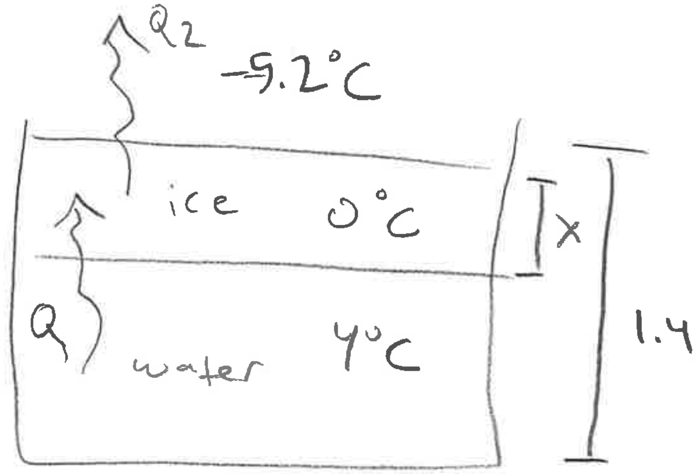
Warm up problem



$K_{ice} = 1.67\ W/mK$

$K_w = 0.502\ W/mK$

Steady state: heat loss = heat gain

$$Q_1 = Q_2$$

$$Q_1 = \frac{K_w A\,(4°C - 0°C)}{1.4 - x}$$

$$Q_2 = \frac{K_{ice} A\,(0 - -5.2)}{x}$$

$$\frac{K_w A\,(4)}{1.4 - x} = \frac{K_{ice} A\,(5.2)}{x}$$

$$(1.4 - x)(K_{ice}\cdot 5.2) = 4\,k_w\,(x)$$

$$7.384\,K_{ice} - 5.2\,K_{ice}\,x = 4\,k_w\,x$$

$$x\,(4k_w + 5.2\,k_{ice}) = 7.384\,k_{ice}$$

$$x = \frac{7.384\,k_{ice}}{(4k_w + 5.2\,k_{ice})}$$

$$\boxed{x = 1.15\,m}$$

Heat

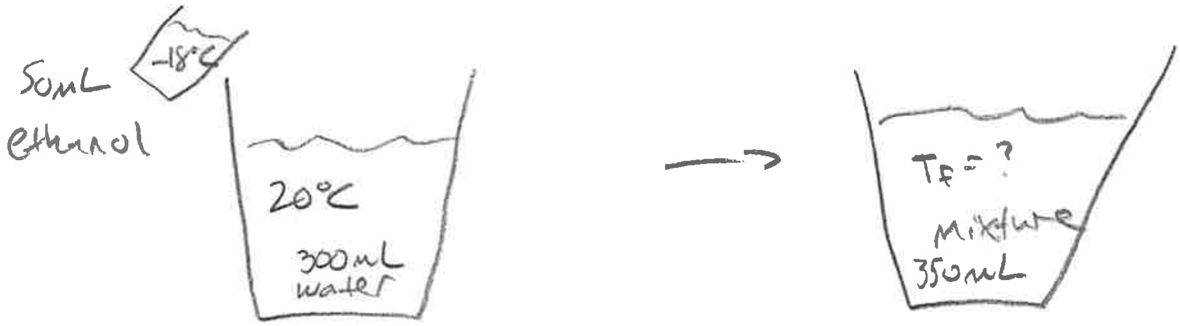
$$Q = mc\Delta T$$

- Heat is simple to express when dealing with one object. What about multiple objects?
- Heat flows until thermal equilibrium (i.e. equal T) has been reached.
- Since heat is a measure of energy, heat is conserved.

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

Heat problem

50 mL of ethanol at -18°C is mixed with 300 mL of water at 20°C. Find the temperature of the mixture once it has reached thermal equilibrium. The density of water and ethanol are 1.0 g/mL and 0.789 g/mL, respectively, and their specific heats are 4186 J/kg K and 2450 J/kg K, respectively.



