EXAMPLE

What volume of air will have its temperature raised by 1.0°C if it receives the heat from $1\,m^3$ of water that changes temperature by the same amount?

mass of $1\,m^3$ water

$$m = \rho V = (1.00 \times 10^3\ kg/m^3)(1\,m^3)$$
$$= 1 \times 10^3\ kg$$

when $1\,m^3$ of water cools by 1°C it releases energy

$$Q = mc\Delta T$$
$$= (1 \times 10^3\ kg)(4186\ J/kg^\circ C)(-1^\circ C)$$
$$= -4 \times 10^6\ J$$

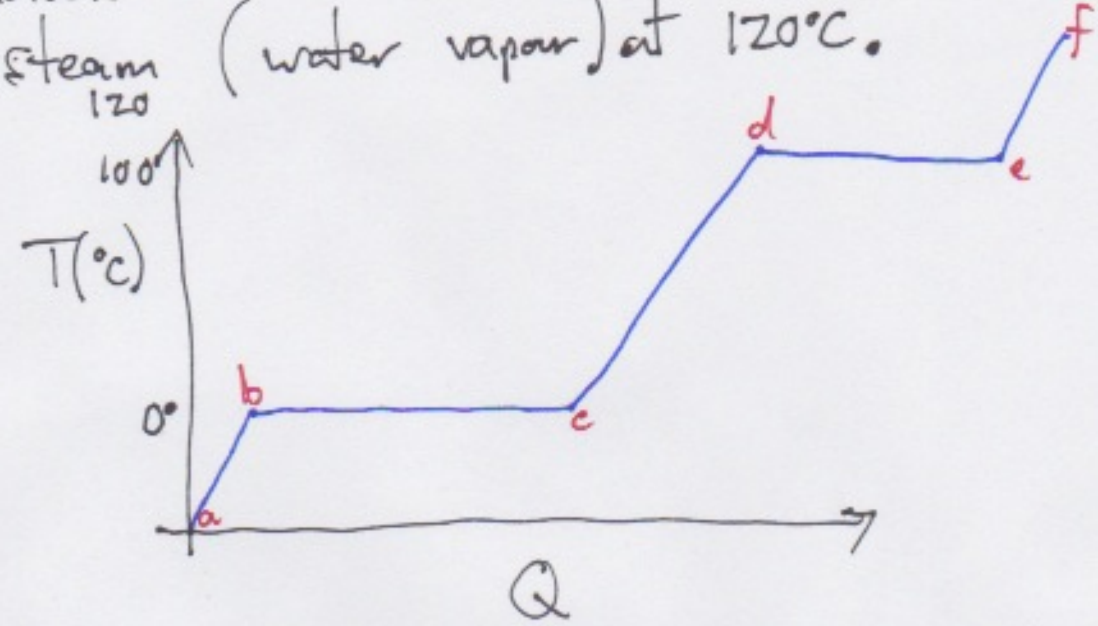
$$Q_{air} = mc\Delta T = \rho_a V c \Delta T$$

$$V = \frac{Q}{\rho_a c \Delta T} = \frac{4 \times 10^6\ J}{(1.3\ kg/m^3)(1 \times 10^3\ J/kg^\circ C)(1^\circ C)}$$
$$= 3 \times 10^3\ m^3$$

3000 x larger

EXAMPLE

Calculate the thermal energy required to convert a 1.0 g block of ice at -30.0°C to steam (water vapor) at 120°C.



$Q_{ab} = m_i c_i \Delta T = (1 \times 10^{-3}\ kg)(2090\ J/kg\,°C)(30.0\,°C)$
$= 62.7\ J$

$Q_{bc} = m L_f = (1 \times 10^{-3}\ kg)(3.33 \times 10^{5}\ J/kg) = 333\ J$

$Q_{cd} = m_w c_w \Delta T = (1 \times 10^{-3}\ kg)(4.19 \times 10^{3}\ J/kg\,°C)(100\,°C)$
$= 419\ J$

$Q_{de} = m L_v = (1 \times 10^{-3}\ kg)(2.26 \times 10^{6}\ J/kg)$
$= 2.26 \times 10^{3}\ J$

