Physics 212 chapter 19 supplemental

Chapter 19 supplimental lecture

1st Law of thermodynamics

$$\Delta E_{th} = W_{ext} + Q$$

Thermal properties of materials

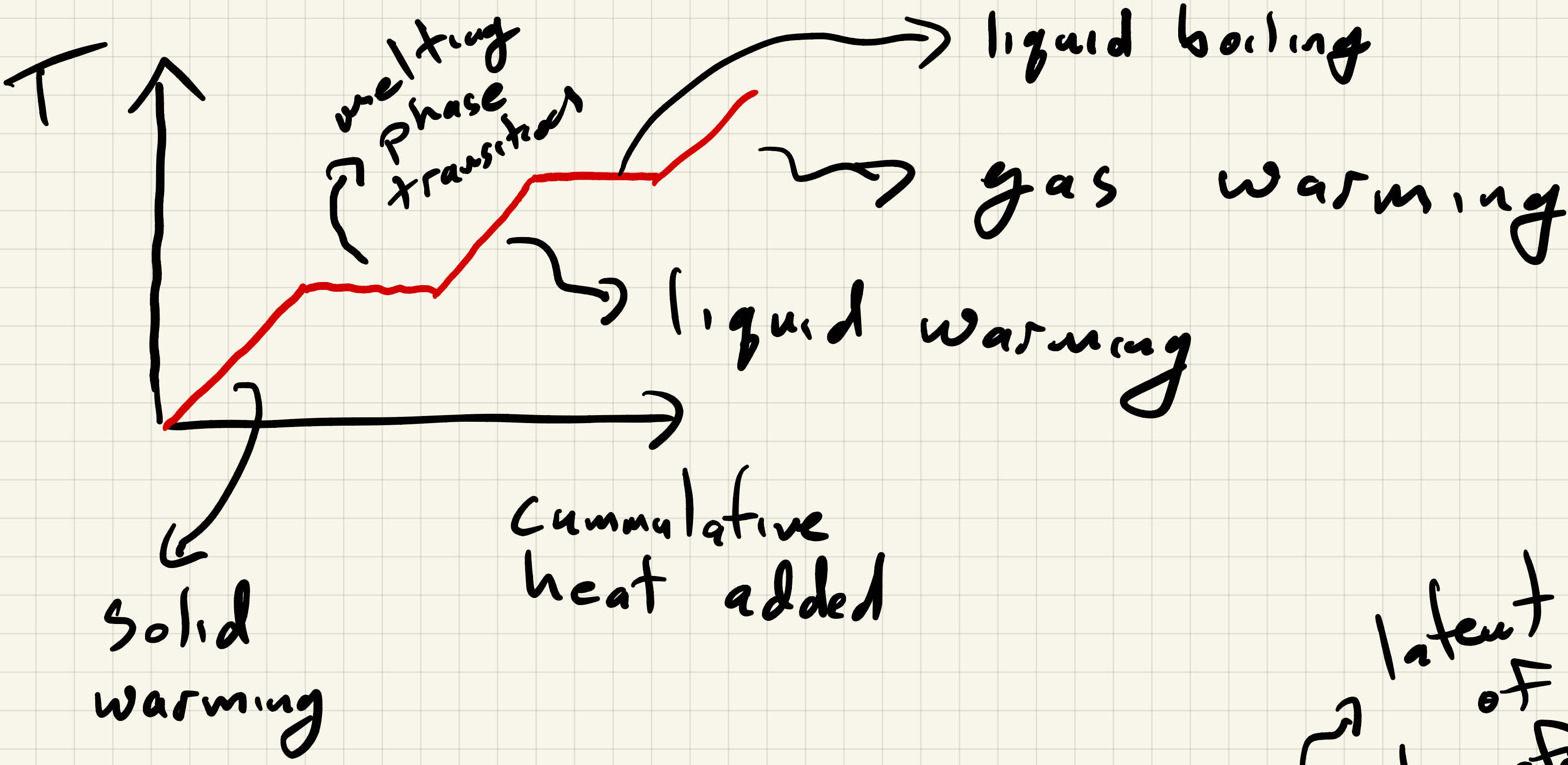
if no work done on system

$$\Rightarrow \Delta E_{th} = Q$$

$$\Delta E_{th} = \underbrace{M}_{\text{mass}}\ \underbrace{c}_{\text{specific heat}}\ \overset{\Delta\text{temp}}{\Delta T}$$

