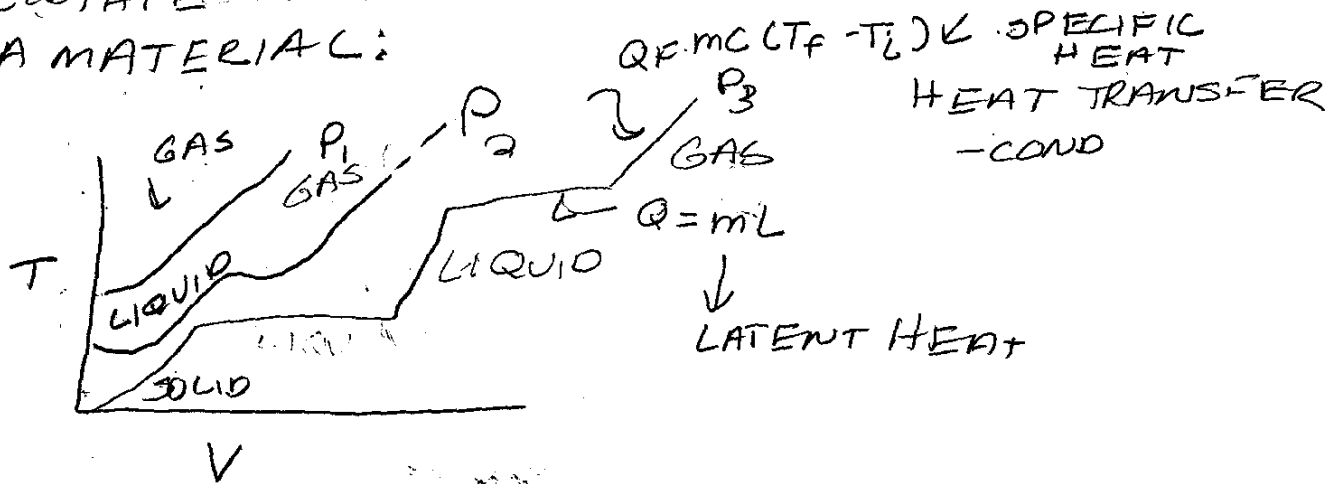


2/27/2018 LECTURE NOTES

THERMODYNAMICS DEAL WITH THE STATE VARIABLES
 (PRESSURE (P), VOLUME (V), AND TEMPERATURE).
 THE STATE VARIABLES DESCRIBE THE PHASES
 OF A MATERIAL:



FIRST LAW: $Q = \Delta U + W$ MUST HAVE TEMPERATURE OR ENERGY (ENTHALPY)

SECOND LAW: $DS \neq 0$ CANNOT CONVERT HEAT

THIRD LAW: $DS = Q$ "ARROW OF TIME"

FIRST LAW

$KE_{INT} = \frac{1}{2} \sum m_i u_i^2$; $U = \frac{3}{2} kT$ FOR AN IDEAL GAS
 FROM LECTURE 2/20

$$\frac{1}{2} \sum m_i u_i^2 = \frac{3}{2} kT \quad \sum m_i = M_{TOT}$$

$$\frac{M_{TOT} \sum u_i^2}{M_{TOT}} = \frac{3kT}{M_{TOT}}$$

$$\sum u_i^2 = \frac{3kT}{M_{TOT}}$$

$$\bar{u_i^2} = \frac{\sum u_i^2}{n}$$

$$n \bar{u_i^2} = \frac{3kT}{M_{TOT}}$$

$$n \bar{u_i^2} = \sum u_i^2$$

$$\sqrt{\bar{u_i^2}} = \sqrt{\frac{3kT}{M_{TOT}}}$$

$$\boxed{u_0 = \sqrt{\frac{3kT}{M_{TOT}}}}$$

FIRST LAW
ADIABATIC EXPANSION (NO HEAT)

$$PV = nRT \quad \text{IDEAL GAS}$$

$$P dV + V dP = nR dT$$

$$Q = \Delta U + W \quad Q = 0$$

$$0 = \Delta U + W$$

$$-W = \Delta U$$

$$dU = -P dV \quad \therefore W = PV$$

FROM THE IDEAL GAS LAW

$$U = \frac{3}{2} nRT$$

$$Q = C_V n \Delta T$$

$$Q = \Delta U + P \Delta V$$

$$C_V = \frac{1}{n} \frac{dU}{dT} = \frac{3}{2} R; \quad C_P = C_V + R \Rightarrow R = C_P - C_V$$

$$C_V = \frac{1}{n} \frac{d(-P dV)}{dT} = \frac{1}{C_V} \frac{d(-P dV)}{dT}$$

$$R n \Delta T = -\frac{P}{C_V} \Delta V R$$

$$\frac{P dV + V dP}{C_P - C_V} = -\frac{P}{C_V} \frac{dV (C_P - C_V)}{C_P - C_V}$$

$$\frac{P dV + V dP}{C_P - C_V} = -\frac{P}{C_V} dV + \frac{P dV}{C_V}$$
$$+\frac{P dV}{C_V}$$

$$\frac{P \Delta V + V \Delta P}{C_p - C_v} + \frac{P \Delta V}{C_v} = 0 \quad \text{NEED A COMMON DENOMINATOR}$$

