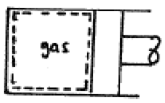
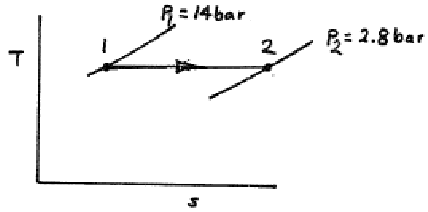
PROBLEM 6.24

KNOWN: A gas expands from a specified initial state to a specified final pressure isothermally and without internal irreversibilities.

FIND: Determine the heat transfer and work, per unit of mass, for (a) R134a (b) Air as an ideal gas.

SCHEMATIC & GIVEN DATA:





ENGR. MODEL: (1) As shown in the accompanying figure, the system is the gas. (2) The expansion takes place isothermally and without internal irreversibilities. (3) There is no change in kinetic or potential energy between the end states. (4) Air is modeled as an ideal gas.

ANALYSIS: Using assumption 2, Eq. 6.23 becomes

$$Q = \int_1^2 T\,dS = mT(s_2 - s_1) \implies Q/m = T(s_2 - s_1)$$

With assumption 2, an energy balance gives

$$W = Q - \Delta U \implies W/m = Q/m - (u_2 - u_1)$$

(a) R134a. Table A-12: $u_1 = 262.17$ kJ/kg, $s_1 = 0.9297$ kJ/kg·K, $u_2 = 277.23$, $s_2 = 1.1079$ kJ/kg·K.

$$\Rightarrow \quad Q/m = 333\,\text{K}\,(1.1079 - 0.9297)\frac{\text{kJ}}{\text{kg}\cdot\text{K}} = 59.34\ \text{kJ/kg} \quad \longleftarrow Q/m$$

$$W/m = 59.34 - (277.23 - 262.17) = 44.28\ \text{kJ/kg} \quad \longleftarrow W/m$$

(b) AIR. Since $T_1 = T_2$, Eq. 6.20a reduces to read

$$s_2 - s_1 = -R \ln P_2/P_1 = -\left(\frac{8.314}{28.97}\frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right)\ln\frac{2.8}{14} = +0.46188\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$$

and

$$Q/m = (333)(0.46188) = 153.81\ \frac{\text{kJ}}{\text{kg}} \quad \longleftarrow Q/m$$

Since internal energy depends on temperature alone for an ideal gas, $\Delta U = 0$ because $T_1 = T_2$. The energy balance then gives

$$W/m = Q/m - (\cancel{u_2 - u_1})^{\,0}$$

$$= Q/m = 153.81\ \text{kJ/kg} \quad \longleftarrow W/m$$