$$\Rightarrow Q = Mc\Delta T$$

or $\Delta T = \dfrac{Q}{Mc}$



latent heat of transformation

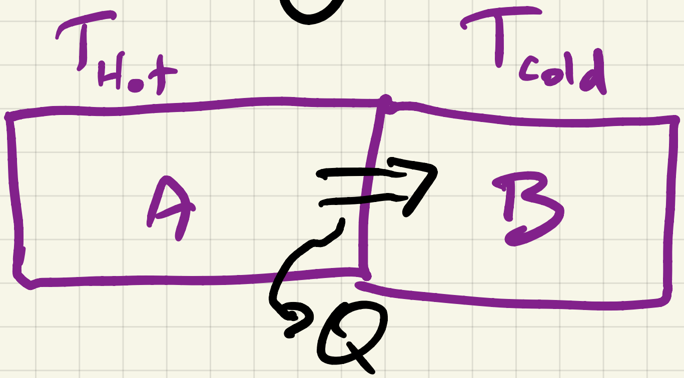
for phase transitions $Q = ML$

$L_f \equiv$ latent heat of fusion (melting or freezing)

$L_v =$ latent heat of vaporization (boiling or condensing)

$$Q = mc\Delta T \quad \& \quad Q = mL$$

Calorimetry



isolated system
conservation of energy

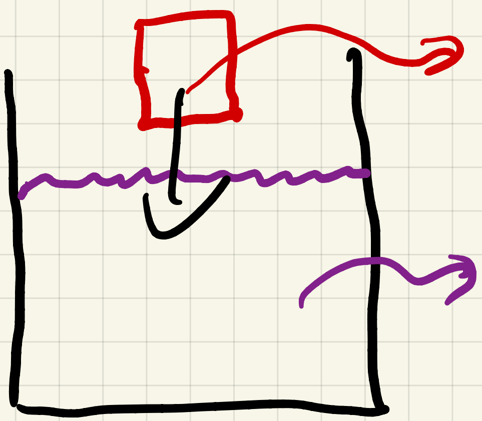
$$Q_A + Q_B = 0$$

$$Q_A = m_A c_A \Delta T_A$$

$$Q_A = m_A c_A (T_{A_f} - T_{A_i})$$

$$Q_B = m_B c_B (T_{B_f} - T_{B_i})$$

in equilibrium (at the end) $T_{A_f} = T_{B_f} = T_f$



100g of copper @ 100°C

400g water @ 20°C

Find Final temp

$Q_{cu} = M_{cu} c_{cu} (T_{cu_f} - T_{cu_i})$ $Q_{water} = M_{water} c_{water} (T_{water_f} - T_{water_i})$

$$M_{cu} c_{cu} (T_{cu_f} - T_{cu_i}) + M_{water} c_{water} (T_{water_f} - T_{water_i}) = 0$$

$$T_{cu_f} = T_{water_f} = T_F$$

$$T_f = \frac{M_{cu} C_{cu} T_{cu_i} + M_{water} C_{water} T_{water_i}}{M_{cu} c_{cu} + M_{water} C_{water}}$$