$Q_{ef} = m c \Delta T = (1 \times 10^{-3}\ kg)(2.01 \times 10^{3}\ J/kg\,°C)(20\,°C)$
$= 40.2\ J$

TOTAL $Q_{af} = 3.11 \times 10^{3}\ J$

since $|Q| < Q_f$, not all ice melts

So final T is 0°C.

b) Originally warmer water will cool to 0°C, so 45.2 kJ goes into ice.

$$m = \frac{Q}{L_f} = \frac{45.2 \times 10^3 \, J}{3.33 \times 10^5 \, J/kg}$$

$$= 0.136 \, kg$$

remaining $m = 0.250 \, kg - 0.136 \, kg$

$$= \underline{0.114 \, kg}$$

X $\Sigma Q = L m_i + m_i c_i (T - 0) + m_w c_w (T - 18) = 0$

Incorrect approach in this case.

EXAMPLE

0.300 kg of coffee at 70.0°C is poured into a 0.120 kg aluminum cup initially at 20.0°C. What is the equilibrium temperature? Assume no heat exchanged with surroundings.

Key point: $\sum Q = 0$

TOTAL HEAT ENERGY CONSERVED

$$\sum Q = Q_c + Q_{Al} = 0$$

$$m_c c_w (T - T_{oc}) + m_{Al} c_{Al} (T - T_{oAl}) = 0$$

solve for T

$$T = \frac{m_c c_w T_{oc} + m_{Al} c_{Al} T_{oAl}}{m_c c_w + m_{Al} c_{Al}}$$

$$= 66.0\,°C$$

EXAMPLE

In an insulated vessel, 250 g of ice at 0°C is added to 600 g of water at 18.0 °C.

a) What is the final temperature of the system?

b) How much ice remains when the system reaches equilibrium.

- Liquid water is losing energy by heat according to $mc\Delta T$
- Ice is gaining energy described by Lm

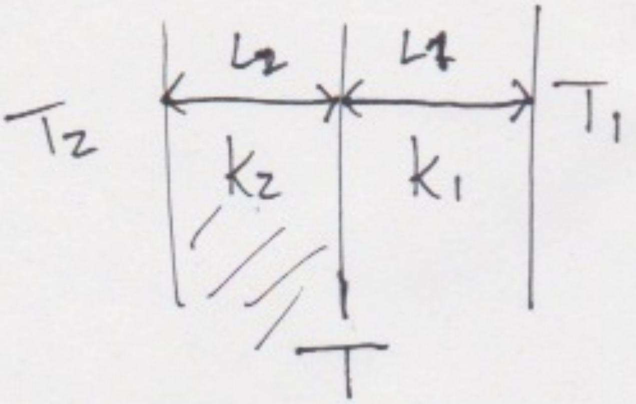
Will all the ice melt?

If all 250 g of ice is melted it must absorb

$$Q_f = L_f m = (0.250\text{ kg})(3.33\times10^5\text{ J/kg})$$
$$= 83.3\text{ kJ}$$

The energy released when 600 g of water cools from 18.0°C to 0.0°C is

$$Q = mc\Delta T$$
$$= (0.600\text{ kg})(4186\text{ J/kg}^\circ\text{C})(-18.0^\circ\text{C})$$
$$= -45.2\text{ kJ}$$



Two slabs as shown are in thermal contact, $T_2 > T_1$. Determine the temperature at the interface and the heat current through the slabs in the steady state condition.

$$H_1 = \frac{k_1 A (T - T_1)}{L_1}$$

$$H_2 = \frac{k_2 A (T_2 - T)}{L_2}$$

In steady state: $H_1 = H_2$

$$\frac{k_1 A (T - T_1)}{L_1} = \frac{k_2 A (T_2 - T)}{L_2}$$

solve for T

$$T = \frac{k_1 L_2 T_1 + k_2 L_1 T_2}{k_1 L_2 + k_2 L_1}$$

$$H = \frac{A(T_2 - T_1)}{(L_1/k_1) + (L_2/k_2)}$$

In general, for n slabs

$$H = \frac{A(T_2 - T_1)}{\sum_{i}^{n} (L_i/k_i)}$$