Heat

Heat Energy is kinetic energy on the molecular/atomic level. Kinetic energy is motion, hence this is the motion of molecules and atoms.

- translational motion (moves from place to place)
- vibrational motion
- rotational motion

The quantity of heat present in a "substance" is the sum of all of these various motions.

Temperature is a measurement of the average kinetic energy (i.e. heat energy) of a "substance" The lowest possible temperature is −273.15 °C and is called absolute zero – no particle motion at all.

Measuring Heat can be done two different ways. You can measure a change in temperature or you can measure heat through a change of state.

1. **Change in Temperature:**

$Q = mc\Delta T$

Q = heat energy (J, kJ, cal, kcal)
1 cal = 4.184 J

m = mass (g, kg)

c = specific heat capacity (J/g°C, kJ/kg°C, cal/g°C etc.)

ΔT = change in temperature (°C, could be K, makes no dif.) $\Delta T = T_f - T_i$

Specific Heat Capacity is a measurable physical property for any given substance. It is the amount of heat required to warm one grams of the substance by 1 °C. Values for most common substances can be easily looked up.

The specific heat capacity for water is

$$4.184\ J/g^{\circ}C \text{ or } 1.000\ cal/g^{\circ}C$$

Conversion between J and cal can be done using a conversion factor based on the relationship that:

$$1\ cal = 4.184\ J$$

Specific heat capacity can be thought of as a substances ability to store heat energy.

eg: Determine the change in temperature that will occur if 3.500 kJ is added to 1 L of water.

$Q = 3.500\ kJ \rightarrow 3500\ J$
$m = 1\ L \rightarrow 1000\ mL \rightarrow 1000\ g$ (1 mL of H_2O = 1 g of H_2O)
$c = 4.184\ J/g^{\circ}C$
$\Delta T = ?$

$$Q = mc\Delta T$$

$$\Delta T = \frac{Q}{mc}$$

$$\Delta T = \frac{3500\ J}{1000\ g \times 4.184\ J/g\,^{\circ}C}$$

$$\Delta T = 0.837\ ^{\circ}C$$

If the temperature increases, $T_F > T_I$, ΔT will be positive. Therefore Q will be positive. Positive Q represent absorption (or addition) of heat to the substance. The reverse is true for a decrease in temperature. Negative Q represent the release of heat from the substance.

2. **Change of State:**

Heat energy in a change of state does not effect temperature (kinetic energy), instead it alters potential energy through changing attractive forces. The heat energy could be thought of as going into (or out of) hiding in a potential energy state (Hence the term Latent Heat).

$Q = L_V m$ or $Q = L_F m$

Q = heat energy (J, kJ, cal, kcal)
L_V or L_F = latent heat of vapourization* / latent heat of fusion* (J/g J/mol, kJ/kg etc.) see pg 307 in text
m = mass (g or kg)

Please note the text refers to "latent heat" as "molar enthalpies". Latent heat refers to kinetic energy. Molar enthalpies refer to the corresponding can in potential energy. There values are the same.

eg: Determine the amount of heat energy absorbed by 550 mg of water as it changes from water at 100 °C to steam at 100 °C.

Q = ? (but will be positive since heat is absorbed)
L_v = 40.8 kJ/mol (found on pg 307 of your text)
m = 550 mg ➜ 0.550 g

