Thermal Energy and Heat

Thermal Energy (Heat):

the **total** kinetic energy and potential energy of the atoms or molecules of a substance.

Measured in: Joules

Temperature:

the **average** kinetic energy and potential energy of the atoms or molecules of a substance.

Measured in: degrees Celsius

Kelvins

Apr 15-8:33 PM

Methods of Heat Transfer (3 ways)

Conduction: the process of transferring heat through a material by the collision of atoms

Example(s): body heat into the chair

Convection: the process of transferring heat by a circulating path of fluid particles

Example(s): Cold air and warm air meet at a weather front.

Radiation: the process in which energy is transferred by means of electromagnetic waves

Example(s): The Sun heating Earth's surface.

Apr 15-9:10 PM

Factors that affect Heat Transfer

1. The change in temperature of the object (ΔT) $Q \propto \Delta T$
2. The mass of the object (m) $Q \propto m$
3. The type of material

→ Specific Heat Capacity (c):

a measure of the amount of energy (heat) to raise the temperature of 1.0 kg of a substance by 1.0^0C

If heat is given the symbol of 'Q', and the formula to measure the quantity of heat gained (or lost) by a body is:

$$Q = mc\Delta T$$

Apr 15-9:13 PM

Ex. How much heat is required to raise the temperature of 500 g of water from 4^0C to 80^0C?

m = 0.500 kg

c = 4200 J/kg^{0}C

$\Delta T = 76^0C$

$$Q = mc\Delta T$$
$$= (0.5)(4200)(76)$$
$$Q = 1.6\times10^5 J$$
$$= 1.6\times10^2 kJ$$

Ex. If you added 45 kJ of energy (as heat) to a 4.0 kg block of aluminum, what would it's final temperature be if it started at 15^0C, and the specific heat capacity of aluminum is 9.2×10^2 J/kg^{0}C

$Q = 45 kJ = 4.5\times10^4 J$

$m = 4.0 kg$

$T_i = 15°C$

$c = 9.2\times10^2 \frac{J}{kg°C}$

$T_f = ?$

$$Q = mc\Delta T$$
$$Q = mc(T_f - T_i)$$
$$T_f - \cancel{T_i} = \frac{Q}{mc} + T_i$$
$$T_f = \frac{4.5\times10^4}{(4.0)(9.2\times10^2)} + 15°C$$
$$T_f = 27°C$$

Apr 15-9:31 PM

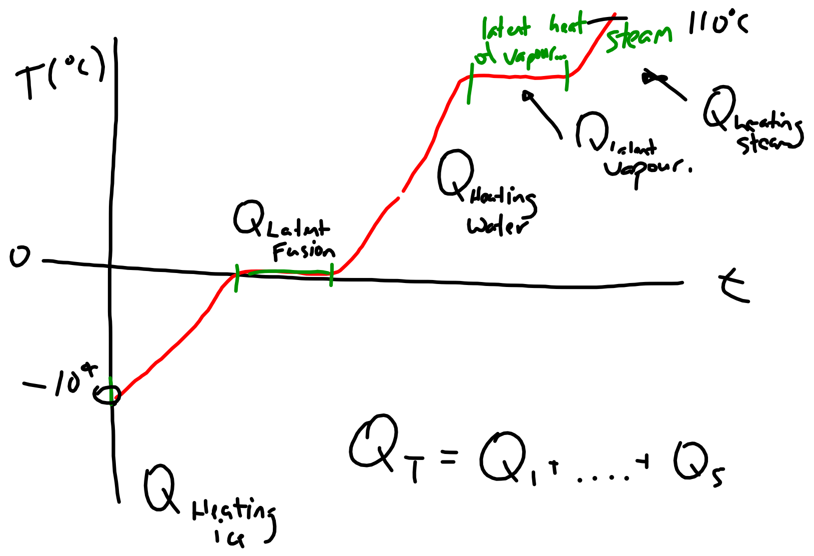
Latent Heat (ℓ)

the energy (Q) required to change states (ie, liquid to gas, or liquid to solid)

$Q = m\ell$ $\ell : \frac{J}{kg}$

Substance	Latent Heat of Fusion (ℓ_f)	Latent Heat of Vapourization (ℓ_v)
water	3.34×10^5	2.260×10^6
Oxygen	1.39×10^4	2.13×10^5
gold	6.3×10^4	1.6×10^5

Apr 18-9:30 AM



$Q_T = Q_1 + \dots + Q_5$

Apr 18-9:50 AM

$W = \Delta E$

$\Delta E = 0$

$$\boxed{Q_{gained} + Q_{lost} = 0}$$

Apr 23-9:20 AM

Thermal Equilibrium

- When two substances at different temperatures are mixed, they will eventually settle at the same temperature.
- The hotter substance must release heat into the cooler substance.

$$Q_{gained} + Q_{lost} = 0$$

$$Q_{gained} = - Q_{lost}$$

Apr 21-10:39 AM

$Q_{gained} = - Q_{lost}$

A 200 g piece of aluminum (c = 900 J/kg°C) is put into 500 g of water. If the aluminum starts at -15°C and the water starts at 30°C, what is the final temperature?

