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بارم هر سوال ۲/۸۰ می باشد.

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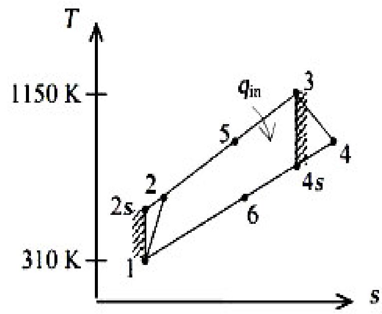
Assumptions **1** The air standard assumptions are applicable. **2** Air is an ideal gas with variable specific heats. **3** Kinetic and potential energy changes are negligible.

Properties The properties of air are given in Table A-17.

Analysis (a) The properties of air at various states are



$$T_1 = 310 \text{ K} \longrightarrow \begin{array}{l} h_1 = 310.24 \text{ kJ/kg} \\ P_{r_1} = 1.5546 \end{array}$$

$$P_{r_2} = \frac{P_2}{P_1} P_{r_1} = (7)(1.5546) = 10.88 \longrightarrow h_{2s} = 541.26 \text{ kJ/kg}$$

$$\eta_C = \frac{h_{2s} - h_1}{h_2 - h_1} \longrightarrow h_2 = h_1 + (h_{2s} - h_1)/\eta_C = 310.24 + (541.26 - 310.24)/(0.75) = 618.26 \text{ kJ/kg}$$

$$T_3 = 1150 \text{ K} \longrightarrow \begin{array}{l} h_3 = 1219.25 \text{ kJ/kg} \\ P_{r_3} = 200.15 \end{array}$$

$$P_{r_4} = \frac{P_4}{P_3} P_{r_3} = \left(\frac{1}{7}\right)(200.15) = 28.59 \longrightarrow h_{4s} = 711.80 \text{ kJ/kg}$$

$$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4s}} \longrightarrow h_4 = h_3 - \eta_T (h_3 - h_{4s}) = 1219.25 - (0.82)(1219.25 - 711.80) = 803.14 \text{ kJ/kg}$$

Thus,

$$T_4 = \mathbf{782.8 \text{ K}}$$

(*b*)

$$\begin{aligned} w_{\text{net}} &= w_{\text{T,out}} - w_{\text{C,in}} = (h_3 - h_4) - (h_2 - h_1) \\ &= (1219.25 - 803.14) - (618.26 - 310.24) \\ &= \mathbf{108.09 \text{ kJ/kg}} \end{aligned}$$

(*c*)

$$\varepsilon = \frac{h_5 - h_2}{h_4 - h_2} \longrightarrow \begin{aligned} h_5 &= h_2 + \varepsilon (h_4 - h_2) \\ &= 618.26 + (0.65)(803.14 - 618.26) \\ &= 738.43 \text{ kJ/kg} \end{aligned}$$

Then,

$$q_{\text{in}} = h_3 - h_5 = 1219.25 - 738.43 = 480.82 \text{ kJ/kg}$$

$$\eta_{\text{th}} = \frac{w_{\text{net}}}{q_{\text{in}}} = \frac{108.09 \text{ kJ/kg}}{480.82 \text{ kJ/kg}} = \mathbf{22.5\%}$$

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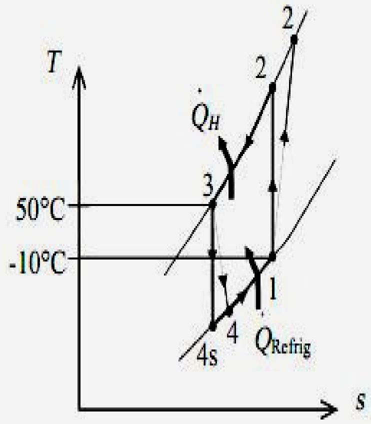
Properties The properties of helium are $c_p = 5.1926$ kJ/kg·K and $k = 1.667$ (Table A-2).



