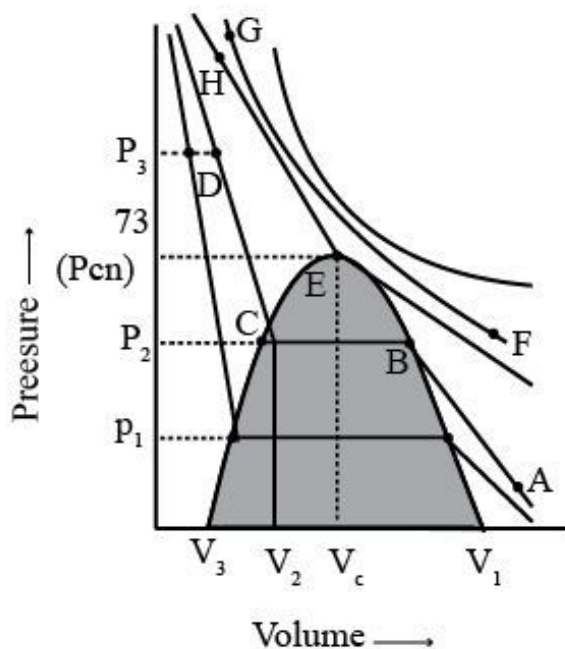


- Trace a path where a gas is compressed isothermally at temperature $T < T_c$. Identify each point where the state changes.
 - Label the inflection point. What is the significance of this point in terms of phase transitions?
 - Draw a path on the diagram to convert the gas to a liquid, ensuring that only one phase exists throughout the process. Describe what you would do to achieve each step.



- Isothermal compression along $A \rightarrow B \rightarrow C \rightarrow D$. A is gas, $B \rightarrow C$ is liquid-gas coexistence region, D is liquid.
- Inflection point is at E , also the critical point. Above this point is supercritical fluid.
- Single phase change along $A \rightarrow F \rightarrow G \rightarrow D$. $A \rightarrow F$ moves between isotherms, so an increase in temperature. $F \rightarrow G$ is an isotherm of supercritical fluid being compressed. $G \rightarrow D$ decreases T .

- Methane ($T_c = 190.6 \text{ K}$, $P_c = 45.99 \text{ bar}$) and propane ($T_c = 369.8 \text{ K}$, $P_c = 42.48 \text{ bar}$) are both at reduced conditions of $T_r = 1.3$ and $P_r = 0.8$. Calculate the actual T and P , and predict which has a greater compressibility factor.

By the law of corresponding states, gases at the same T_r and P_r have the same compressibility factor Z . Therefore $Z_{\text{methane}} = Z_{\text{propane}}$.

Methane:

$$T = T_r \cdot T_c = 1.3 \times 190.6 = 247.8 \text{ K}$$

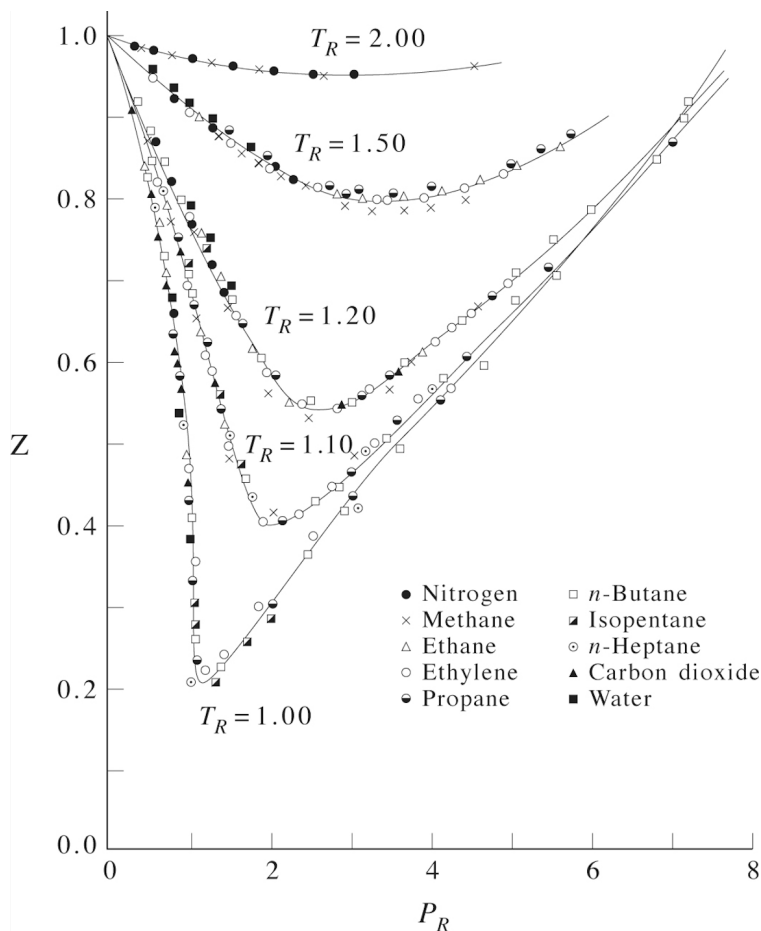
$$P = P_r \cdot P_c = 0.8 \times 45.99 = 36.8 \text{ bar}$$

Propane:

$$T = T_r \cdot T_c = 1.3 \times 369.8 = 480.7 \text{ K}$$

$$P = P_r \cdot P_c = 0.8 \times 42.48 = 34.0 \text{ bar}$$

3. Explain how the figure illustrates the Law of Corresponding states by contrasting it to a Z vs P diagram, and use the figure to estimate the molar volume of CO at 200 K and 180 bar ($T_c = 132.85 \text{ K}$, $P_c = 34.935 \text{ bar}$). The experimental value is $78.3 \text{ cm}^3 \cdot \text{mol}^{-1}$. $R = 0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$



Graph resembles general check mark structure of Z vs P diagrams. But all follow same curve when using reduced quantities, illustrating Law of Corresponding States
 First compute reduced quantities for Law of Corresponding States

$$T_R = \frac{T}{T_c} = \frac{200 \text{ K}}{132.85 \text{ K}} = 1.51$$

$$P_R = \frac{P}{P_c} = \frac{180 \text{ bar}}{34.935 \text{ bar}} = 5.15$$

Reading off the chart, this corresponds to $Z \approx 0.85$

$$Z = \frac{P\bar{V}}{RT} = 0.85$$

$$\bar{V} = \frac{0.85RT}{P} = \frac{0.85 (0.08314 \frac{\text{L}\cdot\text{bar}}{\text{mol}\cdot\text{K}}) 200\text{K}}{180 \text{ bar}} = 0.078 \frac{\text{L}}{\text{mol}} = \boxed{78 \frac{\text{cm}^3}{\text{mol}}}$$

Homework Problem 11

1. Using the van der Waals equation, find the first and second derivatives of the pressure P with respect to the molar volume \bar{V} at constant temperature. Then set both derivatives equal to zero, $\left(\frac{\partial P}{\partial \bar{V}}\right)_T = 0$ and $\left(\frac{\partial^2 P}{\partial \bar{V}^2}\right)_T = 0$ and use this to show $T_c = \frac{8a}{27bR}$.