Apr 21-10:42 AM

$Q_{gained} = - Q_{lost}$

While making yourself a cup of tea, you add 225 g of boiling water (100°C) to a mug. If the mug has a mass of 113 g, starts at a temperature of 21°C, and has a specific heat capacity of 775 J/kg°C, what is the final temperature?

Apr 21-10:44 AM

A 150 g piece of brass is heated to 175°C to be worked by a brass-smith. To cool it down, it is placed in a bucket with 230 g of water at 18°C. What is the final temperature?

$c_b = 3.8\times10^2 \frac{J}{kg°C}$

$Q = mc\Delta T$

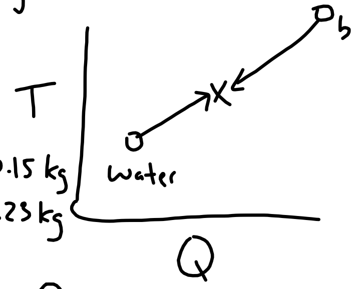
$c_w = 4.18\times10^3$

$t_{i_b} = 175°C$

$t_{i_w} = 18°C$

$m_b = 150\,g = 0.15\,kg$

$m_w = 230\,g = 0.23\,kg$



$Q_{gained} = -Q_{lost}$

$m_w c_w \Delta T = -m_b c_b \Delta T$

$m_w c_w (T_f - T_{i_w}) = -m_b c_b (T_f - T_{i_b})$

$(0.23)(4.18\times10^3)(T_f - 18) = -(0.15)(3.8\times10^2)(T_f - 175)$

$961.4 T_f - 17305.2 = -57 T_f + 9975$

$T_f = \frac{27280}{1018}$

$T_f = 26.8°C$

Apr 23-9:48 AM

An ice cube ($m = 0.05\,kg$) at $-4°C$ is placed into a bowl of soup ($m = 0.42\,kg$) that just came off the stove at 80°C. What is the final temperature of the soup?

Assume $c_{soup} = c_{water}$

$c_{ice} = 2.1\times10^3 \frac{J}{kg°C}$

$c_w = c_{soup} = 4.18\times10^3$

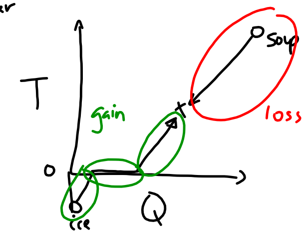
$m_i = 0.05\,kg$

$m_s = 0.42\,kg$

$T_{i_i} = -4°C$

$T_{i_s} = 80°C$

$l_f = 334\,kJ/kg = 3.34\times10^5$



LS $Q_{gain} = -Q_{lost}$

$Q_{gain} = m_i c_i \Delta T + m l_f + m_i c_w \Delta T$

$T_f - T_i = 0 - (-4) = 4$ $T_f - T_i = T_f$

$= (0.05)(2.1\times10^3)(4) + (0.05)(3.34\times10^5) + (0.05)(4.18\times10^3) T_f$

$= 17120 + 209 T_f$

RS $-Q_{lost} = -m_s c_w \Delta T$

$= -(0.42\,kg)(4.18\times10^3)(T_f - 80°C)$

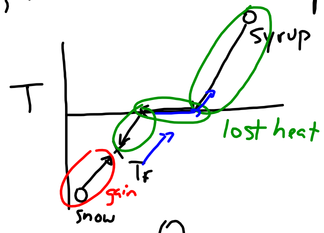
$= -1755.6 T_f + 140448$

$1964.6 T_f = 140448 - 17120$

$T_f = 62.8°C$

Apr 23-10:09 AM

While making maple candy, hot maple syrup is poured into a tray of snow. If you poured 25 g of syrup at 62°C into 400 g of snow at −23°C, what is the final temp.?



$m_{syrup} = 0.025\text{ kg}$

$t_{is} = 62°C$

$m_{ice} = 0.4\text{ kg}$

$t_{ice} = -23°C$

$c_{ice} = 2.1\times10^3$

$c_w = 4.18\times10^3$

$l_{f_w} = 3.34\times10^5\text{ J/kg}$

$$\underline{LS} \quad Q_{gained} = -\underline{RS}\ Q_{lost}$$

LS

$$Q_{gained} = m_i c_i \Delta T$$
$$= (0.4)(2.1\times10^3)(T_f-(-23))$$
$$= 840T_f + 19320$$

