13-30

Nathan Chevays   Brad Etheridge

$P_{CO_2} = 20\,kPa \quad P_{O_2} = 30\,kPa \quad P_{N_2} = 50\,kPa$

$P_{CO_2} + P_{O_2} + P_{N_2} = P_{total}$

$P_{total} = 100\,kPa$

$y_i = \frac{P_i}{P_m} = \frac{N_i}{N_m} \Rightarrow \boxed{y_{CO_2} = 0.2,\ y_{O_2} = 0.3,\ y_{N_2} = 0.5}$ mole fractions

$mf_i = y_i \cdot \frac{M_i}{M_m}$

$M_m = y_{CO_2} \cdot M_{CO_2} + y_{O_2} \cdot M_{O_2} + y_{N_2} \cdot M_{N_2}$

$= 0.2 \cdot 44.01\,\frac{kg}{kmol} + 0.3 \cdot 31.999\,\frac{kg}{kmol} + 0.5 \cdot 28.013\,\frac{kg}{kmol}$

$8.802 + 9.5997 + 14.00065$

$\boxed{M_m = 32.4082\,\frac{kg}{kmol}}$ Apparent molar mass

$mf_{CO_2} = \frac{8.802}{32.4082} = 0.272$

$mf_{O_2} = \frac{9.5997}{32.4082} = 0.296$

$mf_{N_2} = \frac{14.00065}{32.4082} = 0.432$

Mass fractions

$R_m = \frac{R_U}{M_m} = \frac{8.31446\,\frac{kJ}{K \cdot kmol}}{32.4082\,\frac{kg}{kmol}} = \boxed{0.25655\,\frac{kJ}{kg \cdot K}}$

@ 300 K

$Cv_{CO_2} = 0.657\,\frac{kJ}{kg \cdot K}$

$Cv_{O_2} = 0.658\,\frac{kJ}{kg \cdot K}$

$Cv_{N_2} = 0.743\,\frac{kJ}{kg \cdot K}$

$Cv_m = \sum mf_i \cdot Cv_i$

$Cv_m = \left(0.272 \cdot 0.657\,\frac{kJ}{kg \cdot K}\right) + \left(0.296 \cdot 0.658\,\frac{kJ}{kg \cdot K}\right) + \left(0.432 \cdot 0.743\,\frac{kJ}{kg \cdot K}\right)$

$= 0.1787 + 0.1948 + 0.321$

$\boxed{Cv_m = 0.6945\,\frac{kJ}{kg \cdot K}}$

$Cp_{CO_2} = 0.846\,\frac{kJ}{kg \cdot K}$

$Cp_{O_2} = 0.918\,\frac{kJ}{kg \cdot K}$

$Cp_{N_2} = 1.039\,\frac{kJ}{kg \cdot K}$

$Cp_m = \sum mf_i \cdot Cp_i$

$Cp_m = \left(0.272 \cdot 0.846\,\frac{kJ}{kg \cdot K}\right) + \left(0.296 \cdot 0.918\,\frac{kJ}{kg \cdot K}\right) + \left(0.432 \cdot 1.039\,\frac{kJ}{kg \cdot K}\right)$

$= 0.23011 + 0.27173 + 0.44885$

$Cp_m = 0.95069\,\frac{kJ}{kg \cdot K}$

$k_m = \frac{Cp_m}{Cv_m}$

$\frac{0.95069}{0.6945} = \boxed{1.37 = k_m}$

13-39

Find $\dot{M}$

ideal gas law: $P_M \cdot V_M = R_M T_M$

gases:

air, Methane,

15% mole fraction $\rightarrow 0.15 = Y_{CH4}$

85% mole fraction $\rightarrow 0.85 = Y_{air}$

$M_{CH4} = 16.043 \frac{kg}{kmol}$

$M_{air} = 28.97 \frac{kg}{kmol}$

engine $\rightarrow$ 3000 rpm

5 Liter $= 0.005 m^3$

$P_M = 80\ kPa$

$T_M = 20°C$

$M_M = Y_{air} \cdot M_{air} + Y_{CH4} \cdot M_{CH4}$

$0.85 \cdot 28.97 \frac{kg}{kmol} + 0.15 \cdot 16.043 \frac{kg}{kmol}$

$M_M = 24.6245 \frac{kg}{kmol} + 2.4065$

$M_M = 27.031 \frac{kg}{kmol}$

4 strokes = 2 rev

$\dot{V} = \frac{3000\ rpm \cdot 0.005 m^3}{2}$

$\dot{V} = 7.5\ m^3/min$

$mf_{air} = \frac{Y_{air} \cdot M_{air}}{M_M} = \frac{24.6245 \frac{kg}{kmol}}{27.031} = 0.911$

$mf_{CH4} = \frac{Y_{CH4} \cdot M_{CH4}}{M_M} = \frac{2.4065}{27.031} = 0.089$

$R_U = 8.31446 \frac{kJ}{kmol \cdot K}$

$R_M = \frac{R_U}{M_M} = \frac{8.31446 \frac{kJ}{kmol \cdot K}}{27.031 \frac{kg}{kmol}}$

$R_M = 0.3076 \frac{kJ}{kg \cdot K}$

$80 kPa \cdot V_M = 0.3076 \frac{kJ}{kg \cdot K} \cdot 293 K$

$V_M = 1.1265 m^3$

$\dot{m} = \frac{\dot{V}}{v} = \frac{7.5 \frac{m^3}{min}}{1.1265 m^3/kg} = \boxed{\dot{m} = 6.6575 \frac{kg}{min}}$

