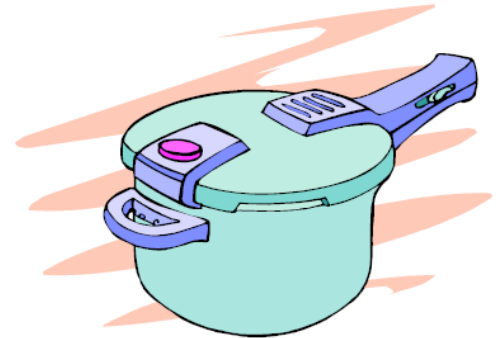


3.64

A pressure cooker has the lid screwed on tight. A small opening with $A = 5 \text{ mm}^2$ is covered with a petcock that can be lifted to let steam escape. How much mass should the petcock have to allow boiling at 120°C with an outside atmosphere at 101.3 kPa ?

Table B.1.1.: $P_{\text{sat}} = 198.5 \text{ kPa}$

$$\begin{aligned} F &= mg = \Delta P \times A \\ m &= \Delta P \times A/g \\ &= \frac{(198.5-101.3) \times 1000 \times 5 \times 10^{-6}}{9.807} \\ &= 0.0496 \text{ kg} = \mathbf{50 \text{ g}} \end{aligned}$$



3.83

A cylindrical gas tank 1 m long, inside diameter of 20 cm, is evacuated and then filled with carbon dioxide gas at 20°C . To what pressure should it be charged if there should be 1.2 kg of carbon dioxide?

Solution:

Assume CO_2 is an ideal gas, table A.5: $R = 0.1889 \text{ kJ/kg K}$

$$V_{\text{cyl}} = A \times L = \frac{\pi}{4}(0.2)^2 \times 1 = 0.031416 \text{ m}^3$$

$$P V = mRT \quad \Rightarrow \quad P = \frac{mRT}{V}$$

$$\Rightarrow P = \frac{1.2 \text{ kg} \times 0.1889 \text{ kJ/kg K} \times (273.15 + 20) \text{ K}}{0.031416 \text{ m}^3} = \mathbf{2115 \text{ kPa}}$$

3.84

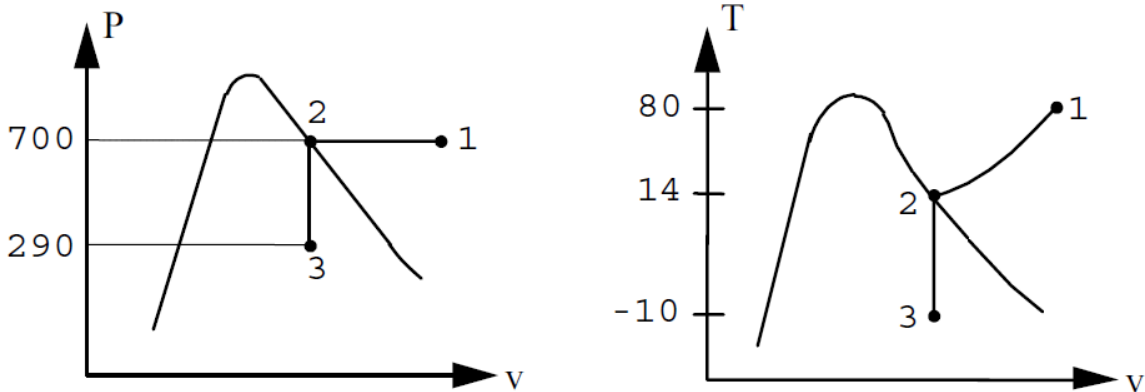
Ammonia in a piston/cylinder arrangement is at 700 kPa, 80°C. It is now cooled at constant pressure to saturated vapor (state 2) at which point the piston is locked with a pin. The cooling continues to -10°C (state 3). Show the processes 1 to 2 and 2 to 3 on both a $P-v$ and $T-v$ diagram.

Solution:

State 1: T, P from table B.2.2 this is superheated vapor.

State 2: T, x from table B.2.1

State 3: T, v two-phase



3.86

Carbon dioxide at 60°C is pumped at a very high pressure 10 MPa into an oil well to reduce the oil viscosity for better oil flow. What is its compressibility?