RS

$$Q_{lost} = m_s c_s \Delta T - ml_f + m_i c_i \Delta T$$
$$= (0.025)(4.18\times10^3)(\cancel{\phi}^{0}-62) - (0.025)(3.34\times10^5)$$
$$+ (0.025)(2.1\times10^3)(T_f-\cancel{\phi}^{0})$$

$$Q_{lost} = 52.5T_f - 14829$$

$$-Q_{lost} = -52.5T_f + 14829$$

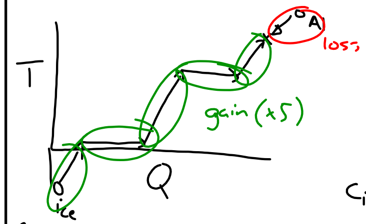
$$LS = RS$$

$$840T_f + 19320 = -52.5T_f + 14829$$

$$T_f = -5°C$$

Apr 24-9:34 AM

A 10 kg bar of aluminum is at 600°C (melting point 660.3°C). To cool the bar down, 300 g of ice at −15°C is placed on the bar. What is the final temperature?



$l_f = 3.34\times10^5$

$l_v = 2.260\times10^6$

$c_{Al} = 9.2\times10^2$

$c_{ice} = c_{steam} = 2.1\times10^3$

$c_w = 4.18\times10^3$

$$\underline{LS} \quad Q_{gain} = -\underline{RS}\ Q_{lost}$$

RS

$$Q_{lost} = m_A c_A \Delta T$$
$$= (10)(9.2\times10^2)(T_f-600)$$
$$Q_{lost} = 9.2\times10^3T_f - 5.52\times10^6$$
$$-Q_{lost} = -9.2\times10^3T_f + 5.52\times10^6$$

LS

$$Q_{gain} = \underset{(ice)}{mc\Delta T} + \underset{(melting)}{ml_f} + \underset{(water)}{mc\Delta T} + \underset{(vapour.)}{ml_v} + \underset{(steam)}{mc\Delta T}$$

$\Delta T = 0-(-15)$, $\Delta T = 15$ $\quad$ $\Delta T = 100-0$, $\Delta T = 100$ $\quad$ $\Delta T = T_f - 100$, $\Delta T = T_f - 100$

$$= 9450 + 1.002\times10^5 + 1.254\times10^5 + 6.78\times10^5$$
$$+ 630T_f - 6.3\times10^4$$

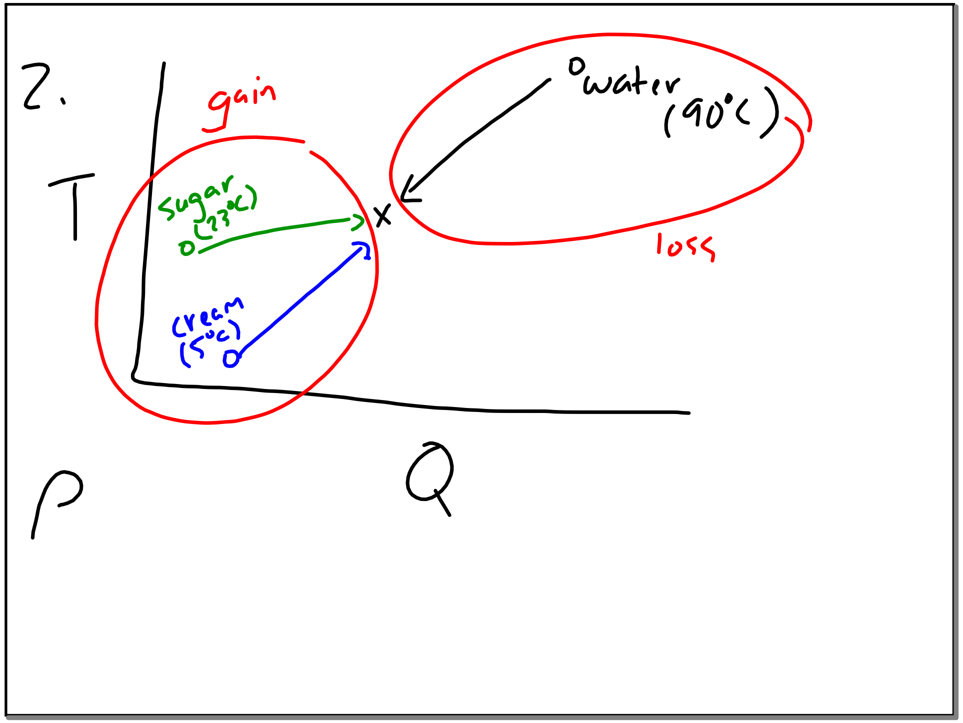
$$Q_{gained} = 630T_f + 8.5\times10^5$$

$$LS = RS$$

$$630T_f + 8.5\times10^5 = -9.2\times10^3T_f + 5.52\times10^6$$

$$T_f = 475°C$$

Apr 24-10:02 AM



Apr 24-10:19 AM