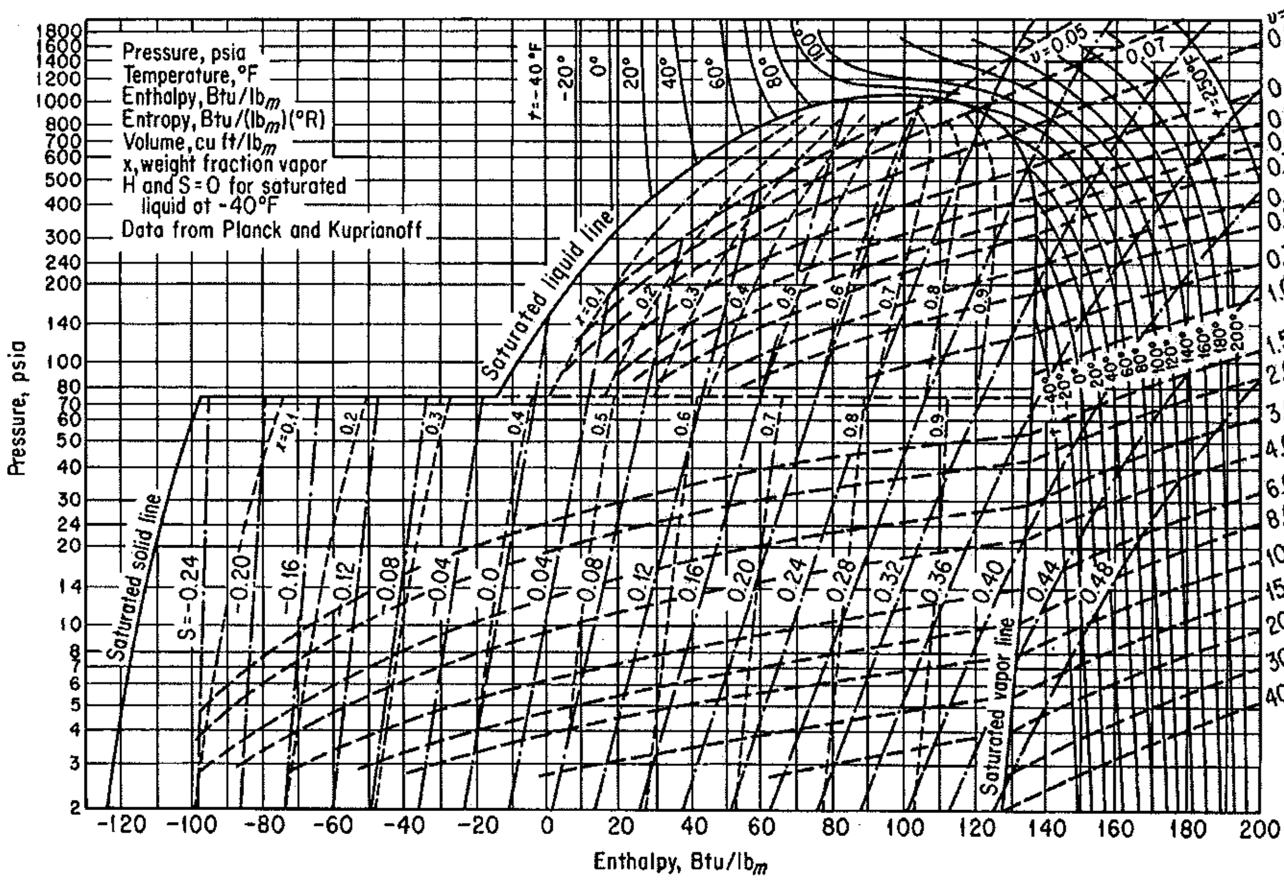
2008Fall PhD Qualify Exam. -- Thermodynamics (Undergraduate level Questions)

1. (25) A turbine is installed to utilize CO_2 at 1800 psia and 250 °F for generating useful work. The design exhaust pressure of the turbine is 300 psia. (i) Estimate the temperature of the exhaust stream if the turbine is run ideally at adiabatic and reversible conditions. How much work can be obtained per lb_m of CO_2? (ii) If an actual adiabatic turbine can achieve only 40 % of the work from the ideal turbine of (a), what will be the exhaust temperature of the steam and what will be the work obtained per kg of steam? What will be the maximum work this turbine can achieve? You will need the attached P-H diagram.

2. (25) A well-insulated tank is divided into two equal chambers by an internal diaphragm, One chamber contains methane at a pressure of 500 bar and 20 °C, and the other chamber is evacuated. Suddenly the diaphragm bursts. Calculate the final temperature and pressure of the gas in the tank after equilibrium is attained assuming methane as (i) an ideal gas and (ii) obeying Clausius equation of state, $P(\underline{V} - b) = RT$ with $b = 0.04$ m^3/kmol. You can assume a constant Cp as 35.56 J/mol/K.

For CO_2



Qualify Exam

Chemical Engineering Thermodynamics

Part (II) Graduate level (50%)

1. 1-Propanol, isopropanol, and methyl ethyl ether are isomers. However, the normal boiling points of these three substances are 370.3 K, 355.4 K, and 280.6 K, respectively. Please explain it on the basis of knowledge of intermolecular forces. (10%)

2. Acetic acid (A) in gas phase may form dimer, A_2, and trimer, A_3. The equilibrium constants (K_i) of the associations are given, respectively, by

$$K_2 = exp\left(\frac{6400}{T} - 20\right)$$

$$K_3 = exp\left(\frac{12000}{T} - 40\right)$$

where T in K. Describe the method to calculate the compressibility factor Z of the substance at 1 bar and 300 K from the ***Chemical Theory*** by assuming that the gas phase is ideal physically. Please list all the necessary equations, but you don't need to solve them. (20 %)

3. (a) Express γ_2^* in terms of γ_2, where $\gamma_2^* = 1 \; as \; x_2 \to 0$ and $\gamma_2 = 1 \; as \; x_2 \to 1$. (10 %)

(b) Derive ln γ_2^*, if

$$ln\,\gamma_2 = x_1^2\left[\tau_{12}\left(\frac{G_{12}}{x_2 + x_1 G_{12}}\right)^2 + \frac{\tau_{21} G_{21}}{(x_1 + x_2 G_{21})^2}\right]$$

$$where \;\; G_{12} = exp\left[-\alpha_{12}\left(\frac{g_{12} - g_{22}}{RT}\right)\right]; \;\; G_{21} = exp\left[-\alpha_{12}\left(\frac{g_{21} - g_{11}}{RT}\right)\right]$$

(10 %)