is used to show the **direction** of heat flow

exothermic changes ⇒ heat leaves the system

- -q

endothermic changes ⇒ heat is gained by the system

- +q

# Thermal Properties

- Properties of a substance that relate to its ability to absorb or release heat without chemically changing
- *heat capacity*
- *specific heat*

# Heat capacity (C)

- The amount of heat that must move into an entire object to raise its temperature by 1°C
- units are J/°C or cal/°C
- specific for that object
- $q = C\Delta T$

# Specific heat (s)

- The amount of heat that must move into 1.0g of a substance to raise its temperature 1°C
- units are J/g°C or cal/g°C
- specific for that substance, *regardless of the amount*
- $q = ms\Delta T$

# $q=ms\Delta T$

m (mass) and s (specific heat) are ALWAYS POSITIVE numbers!

- The sign on $\Delta T$ determines the sign on q
- T⇑, $\Delta T$ is (+), q is (+) → heat flows into the system (endothermic)
- T⇓, $\Delta T$ is (-), q is (-) → heat flows out of the system (exothermic)

- The unit for heat called the *calorie* comes from the specific heat of liquid water
- it takes 1.00 cal of heat to raise the T of 1.00 g of $H_2O_{(l)}$ by $1^{o}C$
- remember, 1 cal = 4.184J
- $S_{H2O}$ = 1.00 cal/g$^{o}$C = 4.184 J/g$^{o}$C

# The **larger** the specific heat,...

- The "harder" it is to heat or cool a substance
  - *The more heat that must flow to cause a $\Delta T$*
- the specific heat of water is relatively large
  - it takes a lot of energy to "heat up" $H_2O$ *(⇑the T)*
  - the $H_2O$ retains the heat well
  - biological, climactic effects

# $q=ms\Delta T$ Another perspective…

- Heat flow = energy = q…
  - instead of "**energy**", think "**money**"
- The amount of a $\Delta T$ you can "buy" depends on how much **q** you can "spend"
- The specific heat **(s)** is like the "cost/item"
  - The larger the s, the "more expensive" the $\Delta T$ will be
    - The more q it will "cost" you to "buy" the same size $\Delta T$

# Example problem

- Cu has a specific heat of *s* = 0.387 J/g°C. How much heat is needed to be absorbed by 27g of copper to raise the T from 50°C to 70°C?
- $q = ms\,\Delta T$
- $q = (27 g)(0.387\ J/g^{o}C)(+20^{o}C)$
- $q = +209\ J$

# Example problem

- How much heat is released if 250mL of water cools from 80°C to 25°C? (1.0 g = 1.0 mL)
- $q = ms\Delta T$
- $q=(250g)(4.184\ J/g^{o}C)(-55^{o}C)$
- $q = -57,530\ J = -57.5\ kJ$

# Example problem

- What is the final T of 400mL of $H_2O$ at 30°C if it absorbs 5 kJ of heat?
- $q = ms\,\Delta T$
- $+5000J = (400g)(4.184\ J/g^{o}C)(\Delta T)$
- $\Delta T = +3^{o}C$
- $T_f = 33^{o}C$

# calorimetry

- A *calorimeter* is a device used to measure the $\Delta T$ for a reacting system
- Often, filled with water to absorb or release heat
- The apparatus (and any water within in) are part of the **SURROUNDINGS**

- Because the heat is absorbed by or released mostly from the water, and a bit from the calorimeter, *measuring $\Delta T$ of the water allows one to measure q for the reaction*

Heat out of system = Heat into surroundings

$$q_{rxn} = -(q_{H2O} + q_{cal})$$

$$q_{rxn} = -(ms\Delta T + C\Delta T)$$

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