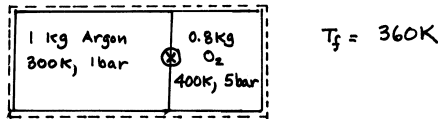


PROBLEM 12.26

KNOWN: Argon at a specified state is allowed to mix with O<sub>2</sub> at a specified state to achieve a mixture at a known temperature.

FIND: Determine (a) the volume of each gas initially, (b) the final pressure, (c) the heat transfer, and (d) the entropy change of each gas.

SCHEMATIC & GIVEN DATA



ASSUMPTIONS: (1) For the system shown in the accompanying figure there is no change in kinetic or potential energy between initial and final states. (2) Each gas and the overall mixture behaves as an ideal gas. The Dalton mixture model applies.

ANALYSIS: (a) The volume of each tank can be determined using the ideal gas equation of state together with known initial data for each gas:

$$V_{Ar} = \frac{n_{Ar}(\bar{R}/M_{Ar})T_{Ar}}{P_{Ar}} = \frac{(1 \text{ kg}) \left( \frac{8314 \frac{\text{N}\cdot\text{m}}{\text{kg}\cdot\text{K}}}{39.94} \right) (300 \text{ K})}{(10^5 \text{ N/m}^2)} = 0.624 \text{ m}^3$$

$$V_{O_2} = \frac{n_{O_2}(\bar{R}/M_{O_2})T_{O_2}}{P_{O_2}} = \frac{(0.8) \left( \frac{8314}{32.0} \right) (400)}{(5 \times 10^5)} = 0.166 \text{ m}^3$$

where  $P_{Ar}$  and  $P_{O_2}$  represent the initial pressures of the argon and oxygen, respectively, and not partial pressures.

(b) The final pressure,  $P_f$ , can also be determined using the ideal gas equation of state:

$$P_f = \frac{n \bar{R} T_f}{V}$$

where  $V = 0.624 \text{ m}^3 + 0.166 \text{ m}^3 = 0.79 \text{ m}^3$  and

$$n = n_{Ar} + n_{O_2} = \frac{m_{Ar}}{M_{Ar}} + \frac{m_{O_2}}{M_{O_2}} = \frac{1}{39.94} + \frac{0.8}{32.0} = 0.025 + 0.025 = 0.05 \text{ kmol}$$

Finally

$$P_f = \frac{(0.05 \text{ kmol}) \left( 8314 \frac{\text{N}\cdot\text{m}}{\text{kmol}\cdot\text{K}} \right) (360 \text{ K})}{0.79 \text{ m}^3} \left| \frac{\text{bar}}{10^5 \text{ N/m}^2} \right| = 1.89 \text{ bar}$$

(c) An energy balance reduces to give  $\Delta U = Q - W$ , or

$$Q = \Delta U = \Delta U_{Ar} + \Delta U_{O_2} = n_{Ar} \bar{c}_{v,Ar} [T_f - T_{Ar}] + n_{O_2} [\bar{u}_{O_2}(T_f) - \bar{u}_{O_2}(T_{O_2})]$$

From Table A-21, for argon  $\bar{c}_p = 5/2 \bar{R}$ . Then, with Eq. 3.45,  $\bar{c}_v = \bar{c}_p - \bar{R} = 3/2 \bar{R}$ . With  $\bar{u}$  data from Table A-23

$$Q = (0.025) \left[ \frac{3}{2} \times 8.314 \right] [360 - 300] + (0.025) [9518 - 8384]$$

$$= -29.4 \text{ kJ}$$

(d) Argon initially is at 300K, 1 bar and finally at 360 K and the partial pressure,  $y_{Ar} P_f = (0.5)(1.89 \text{ bar}) = 0.945 \text{ bar}$ . Thus, with  $\bar{c}_p = 5/2 \bar{R}$

$$(\Delta S)_{Ar} = (0.025) \left[ (0.5)(8.314) \ln \frac{360}{300} - (8.314) \ln \left( \frac{0.945}{1.00} \right) \right] = 0.083 \frac{\text{kJ}}{\text{K}}$$

PROBLEM 12.26 (Contd.)

