Linear Interpolation - question 2-32(c)

Slope = constant

\[
\frac{? - 80}{300 - 293.73} = \frac{90 - 80}{302.84 - 293.73}
\]

\[
? = \frac{300 - 293.73}{302.84 - 293.73} \times (90 - 80) + 80
\]

2-32 (c) \quad T = 80^\circ C \quad P = 600 \text{ kPa}
compressed liq - u,v is strong f(T)

%compressibility = \frac{u_f(T)}{u_f|_{80}}

= 60.43 \text{ ft/psi}

\text{Enthalpy} \rightarrow a \text{ " combo" property}

h = u + Pv

\text{For compressed liquid}

u \approx u_f(T)

v \approx v_f(T)

\text{Or}

h \approx u_f(T) + Pv_f(T)

or

h = h_f(T) + v_f(T) * (P - P_{sat}(T))

= h_f|_T + v_f|_T * (P - P_{sat}|_T)

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\text{Warning: do not interpolate on pressure in compressed liq. tables}

\text{For water because properties are weak functions of pressure. Better to use } y = y_{f(T)}
Blood pressure = \frac{120 \text{ mm Hg}}{\text{ gage pressure}}

\text{gage pressure}

\text{pressure}

\text{gage pressure}

\text{mm Hg} = \text{blood}

\frac{\text{Hg}}{\text{Hg}} = \frac{\text{Hg}}{\text{blood}}

\text{blood} = P - P_{\text{atm}}

Reference State and Reference Values "real"

For each substance, internal energy is assigned a value of zero at some state. Then all other internal energy states are relative to this one.

\text{P}

\text{H}

\text{P}
Recall 3 topics

1) "Real" Substance model
   - two-phase table
   - two-liquid table
   - compressed big table of comp. liq. approximaticns

2) Ideal gas model

3) Incompressible substance model

2) Ideal gas

P-v-t behavior for real substances given by tables.

→ \( Pv = RT \) → \( P-v-T \) behavior for ideal gas

\[ R = \frac{\overline{R}}{M} \] — universal gas constant = \( R_u \)
— molecular weight

When can we assume ideal gas?

1) Air
2) gases at low density
From Fig 2-51, we can see that gases are ideal \(( \gamma = 1)\) when either

1) \( T \geq 2 T_{\text{crit}} \)

or

2) \( P \leq \frac{P_{\text{cr}}}{10} \)

*Other Forms of ideal gas equation of state*

\[
P\nu = RT
\]

\[
P\mathcal{V} = mRT = n\mathcal{V}_0 \frac{RT}{\mu}
\]

\[
\text{Also } P\mathcal{V} = mRT
\]

\[
\text{(Volumetric flow rate)} \quad \text{(mass flow rate)}
\]

\[
\frac{P_1\mathcal{V}_1}{T_1} = \frac{P_2\mathcal{V}_2}{T_2}
\]

\(*\text{for } m = \text{const}\)*

Omit Sections 2.7 and 2.8

*Note: better equations of state are available → they are more complex*
What about internal energy and enthalpy changes for ideal gases?

**Specific Heats - properties**

\[ C_v = \left( \frac{\partial U}{\partial T} \right)_{p=\text{const}} \]

\[ C_p = \left( \frac{\partial H}{\partial T} \right)_{p=\text{const}} \]

**Interesting fact:** For any gas

\[ C_p - C_v = R \left( = \frac{R_u}{M} \right) \]

For ideal gas

\[ U_2 - U_1 = H_{T_2} - H_{T_1} = \int_{T_1}^{T_2} C_v \, dT \]

\[ h_2 - h_1 = h_{T_2} - h_{T_1} = \int_{T_1}^{T_2} C_p \, dT \]

Three ways to evaluate these:

1) If \( C_v \), \( C_p \) = constant between \( T_1 \) and \( T_2 \)

\[ U_2 - U_1 = C_v (T_2 - T_1) \]

\[ h_2 - h_1 = C_p (T_2 - T_1) \]
Fig 2.68 shows variation of $c_p$ with $T$ for several gases.

$CO_2$ and $H_2O$ have large variations in $c_p$.

He, Ne, Ar, Kr, Ra, Xe have almost constant $c_p$.

2) Use a formula (expression) for $c_v(T)$ or $c_p(T)$ and integrate. Table A-2 has polynomial approximations for $c_p(T)$.

Table A-2 has $\bar{c}_p(T)$

\[
\bar{c}_v(T) = \bar{c}_p(T) - \bar{c}_p(T) \\
\bar{c}_p - \bar{c}_v = \bar{c}_p
\]

3) Take a reference state and create a table for $U(T)$ and $U(T)$ for different gases.

Table has $U(T) - U(0) + \Delta U$

$U(T_2) - U(T_1) = (U(T_2) - U(0) + \Delta U) - (U(T_1) - U(0))$.

Great for computer evaluation, but not too handy for routine calculations.
Table A-17 has $h$ and $u$ vs $T$

for $A-11 R$

Table A-18 has $\bar{h}$ for $N_2$

$\bar{h}$ for $O_2$

Note $\bar{h} \frac{K}{\text{kgmol}}$

$M$ relates $\bar{h}$ vs $h$ and $\bar{h}$

$\frac{5 \text{ kg}}{\text{kgmol}} \quad h = \bar{h} / M \quad u = \bar{u} / M$

Example 2-71E

$V = 0.53 \text{ ft}^3 \quad T_1 = 90 \text{F} \quad P_1 = 20 \text{ psig}$

How much air must be added to get $P_2 = 30 \text{ psig}$?

$P_{atm} = 14.6 \text{ psia} \quad T_2 = T_1 \quad \text{and} \quad h_2 = h_1$

In ideal gas law, $P = \text{absolute}$

$T_1 = 90 \text{F} = 550 \text{R}$

$P_1 = 20 \text{ psi} \frac{\text{ft}}{\text{in}^2} = 34.6 \text{ psia}$
Initially \( m_1 = \frac{P_1 A_1}{RT_1} \)

\[ m_1 = \frac{44.6 \text{ lb} \cdot \text{ft}^2 \times \frac{44.6}{A_2}}{0.3704 \text{ psia} \cdot \text{ft}^3} (0.53 \text{ lb}) \]

\[ m_1 = \frac{44.6 \times 44.6}{0.3704 \times 550} \]

\[ m_1 = \frac{2022.86}{201.82} \]

\[ m_1 = 10 \]

Final state \( T_1 = T_2 \) \( V_1 = V_2 \) \( P_2 = 44.6 \text{ lb} \cdot \text{ft}^2 \)

\[ m_2 = \frac{44.6 \times (53)}{(0.3704)(550)} \]

\[ m_2 = \frac{2368.2}{201.82} \]

\[ m_2 = 12 \]

\[ \Delta m = m_2 - m_1 = 2 \]

\( \text{Table A-1E} \)

(2-104 also use Table A-18 for N_2)