Energy Changes and Rates of Reaction

Thermochemistry

* Thermochemistry: The study of the energy changes that accompany physical or chemical changes in matter.

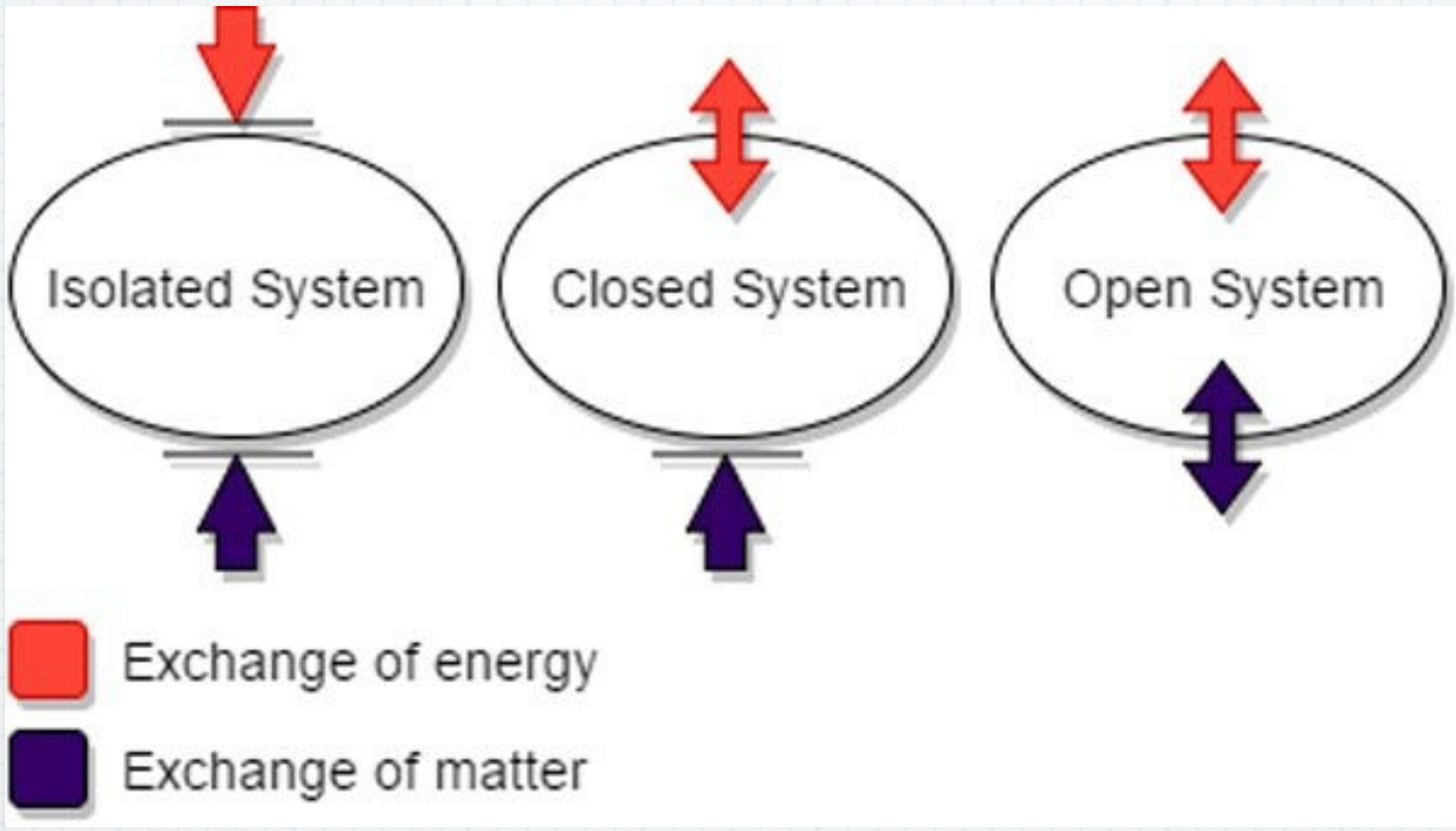
* Changes can be classified as:
  * Physical (hydrogen boils at -252)
  * Chemical (hydrogen burns as fuel)
  * Nuclear (hydrogen undergoes nuclear fusion)

* **Thermal Energy** - energy available from a substance as a result of the motion of its molecules

* **Temperature (T)** - the average kinetic energy of the molecules in a sample, measured in °C or K

* **Heat (q)** - amount of energy transferred between substances, measured in Joules (J)

Energy flows between substances because of their difference in temperature.