Analysis (*a*) From the isentropic relations,

$$T_{2s} = T_1\left(\frac{P_2}{P_1}\right)^{(k-1)/k} = (263\text{K})(3)^{0.667/1.667} = 408.2\text{K}$$

$$T_{4s} = T_3\left(\frac{P_4}{P_3}\right)^{(k-1)/k} = (323\text{K})\left(\frac{1}{3}\right)^{0.667/1.667} = 208.1\text{K}$$

and

$$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4s}} = \frac{T_3 - T_4}{T_3 - T_{4s}} \longrightarrow T_4 = T_3 - \eta_T(T_3 - T_{4s}) = 323 - (0.80)(323 - 208.1) = \mathbf{231.1\ K} = T_{\min}$$

$$\eta_C = \frac{h_{2s} - h_1}{h_2 - h_1} = \frac{T_{2s} - T_1}{T_2 - T_1} \longrightarrow T_2 = T_1 + (T_{2s} - T_1)/\eta_C = 263 + (408.2 - 263)/(0.80) = 444.5\text{ K}$$

(*b*) The COP of this gas refrigeration cycle is determined from

$$\text{COP}_R = \frac{q_L}{w_{\text{net,in}}} = \frac{q_L}{w_{\text{comp,in}} - w_{\text{turb,out}}} = \frac{h_1 - h_4}{(h_2 - h_1) - (h_3 - h_4)} = \frac{T_1 - T_4}{(T_2 - T_1) - (T_3 - T_4)} = \frac{263 - 231.1}{(444.5 - 263) - (323 - 231.1)} = \mathbf{0.356}$$

(*c*) The mass flow rate of helium is determined from

$$\dot{m} = \frac{\dot{Q}_{\text{refrig}}}{q_L} = \frac{\dot{Q}_{\text{refrig}}}{h_1 - h_4} = \frac{\dot{Q}_{\text{refrig}}}{c_p(T_1 - T_4)} = \frac{18\text{ kJ/s}}{(5.1926\text{ kJ/kg}\cdot\text{K})(263 - 231.1)\text{K}} = \mathbf{0.109\ \ kg/s}$$

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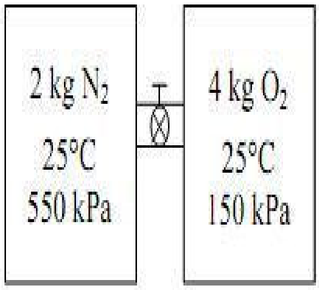
Analysis The volumes of the tanks are

$$V_{N_2}=\left(\frac{mRT}{P}\right)_{N_2}=\frac{(2\text{ kg})(0.2968\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(298\text{ K})}{550\text{ kPa}}=\mathbf{0.322\ m^3}$$

$$V_{O_2}=\left(\frac{mRT}{P}\right)_{O_2}=\frac{(4\text{ kg})(0.2598\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(298\text{ K})}{150\text{ kPa}}=\mathbf{2.065\ m^3}$$



$$V_{total}=V_{N_2}+V_{O_2}=0.322\text{ m}^3+2.065\text{ m}^3=2.386\text{ m}^3$$

Also,

$$N_{N_2}=\frac{m_{N_2}}{M_{N_2}}=\frac{2\text{ kg}}{28\text{ kg/kmol}}=0.07143\text{ kmol}$$

$$N_{O_2}=\frac{m_{O_2}}{M_{O_2}}=\frac{4\text{ kg}}{32\text{ kg/kmol}}=0.125\text{ kmol}$$

$$N_m=N_{N_2}+N_{O_2}=0.07143\text{ kmol}+0.125\text{ kmol}=0.1964\text{ kmol}$$

Thus,

$$P_m=\left(\frac{NR_uT}{V}\right)_m=\frac{(0.1964\text{ kmol})(8.314\text{ kPa}\cdot\text{m}^3/\text{kmol}\cdot\text{K})(298\text{ K})}{2.386\text{ m}^3}=\mathbf{204\ kPa}$$

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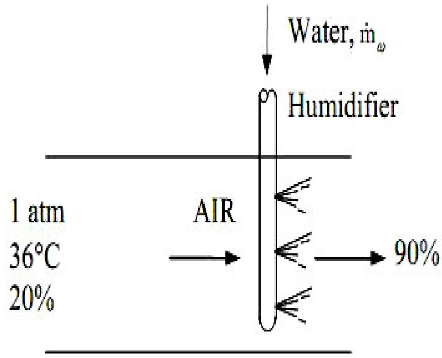
Analysis (*a*) From the psychrometric chart (Fig. A-31) at 36°C and 20% relative humidity we read

$$T_{wb1} = 19.5°C$$
$$\omega_1 = 0.0074 \text{ kg H}_2\text{O/kg dry air}$$
$$v_1 = 0.887 \text{ m}^3\text{/kg dry air}$$



Assuming the liquid water is supplied at a temperature not much different than the exit temperature of the air stream, the evaporative cooling process follows a line of constant wet-bulb temperature. That is,

$$T_{wb2} \cong T_{wb1} = 19.5°C$$

At this wet-bulb temperature and 90% relative humidity we read

$$T_2 = \mathbf{20.5°C}$$
$$\omega_2 = 0.0137 \text{ kg H}_2\text{O / kg dry air}$$

Thus air will be cooled to 20.5°C in this evaporative cooler.