Table B.3.2: $v = 0.00345 \text{ m}^3/\text{kg}$

$$Z = Pv/RT = \frac{10\,000 \text{ kPa} \times 0.00345 \text{ m}^3/\text{kg}}{0.1889 \text{ kJ/kg-K} \times 333 \text{ K}} = \mathbf{0.55}$$

3.87

Find the compressibility for carbon dioxide at 60°C and 10 MPa using Fig. D.1

Solution:

Table A.2 CO₂: $T_c = 304.1 \text{ K}$ $P_c = 7.38 \text{ MPa}$

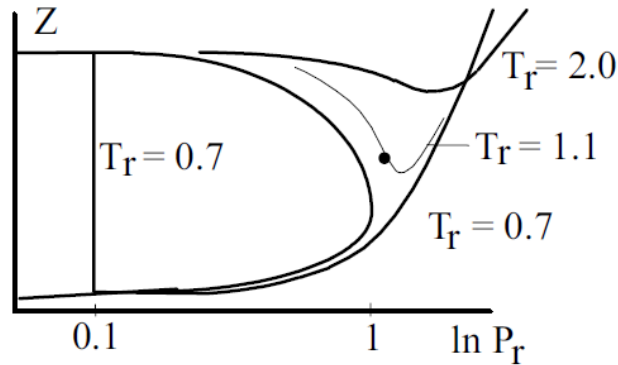
$$T_r = T/T_c = 333/304.1 = 1.095$$

$$P_r = P/P_c = 10/7.38 = 1.355$$

From Figure D.1: **$Z \approx 0.45$**

Compare with table B.3.2: $v = 0.00345 \text{ m}^3/\text{kg}$

$$Z = Pv/RT = \frac{10\,000 \text{ kPa} \times 0.00345 \text{ m}^3/\text{kg}}{0.1889 \text{ kJ/kg-K} \times 333 \text{ K}} = 0.55$$



$$P_1 = 120.8 \text{ kPa}, \quad v_1 = v_f + x v_{fg} = 0.001047 + 0.85 \cdot 1.41831 = 1.20661$$

$$m = V_1 / v_1 = \frac{0.001}{1.20661} = 8.288 \times 10^{-4} \text{ kg}$$

$$v_2 = v_1 (V_2 / V_1) = 1.20661 \times 1.5 = 1.8099$$

$$\& P = P_1 = 120.8 \text{ kPa} \quad (T_2 = 203.5^\circ\text{C})$$

$$P_3 = P_2 + (k_s / A_p^2) m (v_3 - v_2) \quad \text{linear spring}$$

$$A_p = (\pi/4) \times 0.15^2 = 0.01767 \text{ m}^2; \quad k_s = 100 \text{ kN/m (matches } P \text{ in kPa)}$$

$$200 = 120.8 + (100 / 0.01767^2) \times 8.288 \times 10^{-4} (v_3 - 1.8099)$$

$$200 = 120.8 + 265.446 (v_3 - 1.8099) \Rightarrow v_3 = 2.1083 \text{ m}^3/\text{kg}$$

$$T_3 \cong 600 + 100 \times (2.1083 - 2.01297) / (2.2443 - 2.01297) \cong 641^\circ\text{C}$$

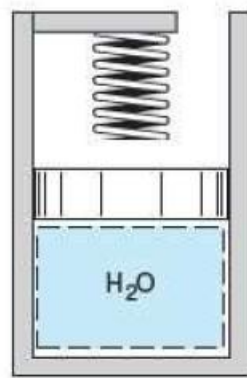
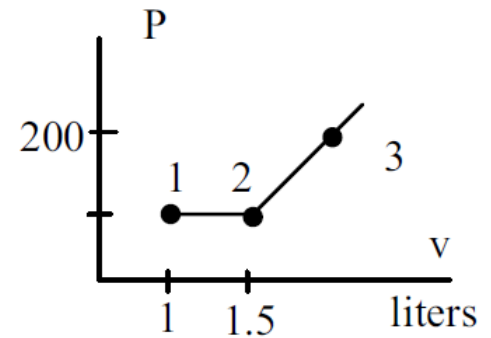


FIGURE P3.119

$$P_1 = 120.8 \text{ kPa}, \quad v_1 = v_f + x v_{fg} = 0.001047 + 0.85 \cdot 1.41831 = 1.20661$$

$$m = V_1 / v_1 = \frac{0.001}{1.20661} = 8.288 \times 10^{-4} \text{ kg}$$

$$v_2 = v_1 (V_2 / V_1) = 1.20661 \times 1.5 = 1.8099$$

$$\& P = P_1 = 120.8 \text{ kPa} \quad (T_2 = 203.5^\circ\text{C})$$

$$P_3 = P_2 + (k_s / A_p^2) m (v_3 - v_2) \quad \text{linear spring}$$

$$A_p = (\pi/4) \times 0.15^2 = 0.01767 \text{ m}^2; \quad k_s = 100 \text{ kN/m (matches } P \text{ in kPa)}$$

$$200 = 120.8 + (100 / 0.01767^2) \times 8.288 \times 10^{-4} (v_3 - 1.8099)$$

$$200 = 120.8 + 265.446 (v_3 - 1.8099) \Rightarrow v_3 = 2.1083 \text{ m}^3/\text{kg}$$

$$T_3 \cong 600 + 100 \times (2.1083 - 2.01297) / (2.2443 - 2.01297) \cong 641^\circ\text{C}$$

