AREN 2110: Property Review topics

A. Basic Concepts
1. Properties
    a. Intensive and extensive properties
    b. Independent properties
    c. Measurement of pressure and temperature, absolute and relative scales
    d. State postulate for simple compressible systems: two independent intensive properties define all others (fix system state)
    e. Pure substances: uniform molecular composition
    f. Phases and phase mixtures
        i. Saturated liquid (add heat → vapor formation; remove heat T decreases)
        ii. Saturated vapor (remove heat → condensation; add heat T increases)
        iii. Quality, x, is mass fraction vapor: $0 < x < 1$
    g. Property diagrams: P-v and T-v
    h. Point functions: $\Delta T = T_2 - T_1$, $\Delta u = u_2 - u_1$, etc.
2. Systems
    a. Open and closed
    b. State – defined by properties
3. Processes
    a. Quasi-equilibrium
    b. Isobaric
    c. Isothermal
    d. Isochoric
    e. Work and heat are path dependent
4. Property relations: to find other properties when two independent properties are known
    a. Internal energy and enthalpy
    b. Specific heat
    c. Energy of ideal gases
    d. Energy of incompressible liquids and solids
    e. Energy of water and refrigerant – liquid vapor mixture and superheated vapor

5. Work
    a. Boundary work

Some Useful Formulas

General:

$V = m*v = m/\rho$
$H = m*h$
$U = m*u$
$\Delta V = m*(v_2 - v_1)$
$\Delta H = m*(h_2 - h_1)$
$\Delta U = m*(u_2 - u_1)$
$\Delta P = P_2 - P_1$
$\Delta T = T_2 - T_1$

<u>Property Relations for Ideal gases</u>
$PV = mRT$
$Pv = RT$
$P = \rho RT$
$PV = N\bar{R}T$
$R = \bar{R}/MW$
Where T = absolute T (K) and P = absolute P

$(h_2 - h_1) = c_P*(T_2 - T_1)$
$(u_2 - u_1) = c_V*(T_2 - T_1)$
Where $c_P = c_V + R$
Values in for c_P and c_V in Tables A-2a, b, c

<u>Property Relations for Ideal Liquids and Solids</u>
For small values of ΔP:
$(u_2 - u_1) = (h_2 - h_1) = c_P*(T_2 - T_1)$
Values for c_P in Table A-3
For small values of ΔT ($\Delta u \sim 0$) (pumps)
$(h_2 - h_1) = v\Delta P = v*(P_2 - P_1)$

Property Tables for water and R-134a: liquid-vapor and superheated vapor
A-4 and A-5 for saturated water liquid-vapor, A-6 for superheated steam
A-11 and A-12 for saturated R-134a liquid-vapor, A-13 for superheated vapor
DO NOT USE SPECIFIC HEAT FORMULAS FOR THESE SUBSTANCES

MIXTURES: **P and T are not independent**. Need additional property

Quality = $x = m_g/m_T = (y - y_f)/(y_g - y_f)$ where y is an intensive property: v, u, h

OR given x, the property, y, of a saturated mixture can be calculated by

$$y = x(y_g - y_f) + y_f$$

using table values for y_g and y_f at the given P_{sat} or T_{sat}

SUPERHEATED VAPOR: **P and T are independent properties for single phase material** and can be used to find other intensive properties.

BOUNDARY WORK

Sign convention: Positive for work done by system on surroundings
Negative for work done on system by surroundings

$$W_B = \int P dV$$

Isobaric boundary work = $P(V_2 - V_1) = P*m*(v_2 - v_1)$ (kJ)
Isothermal boundary work, ideal gas only = $P_1V_1*\ln(V_2/V_1) = P_2V_2*\ln(V_2/V_1)$
$= mRT*\ln(V_2/V_1)$ (kJ)
Isochoric boundary work = 0 since dV = 0

Polytropic process ($PV^n = C$) boundary work
General polytropic boundary work = $(P_2V_2 - P_1V_1)/(1-n)$ $n \neq 1$
Ideal gas polytropic boundary work = $mR(T_2 - T_1)/(1-n)$ $n \neq 1$