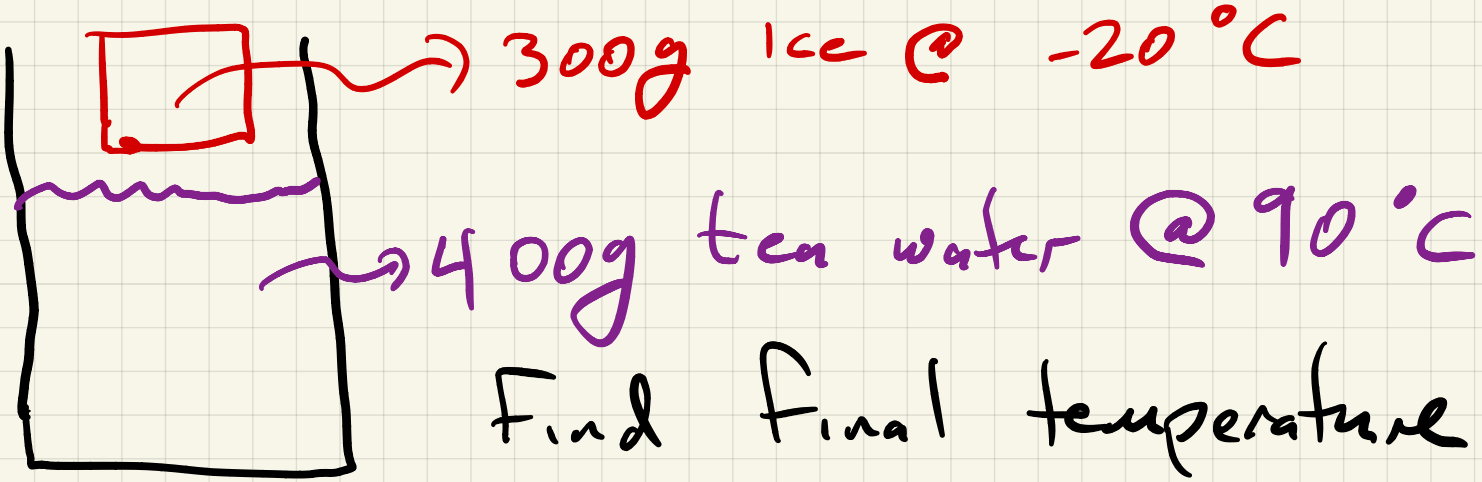
$M_{cu} = 0.1 \text{ kg}$ $M_{water} = 0.4 \text{ kg}$

$C_{cu} = 385 \frac{J}{kg\,K}$ $C_{water} = 4190 \frac{J}{kg\,K}$

For temp changes $C^\circ = K$

$T_{cu_i} = 373\,K$ $T_{water_i} = 293\,K$

$T_F = 294.8\,K = 21.8\ ^\circ C$



Find final temperature

Q_{ice} warming $\quad Q_{ice}$ melting $\quad Q_{ice\,water}$ warming

Q_{tea} cooling

$$M_{ice} c_{ice} \left(\overset{0^\circ C}{\boxed{T_{ice_{final}}}} - T_{ice_i} \right) + M_{ice} L_{fusion\ ice} + M_{ice} c_{water} \left(T_f - \overset{0^\circ C}{\boxed{T_{ice\,water_i}}} \right)$$

