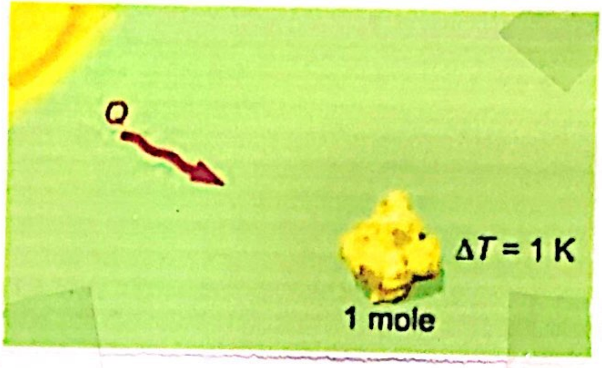
Molar specific heat

A proportionality constant that relates the amount of heat flow per mole to a material's change in temperature.

$$Q = n K \Delta T$$



where

Q: heat

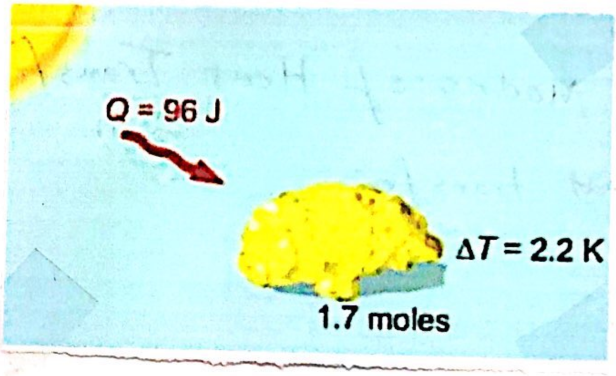
K: molar specific heat (J/mol.K)

n: number of moles

ΔT: temperature change in °C or K

Example: This is a gold nugget. Its temperature increases 2.2K when 96 J of heat are added. what is the molar specific heat of gold?

Solution:



$$Q = nK\Delta T$$

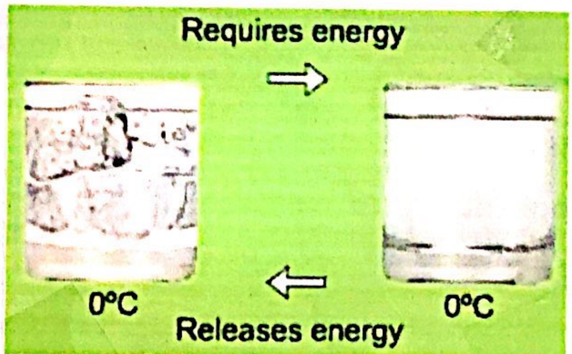
$$96 = 1.7K(2.2)$$

$$K = \frac{96}{1.7(2.2)} \Rightarrow K = 26 \text{ J/mol.K}$$

Phase changes

Transformation between solid and liquid, liquid and gas, or solid and gas.

- phase change consumes energy or release energy
- under phase change process, temperature stays constant.



Latent heat

Energy required per kilogram to cause a phase change in a given material.

- The latent heat of vaporization is the amount of heat per kilogram consumed when a given substance transforms from a liquid into a gas, or released when the substance transforms from a gas back to a liquid.

The latent heat of fusion is the heat flow per Kilogram during a change in phase between a solid and a liquid.

$Q = L_f \, m$

$Q = L_v \, m$

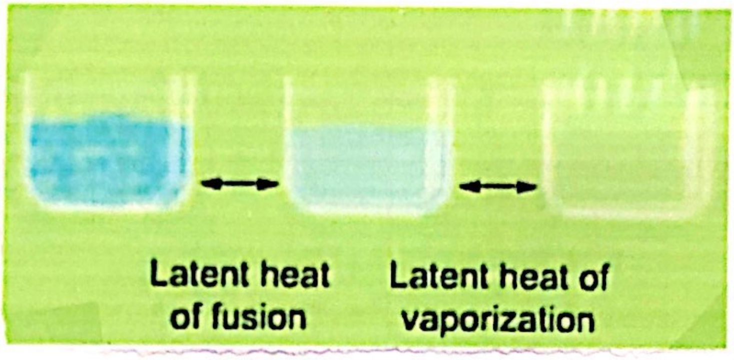
where

Q: heat

m: mass

L_f: latent heat of fusion (J/kg)

L_v: latent heat of vaporization (J/kg)



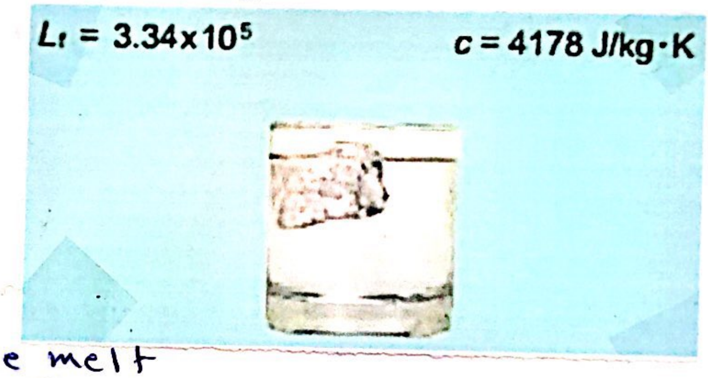
Example: A glass contains 0.0370 kg of ice at 0 °C. How much heat transfers to the ice as it melts without changing temperature?