Oxygen: initially is at 400 K, 5 bar and finally at 360 K and the partial pressure 0.945 bar. with  $\bar{s}^\circ$  data from Table A-23

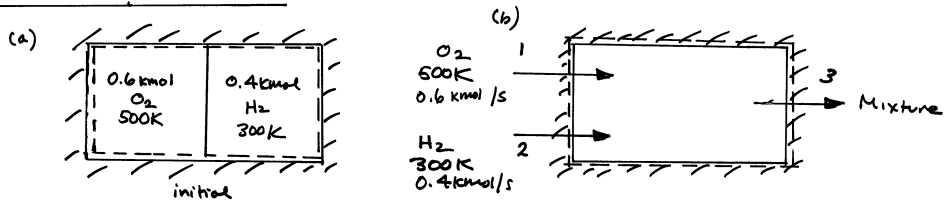
$$(\Delta S)_{O_2} = 0.025 \left[ 210.604 - 213.765 - 8.314 \ln \frac{0.945}{5} \right] = 0.2673 \frac{kJ}{K} \leftarrow (AS)_{O_2}$$

PROBLEM 12.27

KNOWN: Two cases involving the mixing of  $O_2$  and  $H_2$  are specified.

FIND: For each case determine the mixture temperature.

SCHEMATIC & GIVEN DATA:



ASSUMPTIONS: (1) For case (a), a closed system consisting of the  $O_2$  and  $H_2$  is the system. For case (b), a control volume at steady state is the system. (2) For each system,  $\dot{Q} = 0$ ,  $\dot{W} = 0$  (except for flow work in (b)), and there are no significant kinetic/potential energy effects. (3) Each gas and the overall mixture behaves as an ideal gas. The Dalton mixture model applies. (4) Appropriate constant specific heats are employed.

ANALYSIS: (a) An energy balance reduces to read  $\Delta U = \cancel{\dot{Q}} - \cancel{\dot{W}}$ , or  $\Delta U = 0$ . That is

$$[n \Delta \bar{u}]_{O_2} + [n \Delta \bar{u}]_{H_2} = 0 \quad (1)$$

Since the initial temperature difference is just 200 K, and  $c_v$  does not vary significantly over such an interval, an appropriate constant  $c_v$  can be used for each gas. Thus, with data from Table A-20 at 400 K, Eq. (1) reads

$$[n (c_v M) [T_f - T_i]]_{O_2} + [n (c_v M) [T_f - T_i]]_{H_2} = 0$$

$$\Rightarrow (0.6)(0.681 \times 32)[T_f - 500] + (0.4)(10.352 \times 2.016)[T_f - 300] = 0 \Rightarrow T_f = 422 K \leftarrow$$

(b) An energy rate balance reduces to read

$$0 = \cancel{\dot{Q}} - \cancel{\dot{W}} + \dot{n}_{O_2} \bar{h}_{O_2}(T_1) + \dot{n}_{H_2} \bar{h}_{H_2}(T_2) - [\dot{n}_{O_2} \bar{h}_{O_2}(T_3) + \dot{n}_{H_2} \bar{h}_{H_2}(T_3)]$$

$$\text{or} \quad 0 = \dot{n}_{O_2} [\bar{h}_{O_2}(T_1) - \bar{h}_{O_2}(T_3)] + \dot{n}_{H_2} [\bar{h}_{H_2}(T_2) - \bar{h}_{H_2}(T_3)] \quad (2)$$

Then, with  $c_p$  for each gas from Table A-20 at 400 K we get

$$0 = \dot{n}_{O_2} [c_p M]_{O_2} [T_1 - T_3] + \dot{n}_{H_2} [c_p M]_{H_2} [T_2 - T_3]$$

$$0 = (0.6) [(0.911 \times 32)] [500 - T_3] + (0.4) [(4.476)(2.016)] [300 - T_3] \Rightarrow T_f = 422 K \leftarrow$$