$$+ M_{tea} c_{water} \left(T_f - T_{tea_i} \right) = 0$$

$M_{ice} = 0,3\ kg$ $\quad C_{ice} = 2090\ \frac{J}{kg\,K}$

$M_{water} = 0,4\ kg$ $\quad C_{water} = 4190\ J/_{kg\,K}$

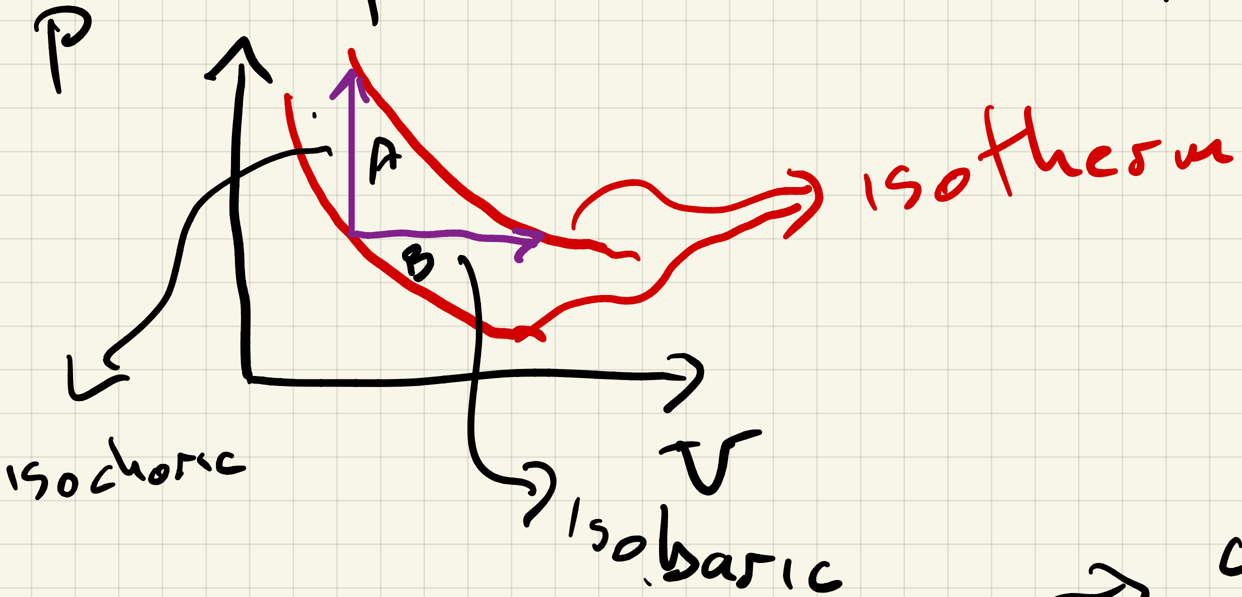
$L_{ice} = 3.33 \times 10^5\ \frac{J}{kg}$

$T_{tea_i} = 369\ K$

$T_{ice\,water_i} = 273$

$$\boxed{T_f = 13,1\ °C}$$

Specific Heats of ideal gases



change in temp.

$Q_A = n C_v \Delta T$

specific heat @ const. volume

\# of moles

$Q_B = n C_p \Delta T$

specific heat @ const. pressure

For isochoric process $\Rightarrow W_{ext} = 0$ so $\boxed{\Delta E_{th} = n C_v \Delta T}$

$C_p = C_v + R$

note the heat added & work done are path dependent.

Adiabatic process

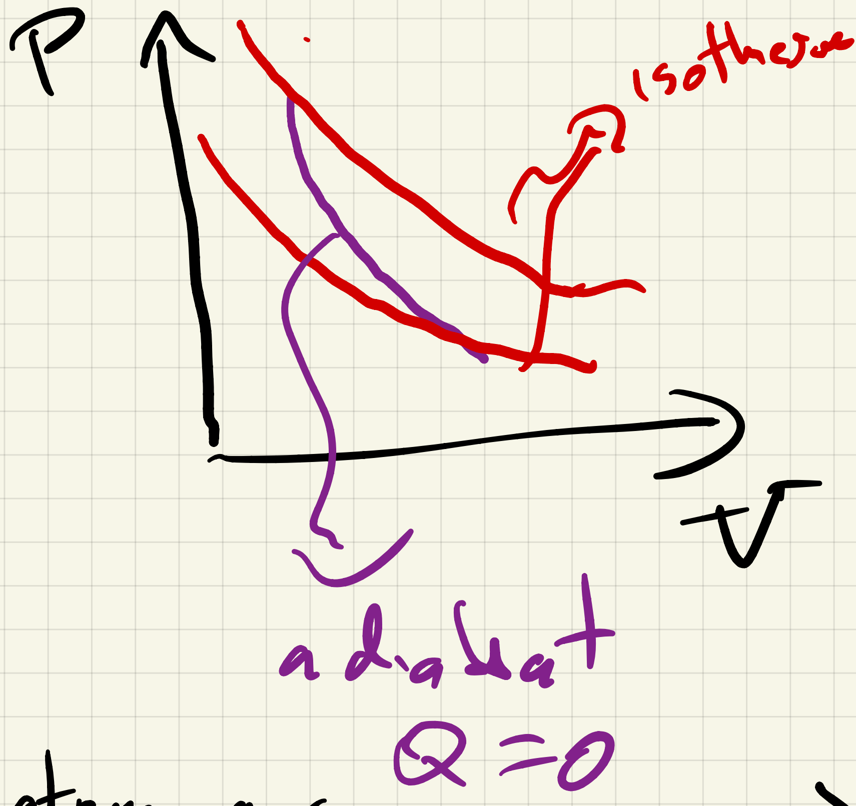
$\Delta E_{th} = n C_v \Delta T$

on adiabat $Q = 0$

$\Rightarrow W_{ext} = \Delta E_{th}$

$\Rightarrow W_{ext} = n C_v \Delta T$

we use $\gamma = \frac{C_p}{C_v}$



(monatomic gas $\gamma = 1.67$ & diatomic $\gamma = 1.40$)