Open System: can exchange matter and energy with surroundings

Closed System: can exchange only energy with surrounding

Isolated System: cannot exchange energy or matter with surrounding

Thermal Energy: sum of all the kinetic energies of all the particles of a sample of matter

Temperature: measure of the average kinetic energy of all the particles of a sample of matter

Coffee cup has a higher temperature (90 C)

Bathtub has a higher thermal energy (15 C)

Exothermic Reactions

* Release thermal energy
* Heat (Q) flows from the system to the surroundings, usually causing an increase in the temperature of the surroundings
* Q has a negative value (Q < 0)

Endothermic Reactions

* Absorbing thermal energy
* Heat (Q) flows into the system from the surroundings, usually causing a decrease in the temperature of the surroundings.
* Q has a positive value (Q > 0)

Calorimetry

* **Calorimetry**: experimental technique used to measure energy changes in chemical systems
* Different substances vary in their ability to absorb amounts of heat

Specific Heat Capacity

* **Specific Heat Capacity**: is the amount of energy required to raise the temperature of one gram of a substance one °C or one K

Subtance	Specific Heat Capacity (J/g°C at SATP)
Aluminum	0.897
Carbon	0.709
Hydrogen Gas	14.304
Air	1.01
Water (liquid)	4.19
Glass	0.84

Calculating Heat

* The amount of heat entering or exiting a system can be calculated using:

Specific Heat Capacity (J/g•°C)

Heat (J)

$$Q = m \bullet c \bullet \triangle T$$

Temperature (° C)

Mass (g)

$$\triangle T = T_{Final} - T_{Initial}$$

Calculating Heat

* The amount of heat entering or exiting a system can be calculated using:

$$Q = m \bullet c \bullet \triangle T$$

A positive Q indicates heat gain

A negative Q indicates heat lost

Example 1

* Many water heaters use the combustion of natural gas (assume methane) to heat the water in the tank. When 150.0 L of water at 10.0°C is heated to 65.0°C, how much heat flows into the water?

* Given:
  * m = 150l x 1kg/l = 150 kg = 150 000 g
  * c = 4.18 J/g°C
  * ΔT = (65°-10°) = 55°C
* Required:
  * Heat or Q
* Equation:
  * Q= (m) (c) (△ T)

* $Q = mc\Delta T$
* $= (150\ 000) \times (4.18) \times (55.0)$
* $= 34\ 567\ 500\ J$ OR $3.46 \times 10^7\ J$ OR $3.46 \times 10^4\ kJ$

Therefore 3.46 x 104 kJ of heat flows into the water

Example 2

* If 25.0 g of aluminum cools from 310°C to 37°C, how many joules of heat energy are lost by the sample?

* Given:
  * m = 25.0 g
  * c = 0.897
  * $\Delta T = 37 - 310 = -273\ ^{0}C$
* Required:
  * Heat or Q
* Equation:
  * $Q = (m)(c)(\triangle T)$

* $Q = mc\Delta T$
* $= (25.0) \times (0.897) \times (-273\ ^{0}C)$
* $= -6122.025\ J$
* $= -6.12\ kJ$

Therefore -6.12 kJ of heat is lost by the sample of aluminum

* The internal energy of a system is equal to the sum of the potential and kinetic energy of all species in the system