13-54

Nathan Cherays Brad Etheridge

given

gases: Neon, Argon

$V_{total} = 0.9\,m^3$

Use ideal gas law $PV = MRT$

$P_{Ne} = 100\,kPa$ $T_{Ne} = 20°C$

$q_{out} = 15\,kJ$ $C_{v\,ne} = 1.7354\,\frac{kJ}{kg\cdot K}$

$P_{Ar} = 200\,kPa$ $T_{Ar} = 50°C$

$C_{v\,Ar} = 0.3122\,\frac{kJ}{kg\cdot K}$

T_{final} Find

P_{total} Find

$M_{ne} = 20.183\,\frac{kg}{kmol}$

$M_{Ar} = 39.948\,kg/kmol$

$$R_{Ne} = \frac{8.31446}{20.183} = 0.41195\,\frac{kJ}{kg\cdot K}$$

$$P_{Ne}\cdot V_{Ne} = R_{Ne}\cdot M_{Ne}\cdot T_{Ne}$$

$$100\,kpa\cdot 0.45\,m^3 = 0.41195\,\frac{kJ}{kg\cdot K}\cdot 293°K\cdot M_{ne}$$

$$m_{ne} = 0.3728\,kg$$

$$R_{Ar} = \frac{8.31446\,\frac{kJ}{kmol\cdot K}}{39.948\,\frac{kg}{kmol}} = 0.20813\,\frac{kJ}{kg\cdot K}$$

$$P_{Ar}\cdot V_{Ar} = M_{Ar}\cdot R_{Ar}\cdot T_{Ar}$$

$$200\,kpa\cdot 0.45\,m^3 = M_{ar}\cdot 0.20813\,\frac{kJ}{kg\cdot K}\cdot 323°K$$

$$1.339\,kg = M_{Ar}$$

1st law $\cancel{q_{in}}^0 - q_{out} + \cancel{W_{in}}^0 - \cancel{W_{out}}^0 = \Delta U = \sum m_i\cdot c_{v_i}\cdot \Delta T$

$$-q_{out} = M_{Ne}\cdot C_{v\,ne}\cdot(T_2 - T_{Ne}) + M_{Ar}\cdot C_{v\,Ar}\cdot(T_2 - T_{Ar})$$

$$-15 = 0.3728\,kg\cdot 1.7354\,\frac{kJ}{kg\cdot K}(T_2 - 293°K) + 1.339\,kg\cdot 0.3122\,\frac{kJ}{kg\cdot K}(T_2 - 323°K)$$

$$-15 = 1.0645\,T_2 - 324.584\,kJ$$

$$\frac{309.584}{1.0645} = T_2 = \boxed{290.69°K} \rightarrow \boxed{17.69°C}$$

$$P_m\cdot V_m = M_m\cdot R_m\cdot T_m$$

$$R_m = \frac{R_u}{M_m} \qquad M_m = \frac{1}{\frac{mf_{Ne}}{M_{Ne}} + \frac{mf_{Ar}}{M_{Ar}}}$$

$$P_m = \frac{1.712\,kg\cdot 0.2525\,\frac{kJ}{kg\cdot K}\cdot 290.69°K}{0.9\,m^3}$$

$$mf_{Ne} = \frac{0.3728}{1.339 + 0.3728} = 0.2178$$

$$\boxed{P_m = 139.6\,Kpa}$$

$$mf_{Ar} = 1 - mf_{Ne} = 0.7822$$

$$M_m = \frac{1}{0.03037} = 32.925\,\frac{kg}{kmol}$$

$$R_m = \frac{8.31446\,\frac{kJ}{kmol\cdot K}}{32.925\,\frac{kg}{kmol}} = 0.2525\,\frac{kJ}{kg\cdot K}$$

13-59

Find Work & Heat transfer

given: compression of mixture $P_{in} = 100\,kPa$ $P_{out} = 1000\,kPa$

gases: methane, propane, butane $T_{in} = 20°C$ $T_{out} = 20°C$

isothermal, reversible, steady flow

$MF_{CH_4} = 0.6$ $MF_{C_3H_8} = 0.25$ $MF_{C_4H_{10}} = 0.15$

$$W_{rev} = R_M \cdot T \cdot \ln\left(\frac{P_2}{P_1}\right)$$ from formulas paper $R_M = \frac{R_U}{M_M}$

$R_U = 8.31446 \frac{kJ}{kmol \cdot K}$

$$M_M = \frac{1}{\frac{MF_{CH_4}}{M_{CH_4}} + \frac{MF_{C_3H_8}}{M_{C_3H_8}} + \frac{MF_{C_4H_{10}}}{M_{C_4H_{10}}}}$$

$$= \frac{1}{\frac{0.6}{16.043 \frac{kg}{kmol}} + \frac{0.25}{44.097 \frac{kg}{kmol}} + \frac{0.15}{58.124 \frac{kg}{kmol}}} = 21.906 \frac{kg}{kmol} = M_M$$

$$R_M = \frac{8.31446}{21.906} = 0.37955 \frac{kJ}{kg \cdot K}$$

$$W = 0.37955 \frac{kJ}{kg \cdot K} \cdot 293°K \cdot \ln\left(\frac{1000\,kPa}{100\,kPa}\right)$$

$$\boxed{W = 256.067 \frac{kJ}{kg}}$$

q_{out}

$$\cancel{q_{in}} - q_{out} + w_{in} - \cancel{w_{out}} = \cancel{\Delta h}$$ isothermal

compressor

$$\boxed{q_{out} = w_{in}}$$

$$\boxed{q_{out} = 256.067 \frac{kJ}{kg}}$$