ENGR 251: Thermodynamics

Solutions Tutorial 2: Chapter 3

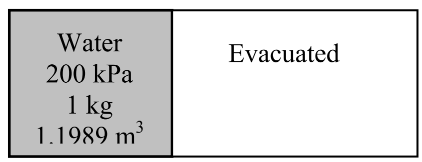
3-23 [*Also solved by EES on enclosed CD*] *Complete the following table for H_2O*:

T, °C	P, kPa	v, m³/kg	Phase description
50	***12.352***	4.16	***Saturated mixture***
120.21	200	***0.8858***	Saturated vapor
250	400	***0.5952***	***Superheated vapor***
110	600	***0.001051***	***Compressed liquid***

3-34 Left chamber of a partitioned system contains water at a specified state while the right chamber is evacuated. The partition is now ruptured and heat is transferred from the water. The pressure at the final state is to be determined.

Analysis The initial specific volume is

$$v_1 = \frac{V_1}{m} = \frac{1.1989\ \text{m}^3}{1\ \text{kg}} = 1.1989\ \text{m}^3/\text{kg}$$



At the final state, the water occupies three times the initial volume. Then,

$$v_2 = 3v_1 = 3(1.1989\ \text{m}^3/\text{kg}) = 3.5967\ \text{m}^3/\text{kg}$$

Based on this specific volume and the final temperature, the final state is a saturated mixture and the pressure is

$$P_2 = P_{\text{sat @ 3°C}} = \mathbf{0.768\ kPa} \quad \text{(Table A-4)}$$

3-63 Heat is supplied to a piston-cylinder device that contains water at a specified state. The volume of the tank, the final temperature and pressure, and the internal energy change of water are to be determined.

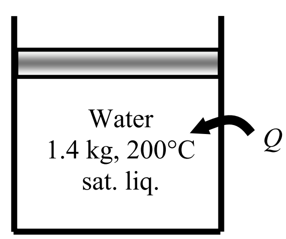
Properties The saturated liquid properties of water at 200°C are: $v_f = 0.001157$ m³/kg and $u_f = 850.46$ kJ/kg (Table A-4).

Analysis (*a*) The cylinder initially contains saturated liquid water. The volume of the cylinder at the initial state is

$$V_1 = mv_1 = (1.4\ \text{kg})(0.001157\ \text{m}^3/\text{kg}) = 0.001619\ \text{m}^3$$

The volume at the final state is

$$V = 4(0.001619) = \mathbf{0.006476\ m^3}$$



(*b*) The final state properties are

$$v_2 = \frac{V}{m} = \frac{0.006476\ \text{m}^3}{1.4\ \text{kg}} = 0.004626\ \text{m}^3/\text{kg}$$

$$\left.\begin{array}{l} v_2 = 0.004626\ \text{m}^3/\text{kg} \\ x_2 = 1 \end{array}\right\} \begin{array}{l} T_2 = \mathbf{371.3°C} \\ P_2 = \mathbf{21{,}367\ kPa} \\ u_2 = 2201.5\ \text{kJ/kg} \end{array} \quad \text{(Table A-4 or A-5 or EES)}$$

(*c*) The total internal energy change is determined from

$$\Delta U = m(u_2 - u_1) = (1.4\ \text{kg})(2201.5 - 850.46)\ \text{kJ/kg} = \mathbf{1892\ kJ}$$

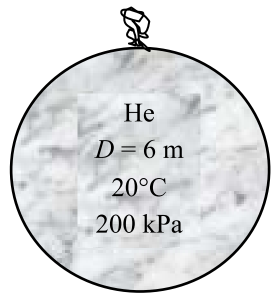
3-77 A balloon is filled with helium gas. The mole number and the mass of helium in the balloon are to be determined.

Assumptions At specified conditions, helium behaves as an ideal gas.

Properties The universal gas constant is R_u = 8.314 kPa.m^3/kmol.K. The molar mass of helium is 4.0 kg/kmol (Table A-1).

Analysis The volume of the sphere is

$$\mathbf{V} = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(3\text{ m})^3 = 113.1\text{ m}^3$$



Assuming ideal gas behavior, the mole numbers of He is determined from

$$N = \frac{P\mathbf{V}}{R_u T} = \frac{(200\text{ kPa})(113.1\text{ m}^3)}{(8.314\text{ kPa}\cdot\text{m}^3/\text{kmol}\cdot\text{K})(293\text{ K})} = \mathbf{9.28\ kmol}$$

Then the mass of He can be determined from

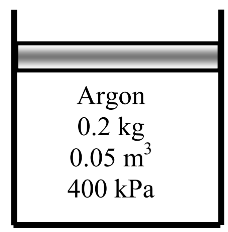
$$m = NM = (9.28\text{ kmol})(4.0\text{ kg/kmol}) = \mathbf{37.15\ kg}$$

3-84 A piston-cylinder device containing argon undergoes an isothermal process. The final pressure is to be determined.

Assumptions At specified conditions, argon behaves as an ideal gas.

Properties The gas constant of argon is R = 0.2081 kJ/kg·K (Table A-1).

Analysis Since the temperature remains constant, the ideal gas equation gives



$$m = \frac{P_1\mathbf{V}_1}{RT} = \frac{P_2\mathbf{V}_2}{RT} \longrightarrow P_1\mathbf{V}_1 = P_2\mathbf{V}_2$$

which when solved for final pressure becomes

$$P_2 = P_1\frac{\mathbf{V}_1}{\mathbf{V}_2} = P_1\frac{\mathbf{V}_1}{2\mathbf{V}_1} = 0.5P_1 = 0.5(400\text{ kPa}) = \mathbf{200\ kPa}$$

3-88 The specific volume of steam is to be determined using the ideal gas relation, the compressibility chart, and the steam tables. The errors involved in the first two approaches are also to be determined.

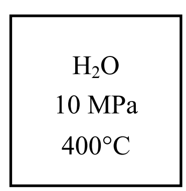
Properties The gas constant, the critical pressure, and the critical temperature of water are, from Table A-1,

R = 0.4615 kPa·m^3/kg·K, T_{cr} = 647.1 K, P_{cr} = 22.06 MPa

Analysis (*a*) From the ideal gas equation of state,

$$v = \frac{RT}{P} = \frac{(0.4615\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(673\text{ K})}{(10{,}000\text{ kPa})} = \mathbf{0.03106\ m^3/kg\ \ (17.6\%\ error)}$$

(*b*) From the compressibility chart (Fig. A-15),



$$\left.\begin{aligned} P_R &= \frac{P}{P_{cr}} = \frac{10\text{ MPa}}{22.06\text{ MPa}} = 0.453 \\ T_R &= \frac{T}{T_{cr}} = \frac{673\text{ K}}{647.1\text{ K}} = 1.04 \end{aligned}\right\} Z = 0.84$$

Thus,

$$v = Zv_{\text{ideal}} = (0.84)(0.03106\text{ m}^3/\text{kg}) = \mathbf{0.02609\ m^3/kg\ \ (1.2\%\ error)}$$

(*c*) From the superheated steam table (Table A-6),

$$\left.\begin{aligned} P &= 10\text{ MPa} \\ T &= 400°\text{C} \end{aligned}\right\} v = \mathbf{0.02644\ m^3/kg}$$