$$\frac{C_v (P \Delta V + V \Delta P) + (C_p - C_v) P \Delta V}{(C_p - C_v) C_v} = 0$$

$$\frac{C_v P \Delta V + C_v V \Delta P + C_p P \Delta V - C_v P \Delta V}{(C_p - C_v) C_v} = 0$$

$$\frac{C_v V \Delta P + C_p P \Delta V}{\frac{P V}{nT} C_v} = 0$$

$$\frac{C_v V \Delta P}{\frac{P V}{nT} C_v} + \frac{C_p P \Delta V}{\frac{P V}{nT} C_v} = 0$$

$$\frac{1}{nT} \left[\frac{\Delta P}{P} + \frac{C_p}{C_v} \frac{\Delta V}{V} \right] = 0$$

$$\frac{\Delta P}{P} + \frac{C_p}{C_v} \frac{\Delta V}{V} = 0 \quad ; \quad \gamma = \frac{C_p}{C_v}$$

$$\frac{\Delta P}{P} + \gamma \frac{\Delta V}{V} \quad \text{WITH INTEGRATION} \quad \int \frac{dx}{x} = \ln x ; \int c dx = K$$

$\ln a + \ln b = \ln(ab)$
 $a^x b^y = \ln b^a$

$$\int \frac{dP}{P} + \gamma \int \frac{dV}{V} = \int 0$$

$$\ln P + \gamma \ln V = K$$

$$\ln P + \ln V^\gamma = K$$

$$e^{\ln(PV^\gamma)} = e^K ; e^K = K \Rightarrow \boxed{PV^\gamma = K}$$

$$PV = nRT$$

$$R = C_p - C_v$$

$$\frac{PV}{nT} = \frac{nRT}{nT}$$

$$\frac{PV}{nT} = C_p - C_v$$

FOR OUR WORK $\Rightarrow \Delta W = P \Delta V$; $P = \frac{k}{V^\gamma}$

$$W = k \int_{V_1}^{V_2} \frac{\gamma dV}{V^\gamma}; \int \frac{1}{x^a} dx = \int x^{-a} dx = \frac{x^{1-a}}{1-a}$$

$$W = \frac{k(V_2^{1-\gamma} - V_1^{1-\gamma})}{1-\gamma} = \frac{PV_2^\gamma(V_2^{1-\gamma} - V_1^{1-\gamma})}{1-\gamma} = \boxed{\frac{PV}{1-\gamma}}$$

EXAMPLE

HOW MUCH ENERGY TO CONVERT 3 MOLES OF ALCOHOL FROM SOLID TO GAS FROM -120°C TO 100°C AND THE VOLUME CHANGE ADIABATICALLY IN 1 ATMOSPHERE OF PRESSURE.

3 MOLES ALCOHOL = 0.15 kg BOIL = 79.0°C ; MELTING = -117°C
 SOLID = 117 J/mole K ; LIQUID = 112 J/mole K ; GAS = 78.3 J/mole K
 VAPORIZATION = $4.90 \times 10^3 \text{ J/mole}$; FUSION = 38.6 kJ/mole

WE NEED TO ADD $273.^\circ\text{C}$ TO CONVERT TO KELVIN

$$T_1 = -120^\circ + 273 = 153^\circ\text{K}; T_{\text{MELT}} = 156^\circ\text{K}; T_{\text{VAPOR}} = 352^\circ\text{K}; T_2 = 373\text{K}$$

$$\text{MELT: } Q_1 = mC(T_{\text{MELT}} - T_1) = (3 \text{ mole})(117 \text{ J/mole K})(156^\circ\text{K} - 153^\circ\text{K}) = \boxed{999 \text{ J}}$$

$$\text{LIQUID: } Q_2 = mL_f = (3 \text{ mole})(38.6 \times 10^3 \text{ J/mole}) = \boxed{116,000 \text{ J}}$$

$$\text{EVAP: } Q_3 = mC(T_{\text{VAP}} - T_{\text{MELT}}) = (3 \text{ mole})(112 \text{ J/mole K})(352^\circ\text{K} - 156^\circ\text{K}) = \boxed{67,200 \text{ J}}$$

$$\text{GAS: } Q_4 = mL_v = (3 \text{ mole})(4.90 \times 10^3 \text{ J/mole}) = \boxed{14,700 \text{ J}}$$

$$\text{VAPOR: } Q_5 = mC(T_2 - T_{\text{VAP}}) = (3 \text{ mole})(78.3 \text{ J/mole K})(373^\circ\text{K} - 352^\circ\text{K}) = \boxed{4,930 \text{ J}}$$

$$Q_{\text{TOT}} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$$

$$= 999 \text{ J} + 116,000 \text{ J} + 67,200 \text{ J} + 14,700 \text{ J} + 4,930 \text{ J}$$

$$= \boxed{204,000 \text{ J}}$$

$$W = \frac{PV}{1-\gamma} \Rightarrow \frac{W(1-\gamma)}{P} = \frac{PV}{P} \Rightarrow V = \frac{W(1-\gamma)}{P}$$

$$\gamma = 1.66; P = 101,000 \frac{\text{kg}}{\text{m}^2 \text{s}^2}$$

$$V = \frac{(204,000 \text{ kg m}^2/\text{s}^2) \cdot (1-1.66)}{101,000 \text{ kg}/\text{m}^2 \text{s}^2} = -1.33 \text{ m}^3$$