(*b*) The mass flow rate of dry air is

$$\dot{m}_a = \frac{\dot{V}_1}{v_1} = \frac{4 \text{ m}^3\text{ / min}}{0.887 \text{ m}^3\text{ / kg dry air}} = 4.51 \text{ kg/min}$$

Then the required rate of water supply to the evaporative cooler is determined from

$$\dot{m}_{supply} = \dot{m}_{w2} - \dot{m}_{w1} = \dot{m}_a(\omega_2 - \omega_1)$$
$$= (4.51 \text{ kg/min})(0.0137 - 0.0074)$$
$$= \mathbf{0.028 \text{ kg/min}}$$

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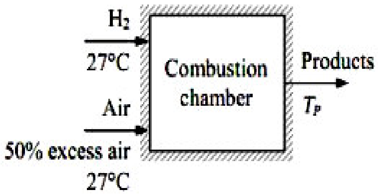
Analysis Adiabatic flame temperature is the temperature at which the products leave the combustion chamber under adiabatic conditions ($Q = 0$) with no work interactions ($W = 0$). Under steady-flow conditions the energy balance $E_{in} - E_{out} = \Delta E_{system}$ applied on the combustion chamber reduces to

$$\sum N_P\left(\bar{h}_f^\circ + \bar{h} - \bar{h}^\circ\right)_P = \sum N_R\left(\bar{h}_f^\circ + \bar{h} - \bar{h}^\circ\right)_R$$



The combustion equation of H_2 with 50% excess air is

$$H_2 + 0.75(O_2 + 3.76N_2) \longrightarrow H_2O + 0.25O_2 + 2.82N_2$$

From the tables,

Substance	$\bar{h}_f^\circ$ kJ/kmol	$\bar{h}_{300K}$ kJ/kmol	$\bar{h}_{298\,K}$ kJ/kmol
H_2	0	8522	8468
O_2	0	8736	8682
N_2	0	8723	8669
H_2O (*g*)	-241,820	9966	9904

Thus,

$$(1)(-241{,}820 + \bar{h}_{H_2O} - 9904) + (0.25)(0 + \bar{h}_{O_2} - 8682) + (2.82)(0 + \bar{h}_{N_2} - 8669)$$
$$= (1)(0 + 8522 - 8468) + (0.75)(0 + 8736 - 8682) + (2.82)(0 + 8723 - 8669)$$

It yields

$$\bar{h}_{H_2O} + 0.25\bar{h}_{O_2} + 2.82\bar{h}_{N_2} = 278{,}590 \text{ kJ}$$

The adiabatic flame temperature is obtained from a trial and error solution. A first guess is obtained by dividing the right-hand side of the equation by the total number of moles, which yields 278,590/(1 + 0.25 + 2.82) = 68,450 kJ/kmol. This enthalpy value corresponds to about 2100 K for N_2. Noting that the majority of the moles are N_2, T_P will be close to 2100 K, but somewhat under it because of the higher specific heat of H_2O.

At 2000 K: $\bar{h}_{H_2O} + 0.25\bar{h}_{O_2} + 2.82\bar{h}_{N_2} = (1)(82{,}593) + (0.25)(67{,}881) + (2.82)(64{,}810)$
$= 282{,}330 \text{ kJ}$ (Higher than 278,590 kJ)

At 1960 K: $\bar{h}_{H_2O} + 0.25\bar{h}_{O_2} + 2.826\bar{h}_{N_2} = (1)(80{,}555) + (0.25)(66{,}374) + (2.82)(63{,}381)$
$= 275{,}880 \text{ kJ}$ (Lower than 278,590 kJ)

By interpolation, T_P = **1977 K**

Discussion The adiabatic flame temperature cam be obtained by using EES without a trial and error approach. We found the temperature to be **1978 K** by EES. The results are practically identical.