$$Q = L_V m$$

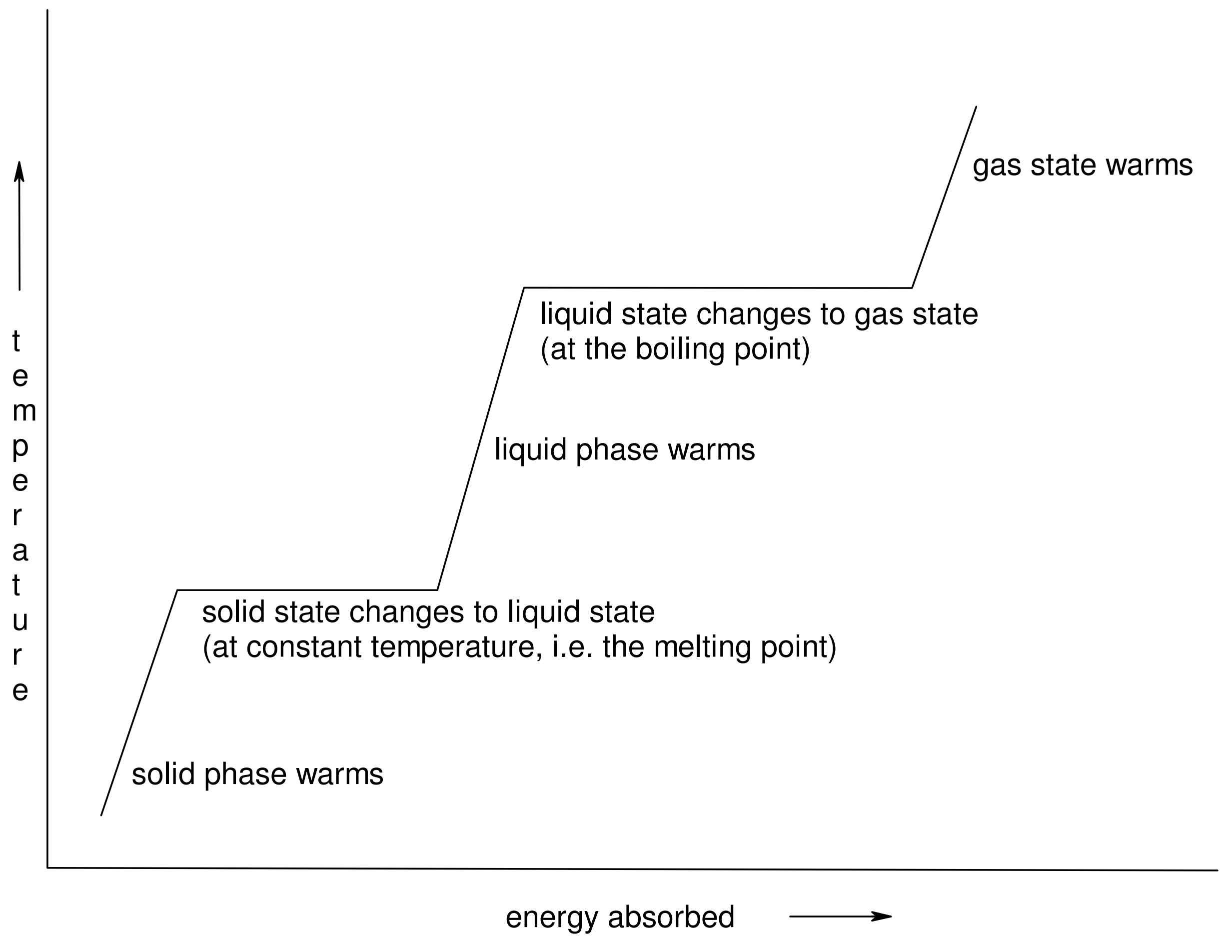
$$Q = \left(\frac{40.8\ \text{kJ}}{1\ \text{mol}} \text{ x } \frac{1\ \text{mol}}{18.02\ \text{g}}\right) \text{ x } 0.550\ \text{g}$$

$$Q = 1.245\ \text{kJ}$$

If the change of state goes to a "warmer" state, Q will be positive, heat has been added. If the change of state goes to a "cooler" state, Q will be negative, heat has been removed. Show this by adding a negative sign to your latent heat value.

Heating and Cooling Curves:

A heating curve shows changes in temperature vs heat absorbed. The temperature remains constant whenever a change of state occurs.



For a cooling curve, the same process happens in reverse. The curve is a left to right mirror image.

The total energy involved can be calculated using a combination of $Q = mc\Delta T$ and $Q = Lm$ calculations. Remember to consider the sign of Q when changed of state are involved.

Thermal Equalization Principle:

When two substances at different temperature come into thermal contact*, the substance will eventually become the same temperature. The warmer substance loses heat to the cooler substance. The heat lost by one substance will exactly equal the gained by the other.

$$-Q_W = Q_C$$

See example question from “thermodynamics questions #1" question #2

* Thermal contact requires heat transfer. There are three methods of heat transfer

- conduction (particle motion spreads by contact) – SLOW
- convection (transfer of matter by currents) – FASTER (wind and ocean currents)
- radiation (infrared radiation) – FAST AS LIGHT (travels through a vacuum, even the vacuum of space

Thermal equalization taken to extremes will result in the thermal death of the universe.