$$m_w = \rho_w \cdot V_w$$

$$m_w = 1\,g/mL\,(300\,mL)$$

$$m_w = 300\,g = .3\,kg$$

$$T_{i,w} = 20°C$$

$$T_f = ?$$

$$C_w = 4186\,J/kg\,°C$$

$$m_e = \rho_e \cdot V_e$$

$$m_e = 0.789\,g/mL\,(50\,mL)$$

$$m_e = 39.45\,g = 0.03945\,kg$$

$$T_{i,e} = -18°C$$

$$T_f = ?$$

$$C_e = 2450\,J/kg\,°C$$

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

water loses heat, ethanol gains

$$m_e C_e \Delta T_e = -m_w C_w \Delta T_w$$

$$m_e C_e (T_f - T_{i,e}) = -m_w C_w (T_f - T_{i,w})$$

$$m_e C_e T_f - m_e C_e T_{i,e} = -m_w C_w T_f + m_w C_w T_{i,w}$$

$$m_e C_e T_f + m_w C_w T_f = m_w C_w T_{i,w} + m_e C_e T_{i,e}$$

$$T_f (m_e C_e + m_w C_w) = m_w C_w T_{i,w} + m_e C_e T_{i,e}$$

$$T_f = \frac{m_w C_w T_{i,w} + m_e C_e T_{i,e}}{m_e C_e + m_w C_w}$$

$$\boxed{T_f = 17.3°C}$$

Latent Heat

- Heat released or required for phase change

Solid $\longleftrightarrow$ Liquid

"Latent Heat of fusion"

L_f

Liquid $\longleftrightarrow$ Gas

"Latent Heat of vaporization"

L_v

$$Q = mL_f \quad \text{or} \quad Q = mL_v$$

Q - heat (J)

m - Mass (kg)

L_f - latent heat of fusion/vaporization (J/kg)

- During phase change T does not change

Latent Heat Problem

Calculate the heat required to convert 5 kg of ice at $-20°C$ into steam at $100°C$.

$$Q = \underbrace{m_{ice} C_{ice} \Delta T_{ice}}_{\text{heating ice}} + \underbrace{m L_f}_{\text{melting ice}} + \underbrace{m_w c_w \Delta T_w}_{\text{heating water}} + \underbrace{m L_v}_{\text{boiling water}}$$

$m_{ice} = m = m_w = 5\ kg$

$C_{ice} = 2090\ J/kg\ °C$

$\Delta T_{ice} = 0°C - -20°C = 20°C$

$L_f = 334\ kJ/kg = 334000\ J/kg$

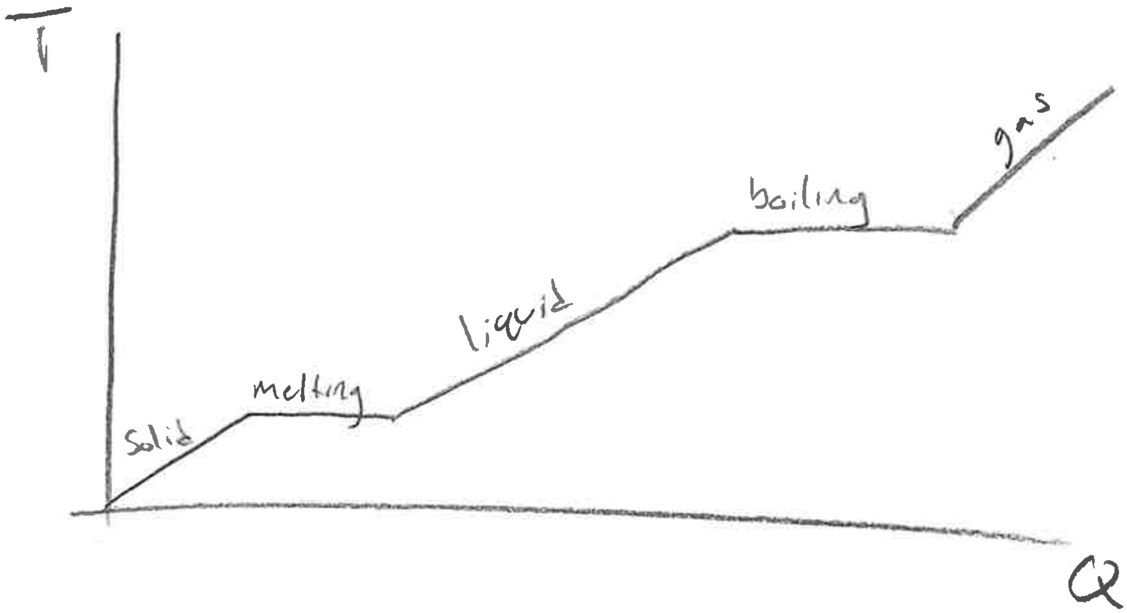
$c_w = 4186\ J/kg\ °C$

$\Delta T_w = 100°C - 0°C = 100°C$

$L_v = 2256\ kJ/kg = 2\,256\,000\ J/kg$

$$\boxed{Q = 15.252\ MJ}$$

$1\ MJ = 10^6\ J$



Constant T during phase changes.