Solution:

$Q = L_f \, m$

$Q = 3.34 \times 10^5 (0.0370)$

$Q = 1.23 \times 10^4$ J



Sample problem: watching ice melt

The glass contains 0.16 kg of water at 30.0 °C and 0.037 kg of ice at 0.0 °C. what is the resulting temperature of the water at thermal equilibrium after the ice melts?

Solution:

in the insulated container, the only source of the heat to melt the ice is the surrounding water. The water's temperature will decrease as the ice melt. The ice will melt while staying at 0 °C. There is a tricky part to solving this problem: when the ice melts it turns into water, and this extra water must be accounted for when calculating the final temperature.

It is important to distinguish between the two masses of water in the final mixture: the masses that was initially liquid, and the mass that was initially solid ice. we use the subscripts L and S to distinguish these masses of water.

In the section on latent heat, we calculated the heat transferred to the same amount of ice as it melted to be 1.23×10^4 J. Here, we need the heat transferred from the water, not to the ice. Since the water loses heat, we state this as -1.23×10^4 J, with negative sign.

mass of liquid water, $m_L = 0.16$ kg

mass of solid ice, $m_S = 0.037$ kg

heat transferred from water to melt ice, $Q = -1.23 \times 10^4$ J

initial temperature of liquid water, $T_{Li} = 30$ °C

initial temperature of solid ice, $T_{Si} = 0$ °C

temperature of liquid water after ice melts, T_{Lf}

temperature of ice-melt, $T_{Sf} = 0$ °C

final temperature of liquid water + melted ice, T

heat transferred to melted ice for thermal equilibrium, Q_S

specific heat of water, $C = 4178$ J/kg·k

$Q = mc\,\Delta T$

As the two masses of water reach thermal equilibrium, the heat transferred from the originally liquid water plus the heat transferred to the the melted ice must sum to Zero

$$Q_L + Q_S = 0$$

First we calculate the temperature of the liquid water after it gives up heat to melt the ice

$$Q = mc\,\Delta T$$

$$-1.23 \times 10^4 = 0.16\,(4178)\,\Delta T \Rightarrow \Delta T = -18.4\,K = -18.4\ °C$$

Since

$$\Delta T = T_{Lf} - T_{Li}$$

$$T_{Lf} = \Delta T + T_{Li}$$

$$T_{Lf} = -18.4 + 30$$

$$T_{Lf} = 21.6\ ^{\circ}C$$

Now we use the fact that the heat transfers sum to zero as the two masses of water reach thermal equilibrium to calculate the final temperature of the total mass of water

$$Q_L + Q_S = 0$$

$$m_L C (T - T_{Lf}) + m_S C (T - T_{Sf}) = 0$$

$$m_L C T - m_L C T_{Lf} + m_S C T - m_S C T_{Sf} = 0$$

$$T(m_L C + m_S C) = m_L C T_{Lf} + m_S C T_{Sf}$$

$$T = \frac{\cancel{C}(m_L T_{Lf} + m_S T_{Sf})}{\cancel{C}(m_L + m_S)}$$

$$T = \frac{0.16(21.6) + 0.037(0)}{0.16 + 0.037}$$

$$T = 17.5\ ^{\circ}C$$

Modes of Heat Transfer

Heat can be transferred in three basic modes as follow:

1- Conduction

2. Convection

3. Radiation

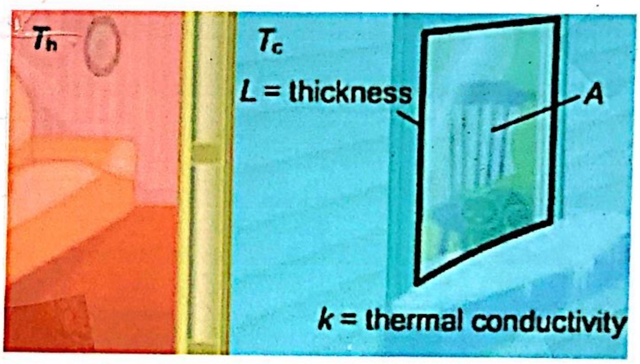
Conduction: The flow of thermal energy directly through a material without motion of the material itself.

Examples on heat Conduction

- Heating a metal spoon when it suddenly immersed in a cup of hot tea.
- losing heat from heated room to outside during the winter season.

Rate of heat conduction $\propto \dfrac{(\text{Area})(\text{temp. difference})}{\text{thickness}}$

$$q = K A \frac{\Delta T}{\Delta X}$$



where

q: heat transfer rate, J/s, W

k: thermal conductivity, W/m.K, W/m.°C

A: Area of heat transfer, m2

ΔT: temperature difference, °C, K

ΔX: thickness of the plane wall, m

	Thermal conductivity	Thermal resistance (for 1 inch)	
	k (W/m·K)	RSI-value (m²·K/W)	R-value (ft²·F°·h/Btu)
Air, sea level (15° C)	0.025	1.00	5.70
Fiberglass (50° C)	0.04	0.64	3.61
Urethane foam	0.06	0.42	2.40
Plywood	0.11	0.23	1.31
Wood (fir)	0.14	0.18	1.03
Water	0.598	0.04	0.24
Concrete (0° C)	0.8	0.03	0.18
Window glass (0° C)	0.95	0.03	0.15
Ice (0° C)	2.14	0.01	0.07

values approximate for building materials at 10^5 Pa, 20° C