Thermal Energy

Matter and Kinetic Theory

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Kinetic Theory

- Matter is composed of particles
- The particles are in constant motion
- The particles collide elastically unless they react
- All the particles of the same substance do not have the same kinetic energy

Phases of Matter

- Gas - particles far apart, no definite shape or volume
- Liquid - particles loosely glued together, definite volume but no definite shape
- Solid - particles have a regular arrangement, a repeating pattern, solids have a definite shape and a definite volume

Energy and Matter

- Temperature - measure of the average kinetic energy of a group of particles
- Thermal energy - sum of KE and PE of a group of particles
- Heat - Movement of thermal energy from a higher Temp to a lower Temp

Temperature gives the direction of heat flow

Types of Matter (identity)

- Element - simplest unit is the atom
- Compounds - composed of groups of atoms from different elements, "molecules"

Properties and Changes of Matter

- Physical - no change in identity (melting, boiling, bending, cutting, density, etc)
- Chemical - involve a change in identity (chemical reaction)

Mixtures of Matter

- Homogeneous - can't see different types or phases of the matter
- Heterogeneous - can see different types or phases of the matter

Energy changes during phase changes and temperature changes

As heat is added to a substance it undergoes temperature changes (KE changes) and phase changes (PE changes).

Temp changes

As we add heat to a solid, liquid or gas the temperature changes. The amount of heat needed to change the temp depends on 3 factors: (1) the amount of material, (2) what the material is, (3) the amount of temperature change needed.

These factors form the basis for an equation:

$$Q = m\ Cp\ DT$$

Q [=] J and is the heat required

m [=] g (usually) and is the amt of substance

ΔT [=] C° and is the change in temperature

ΔT also equal $T_f - T_i$ where T_f and T_i represent the final and initial temperatures

Note: Q will be positive if the temp is increasing (ΔT +) and negative if the temp is decreasing (ΔT -).

C_p is the amount of heat needed to change a unit mass of material by a unit temperature change. It is called the specific heat capacity. Most commonly the units are J/gC° or J/mole C°. The value of C_p changes from one phase to another and from one substance to another. The subscript p refers to the fact that the is the heat capacity at constant pressure - a situation that is commonly encountered when processes occur that are open to the atmosphere.

Phase changes

The above equation can be used for any temperature change to calculate either the heat needed for a process or the temp change that will result from the addition or subtraction of a given amount of heat. What happens at the phase change point?

The important point is that when a solid changes to a liquid or a liquid to a gas, the temp does not change until all the pure substance has undergone the phase change. Thus we add heat to a solid at the MP and the temp does not change. Likewise we add heat to a liq at the BP and the temp does not change.

The equations that govern these changes are:

$Q = m H_f$ $Q = m H_v$

H_f [=] J/g and is the heat of fusion, the amount of heat needed to change 1 g of solid to liquid. This is a positive number. The value for the change from liq to solid is a negative number.

H_v [=] J/g and is the heat of vaporization, the amount of heat needed to change 1 g of liquid to gas. This is a positive number. The value for the change from gas to liquid is a negative number.

The Importance of the algebraic sign of Q

A positive value of Q means that heat is flowing into the substance. This is called an endothermic process.

A negative value of Q means that heat is flowing out of the substance. This is called an exothermic process.

The Big Picture

We can put all these changes into a graph of Q versus T to see the big picture. To go from a solid below the freezing point all the way to a gas above the boiling point requires 5 steps or transitions. We can label these as Q_1 to Q_5.

Q_1, Q_3, and Q_5 are temperature changes; Q_2 and Q_4 are phase changes.

To calculate the amount of heat needed to go from one temp to another, you must:

- Identify the phase you are in at the beginning temp.
- Identify the phase you are in at the end temp.
- Use the appropriate steps (transitions) to get from the beginning to the end. Add the various steps together to get the total.

Example: How much heat is needed to change 10.0 g of solid ice at 0.0°C to steam at 105.0°C under normal pressure conditions?

C_p(solid) = 2.06 J/gC°

C_p(liquid) = 4.18 J/gC°

C_p(gas) = 2.03 J/gC°

H_f = 333 J/g

H_v = 2260 J/g

How is Heat Transferred?

- Conduction – heat transfer by the collisions of particles (especially in a solid)

  Heat is conducted from a higher to a lower temperature.

  Poor conductors are called *insulators*.

- Convection – heat transfer in a gas or liquid by means of the movement of the fluid has a whole

  Convection currents bring heating and cooling to most university buildings.

  Convection currents in the atmosphere result in wind.

- Radiation – heat transfer by mean of electromagnetic waves

  Includes radio waves, microwaves, infrared waves, visible light, ultraviolet waves, x-rays and gamma rays. Frequency of radio waves the smallest and gamma rays the largest.

  All substances above absolute zero emit radiant energy. The peak frequency is proportional to the absolute temperature. This means that the sun emits a large amount of visible light but the earth (and you and me) emit radiation of a lower frequency (mainly IR)

Absorption and Emission

Good absorbers are good emitters. Poor absorbers are poor emitters. Dark objects absorb radiant energy faster than lighter colored objects but also emit the radiation (cool) faster.

Question: Will coffee stay hot longer in a shiny, mirrorlike pot or a blackened one? Will ice water heat up quicker in a shiny, mirrorlike pot or a blackened one?

Absorption is the opposite of reflection. A good absorber appears dark.

Question: Why does the pupil in your eye appear dark?

Cooling at Night by Radiation

Bodies that radiate more energy than they receive become cooler. The temperature of conductors that are in contact with the ground are stabilized. Insulators become cooler than their surroundings.

Examples: Frost forms on grass in the fall on cool mornings when the air temperature is just below freezing. Bridges freeze before roads in the wintertime.

Putting it all together: Explain how a thermos bottle keeps hot things hot and cold things cold.