Phase Changes

Imagine a simplified model of a solid as tiny particles bonded together by springs. The spring represents the electromagnetic forces between the particles. If the thermal energy of a solid is increased, both the potential and kinetic energy of the particles increase. The temperature is a measure of the average kinetic energy of the particles.

At higher temperatures, the forces between the particles are no longer strong enough to hold them in fixed locations. Eventually the particles become free to slide past each other. The substance has changed from a solid to a liquid. The temperature at which this occurs is called the melting point.

When a substance is in the process of melting, added thermal energy increases the potential energy of particles, breaking the bonds holding them together. The added thermal energy does not increase the kinetic energy of the particles. Thus, the temperature does not increase.

The amount of energy needed to melt a unit mass of a substance is called the heat of fusion of that substance. For example, the heat of fusion of ice is 334 J/g. If one gram of ice at its melting point (0°C, absolute 273 K) is left to thaw, 1 gram of water at the same temperature (0°C, 273 K) is produced. The added energy causes a change in state but not in temperature.

After the substance is totally melted, a further increase in thermal energy once again increases the temperature. Added thermal energy increases both the kinetic and potential energy. As the temperature increases, some particles in the middle of the liquid obtain enough energy to break free from other particles. A tiny bubble of vapor is formed and rises to the surface. The liquid begins to boil. Only added thermal energy is used to increase the potential energy of particles and change them from the liquid to the vapor state. This temperature is known as the boiling point. The amount of thermal energy needed to vaporize a unit mass of liquid is called the heat of vaporization. For water, the heat of vaporization is 2260 J/g. Every substance has a characteristic heat of vaporization and of fusion.

When substances are condensed and freeze energy is released. These processes are exothermic. The heat of condensation is the amount of energy per gram released when condensing a gas into a liquid. The heat of crystallization (solidification) is the amount of energy per gram released when freezing a liquid into the solid phase. The amount of energy released in the same amount as was taken in during the endothermic processes of boiling and melting. A negative sign is used to indicate the release of energy.

Example:
Calculate the heat energy required, in joules, to melt 5.00 x 10^2 grams of ice which is at 0.0 °C. The heat of fusion of ice is 333 J/g.

ice (0.0 °C) ⟶ water (0.0 °C)

q = mH_f