Kinetic Energy

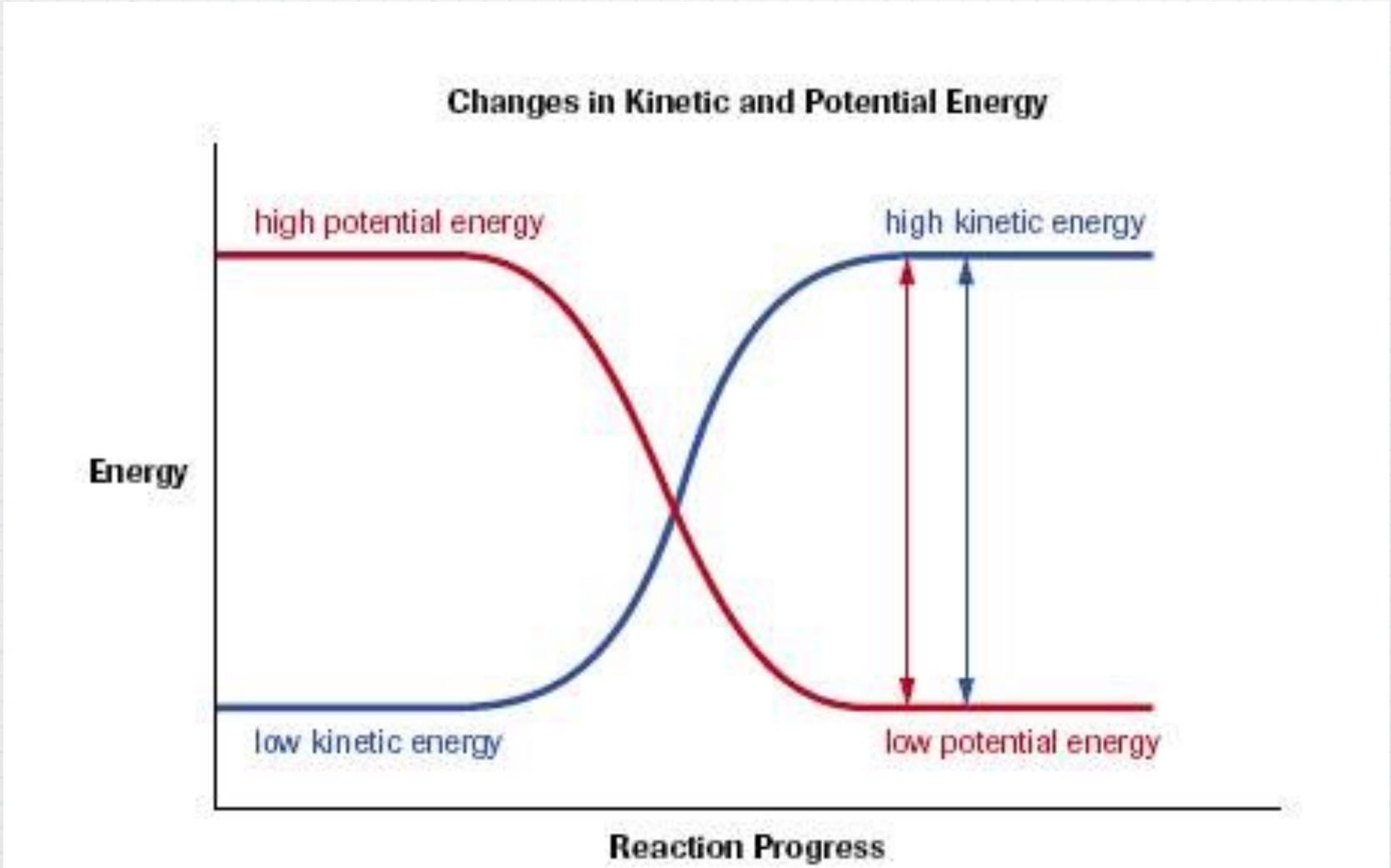
* moving electrons in atoms
* vibration, rotation and translation of atoms and molecules

Potential Energy

* nuclear potential energy of protons and neutrons
* bond energy
* intra and intermolecular forces

* It is not possible to measure all of these energies for a system

* Instead, we study the energy absorbed or released to the surroundings during a change in the system – the change in enthalpy, ΔH



Here △ H represents an exothermic reaction or release of energy

Homework

* Do p281 #2, 4-6; p291 #1, 5, 6, 10