on an adiabat

$PV^{\gamma} = \text{const} \Rightarrow P_i V_i^{\gamma} = P_F V_f^{\gamma}$

$TV^{\gamma-1} = \text{const} \qquad T_i V_i^{\gamma-1} = T_F V_f^{\gamma-1}$

diatomic gas in an engine is compressed (adiabatic) by a factor of 20 starting at 1 Atm & 30°C find P_F & T_f

$$P_F = \left(\frac{V_i}{V_F}\right)^{\gamma} P_i = 1\,\text{Atm}\,(20)^{1.4} = 66.3\,\text{Atm}$$

$$T_f = T_i \left(\frac{V_i}{V_F}\right)^{\gamma-1} = 303\,\text{K}\,(20)^{0.4} = 1004.3\ \text{K}$$

$$= 731\ °\text{C}$$

Heat transfer

conduction, convection, radiation

⇒ Conduction

$$\frac{dQ}{dt} = k\frac{A}{L}\Delta T$$

A → area in m^2

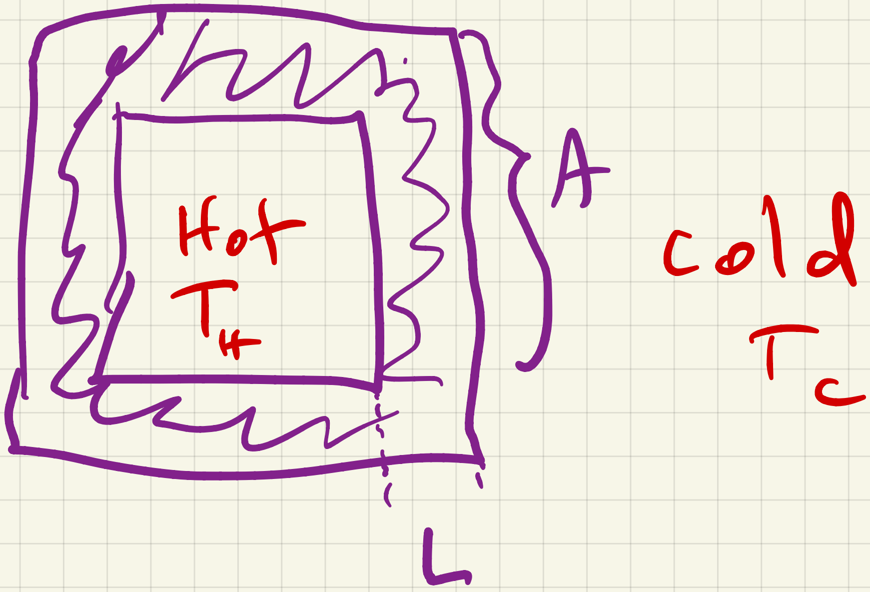
ΔT → temp

L → thickness in m

$\frac{dQ}{dt}$ → J/sec

k → thermal conductivity $\frac{W}{mK}$

→ smaller is better



	k
Air →	0.023
glass →	0.8
steel →	14
diamond →	2000

⇒ convection – moving stuff in a Fluid

⇒ Radiation (EM waves)

$$\frac{dQ}{dt} = \varepsilon \sigma A T^4$$

→ temp. in K

→ area in m^2

emissivity (0-1)

→ Stefan-Boltzmann const.

$5.67 \times 10^{-8} \frac{W}{m^2 K^4}$

$$\frac{dQ_{net}}{dt} = \varepsilon \sigma A \left(T^4 - T_0^4\right)$$

↳ background temp