

1. Let's compare the pressure-temperature behavior of two important expansion processes that are used for refrigeration and cooling applications:
 - (i) expansion across a Joule-Thompson valve
 - (ii) expansion in an adiabatic turbine

To carryout this comparison it is helpful to construct an equation to express the ratio of how temperature varies with pressure for each process. Defining this ratio as follows:

$$\alpha \equiv \frac{(\partial T / \partial P)_{process (i)}}{(\partial T / \partial P)_{process (ii)}}$$

We will also need to specify the type of fluid to be expanded. To keep things simple, let's limit our analysis to pure CO₂ which can be represented by four constitutive property models whose accuracy will depend on the *PVT* region where the expansion is carried out. The four models are:

- (1) ideal gas
 - (2) The Law of Corresponding States
(Hint: Express α in terms of Z and its derivatives)
 - (3) PR EOS
 - (4) Thermodynamic charts given in Figures 8.12 a,b
- (a) What is the initial value of α for each model above for the expansion of pure CO₂ from an initial state of 100 bar and 37°C?
 - (b) Which process would you expect to liquefy a greater fraction of the entering CO₂ gas if the final pressure state for the expansion is 10 bar?
 - (c) What technological and economic issues would be important in selecting a process for practical use?

Physical property data for carbon dioxide are given at the end of the problem set and in Appendix G of the text.

(continued...)

2. Rocky and Rochelle are having one of their classic arguments regarding thermodynamics and they need your help. Imagine a process where supercritical CO₂ gas at 320 K and 100 bar is added to a cylinder while maintaining the total entropy and pressure constant. Rocky says that the temperature will increase and Rochelle says it will decrease. Who is correct? Is it possible that they both could be correct? You may want to start your analysis by developing an expression for the temperature change per mole of component j added to a multicomponent mixture under conditions of constant \underline{S} , P and $N_{i \neq j}$. Relevant property data are given at the end of the problem. In formulating your solution, you may want to use the data provided in the Table 4-5 of Tables of Thermal Properties of Gases, Hilsenrath et al., National Bureau of Standards Circular 564, 1955. You will have to extrapolate a bit.
3. We would like to make a few modifications to the van der Waals EOS and evaluate how the PVT behavior of a pure fluid might change.
- (a) expand the $RT/(V-b)$ term of the vdw EOS as a polynomial power series in b/V
 - (b) If we truncate the expansion after the $(b/V)^2$ term, how does the compressibility change as a function of density from very low density ($\rho = 0$) to high density ($\rho = 1/b$)?
 - (c) Is it possible for a fluid obeying this modified EOS to reach a Zeno condition where $Z = 1$? If so, where does this occur?
 - (d) Assuming that the Zeno condition is met for this pure material, estimate the fugacity coefficient (ϕ_i) at this point. How do you interpret your estimate?

Be sure to state and justify all assumptions made.

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