Thermal Properties Of Matter

3.2.2 Explain why different substances have different specific heat capacities.

Heat two same size objects of different materials for the same amount of time they will not necessarily have the same temperature. Some material's temperature increases (and decreases) more quickly or in other words with less heat energy added (or removed). Objects of the same size or same mass have different numbers of molecules or particles and those molecules/particles have different masses. There are many factors that influence how much heat it takes to change the temperature of a material…

Heat capacity of a body is the ratio of heat supplied to the corresponding rise in temperature of the body:

(1)

$HeatCapacity = Q / \Delta T$

Where Q is the heat and is the change in temperature. The heat capacity of an object is useful but does not tell us much about the material the object is made of, 4 kg of water will have a larger heat capacity than 1 kg of water. Therefore it makes sense to define specific heat capacity:

(2)

$c = Q / m\Delta T$

Specific heat capacity is the heat capacity per unit mass. This gives us information about particular materials not just an individual object.

Units: The units for heat are Joules (J), mass is kilograms (kg) and for temperature is Kelvin or Celsius (K or °C). This gives specific heat capacity the units of $J \cdot kg{-}1 \cdot K{-}1$.

3.2.3 Describe methods to measure the specific heat capacity of solids and liquids.

3.2.4 Solve problems involving specific heat capacities

Energy is conserved. The energy put into heating an object must be equal to the energy coming out of the object as it cools. So who cares? This provides a simple way of measuring the specific heat capacity of a material…

A calorimeter is used to measure the specific heat capacity of materials. It usually consists of a thin metal canister that is thermally insulated from the environment. The calorimeter is filled with a know mass of water and the temperature of the water is recorded. The material whose specific heat capacity is to be measured is heated and its temperature is taken. The material is then placed in the water and the water is stirred. After the water comes to thermal equilibrium the temperature of the water is recorded. Knowing the specific heat capacity of water, the mass of the water and the temperature change of the water we can calculate the heat energy transferred to the water from the heated material. From that we can calculate backwards to find the specific heat capacity of the material in question.

In terms of the math:

(3)

$$\Delta Q_x = \Delta Q_w$$

(4)

$$m_x c_x \Delta T_x = m_w c_w \Delta T_w$$

(5)

$$c_x = m_w c_w \Delta T_w / m_x \Delta T_x$$

Where the subscripts x and w stand for material x and water respectively. For accurate measurements the heat absorbed by the water and by the thermometer needs to be taken into account.
Of course you may notice that this method only work if the specific heat capacity of water is known. To measure the specific heat of water (or other liquid) you must have an accurate way of measuring the heat energy added to the water. You must also have a way to ensure that all or a known amount of the energy goes into heating of the water. With the use of a modern (electric) joulemeter this is done with relative ease.

3.2.5 Describe the solid, liquid and gaseous states in terms of molecular structure and motion

In a solid the particles are held tightly in a lattice. There is very small space between individual particles. The particles have vibrational kinetic energy. Particles in solid have lower energy than in liquid or gas form. Most solids are considered incompressible, meaning you push on it and the volume doesn't change.

In a liquid the particles are still packed closely together but they are free to move relative to one another, thus liquids can flow. The particles have vibrational, rotational and translational kinetic energy. Particles in solids have lower energy than in a gas. Liquids are virtually incompressible; this is why they can be used in hydraulic systems.

In a gas the particles are very spread out. The particles have vibrational, rotational and translational kinetic energy. Gases are highly compressible; the volume of a gas is largely dependent on its temperature and the pressure of the gas.

3.2.6 Describe and explain the process of phase changes in terms of molecular behavior.

When a material goes from solid to liquid or liquid to gas it is called a phase change.

As a solid is heated, energy is added to the material, the solid will eventually melt as the particles collect to much energy to stay in the tight lattice pattern. If the resulting liquid continues to be heated then particles will eventually "fly free" and form a loosely associated gas.

3.2.7 Explain in terms of molecular behavior why temperature does not change during a phase change

When a material undergoes a phase change energy has to be continuously added to the material to continue the phase change, but the temperature of the material does not change. When a material goes from a solid to a liquid the distance between particles does not increase significantly. The energy goes into breaking the intermolecular or interparticle forces. As a material goes from a liquid to a gas (vaporized), again the temperature does not increase the energy is going into further disassociating the particles or adding potential energy to the particles. The further particles are away from each other the greater potential energy they have, just like with gravitational forces the further to bodies are away the more potential energy they have.

3.2.8 Define specific latent heat

Specific latent heat is defined as the energy or heat per unit mass required for a material to undergo a phase change. Specific latent heat of fusion is defined as the energy per unit mass required to melt a material:

(6)

$$L_f = Q/M$$

Specific latent heat of vaporization is defined as the energy per unit mass required to vaporize or convert a material from liquid to gas:

(7)

$$L_v = Q/M$$

The particles in a liquid are nearly as dense as in a solid, but the particles in a gas are much less dense than in a liquid or solid. Thus the specific latent heat of vaporization is usually far greater than the specific latent heat of fusion.

It should be noted that the energy required to melt or vaporize a material is then released if the material is allowed to cool and return to solid (freezing or solidification) or liquid (condensation) form.

3.2.9 Describe a method for measuring the specific latent heat of fusion and a method for measuring the specific latent heat of vaporization

3.2.10 Solve problems involving specific latent heats

In order to measure the specific latent heat you must be able to accurately measure the amount of heat going into or out of a material. The mass of the material must also be accurately measured, but that’s not too tough.

As energy is added to the material the temperature will become constant as the material starts to undergo a phase change. At this point the amount of energy being transferred to the material needs to be recorded or tracked until the temperature starts to change again (the phase change is finished).

It is also possible under specific conditions for a material to straight from solid to gas. This is called sublimation. Frozen carbon dioxide will sublime at standard temperature and pressure. There is a latent heat associated with this as well, it’s called specific latent heat of sublimation, surprise surprise.

3.2.11 Describe the evaporation process in a liquid in terms of molecular behavior

3.2.12 Identify factors that affect evaporation rate.

If a water is left in an open container at room temperature it will slowly evaporate, yet it's boiling point is well above room temperature… At room temperature most of the water molecules do not have enough energy to disassociate and vaporize, but some do. The molecules that have sufficient energy evaporate and take their energy with them. This has the effect of lowering the average energy per molecule of the water, which reduces the temperature of the water. This is called evaporative cooling. This is why you sweat when you exercise. As the sweat evaporates off your skin your body is cooled.

There are several factors that affect the evaporation rate. Increasing the temperature of the liquid will increase the evaporation rate. Increasing the exposed surface area will also increase the evaporation rate. A decrease in atmospheric pressure above the liquid will reduce the evaporation rate.

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