Problem 1

The equilibrium states of a hot steam is given by

$$v - b = \frac{rT}{P} - \frac{a}{T^m},$$

where b, r, a, m are constants. Calculate the volume expansion co-efficient (β) and iso-thermal compressibility (κ) of the system.

Problem 2

Show that during an adiabatic process, the equation of state for an ideal gas with f-degree of freedoms can be written as

$$PV^{\gamma} = Constant$$

where γ = (f+2)/f is called adiabatic exponent.

Problem 3

The equation of state for a system is given by $PV^{\gamma} = C$, where γ and C are constants. Show that the work done in a quasi-static process while going from the state (P_i, V_i) to (P_f, V_f) is given by

$$W = -\frac{P_i V_i - P_f V_f}{\gamma - 1}.$$

If the initial pressure and volume are 10^6 Pa and 10^{-3} m^3, respectively, and the final values are 2×10^5 Pa and 3.16×10^{-3} m^3, respectively, how much work is done on the gas with γ = 1.4?

Problem 4

Calculate the work done upon expansion of 1 mol of van der Waals gas quasi-statically and isothermally from volume v_i to v_f. The equation of state of a van der Waals gas is given by

$$(P + \frac{a}{V^2})(v - b) = RT.$$

If $a = 1.4 \times 10^9$ N.m^4/mol and $b = 3.2 \times 10^{-5}$ m^3/mol, how much work is done when the gas expands from 10 liters to 22.4 liters at the room temperature.

Problem 5

Consider U as a function of P, V or T. Derive the following equations.

$$(i)\ \text{đ}Q = \left(\frac{\partial V}{\partial P}\right)_V dP + \left[\left(\frac{\partial U}{\partial V}\right)_P + P\right] dV$$

$$(ii)\quad \left(\frac{\partial U}{\partial P}\right)_V = \frac{C_V \kappa}{\beta}$$

$$(iii)\quad \left(\frac{\partial U}{\partial V}\right)_P = \frac{C_P}{V\beta} - P,$$

where β, κ, C_V and C_P are volume expansion co-efficient, iso-thermal compressibility, heat capacity at constant volume and pressure, respectively.

Problem 6

The Gibbs-Duhem relation is given by

$$SdT + \sum_{j=1}^{t} X_j dP_j = 0.$$

Show that it can be written in the entropy representation as

$$\sum_{k=0}^{t} X_k dF_k = 0,$$

where X_0 = U, X_1 = V, X_2 = N$_1$, ..., X_t=N$_r$, $P_j = (\frac{\partial U}{\partial X_j})_{S,\ldots,X_k,\ldots}$ and $F_k = -\frac{P_k}{T}$.

Problem 7

Find the three equations of state for a system whose fundamental equation is given by

$$U = \left(\frac{v_0\theta}{R^2}\right)\frac{S^3}{NV},$$

where v_0 and θ are constants. Further, check that the equations of state are homogeneous zero order.

Problem 8

The equation of state of a van der Waals gas is given by

$$(P + \frac{N^2 a}{V^2})(V - Nb) = NRT$$

where a, b, and R are constants. Calculate the fundamental equation for this system.