

① $T_F = 9/5 T_C + 32$ and $T_C = T_K - 273.15$
 $\Rightarrow T_F = 9/5 T_K + 32 - 9/5 (273.15) = 9/5 T_K - 459.67$
 Now let $T_F = T_K = T \Rightarrow (9/5 - 1) T = 459.67$
 $\Rightarrow \boxed{T = (5/4)(459.67) = 574.59}$

② a) $X = aT + b \Rightarrow X_I = b$ and $X_S = 100a + b$
 $\Rightarrow \underline{b = X_I}$ and $\underline{a = (X_S - X_I) / 100}$

$\Rightarrow \boxed{T = \frac{1}{a}(X - b) = 100 \frac{X - X_I}{X_S - X_I}}$

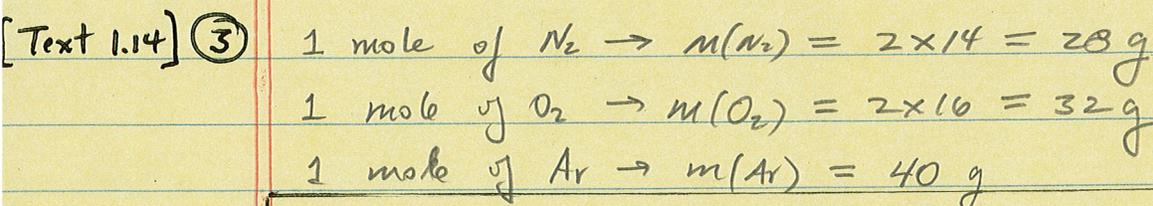
b) $X = \exp[(T - b)/a] \Rightarrow X_I = e^{-b/a}$ and $X_S = e^{(100 - b)/a}$

$\Rightarrow b = -a \ln X_I$ and $100 - b = a \ln X_S$

$\Rightarrow -a \ln X_I = 100 - a \ln X_S \Rightarrow \underline{a = 100 / \ln(X_S / X_I)}$

$\Rightarrow b = -100 \ln(X_I) / \ln(X_S / X_I)$

$\Rightarrow \boxed{T = a \ln X + b = 100 \frac{\ln(X / X_I)}{\ln(X_S / X_I)}}$



$\boxed{1 \text{ mole of air} = 0.78 m(N_2) + 0.21 m(O_2) + 0.01 m(Ar) = 29.0 \text{ g}}$

④ (a) $V = 0.5 \text{ m}^3$, $P = 1.5 \times 10^6 \text{ Pa}$, $T = 20^\circ\text{C} = 293 \text{ K}$

$R = 8.315 \text{ J/mole} \Rightarrow n = PV/RT = 308 \text{ moles}$

(b) molar mass $M = 32 \text{ g/mole} \Rightarrow m = Nm = 9.85 \text{ kg}$

(c) $T' = 500 \text{ C} = 773 \text{ K}$

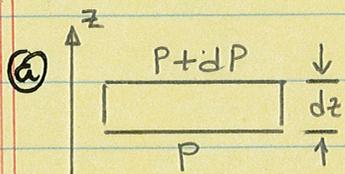
Isochoric process $\Rightarrow P'/T' = P/T \Rightarrow P' = P(T'/T)$

$\Rightarrow P' = 3.96 \times 10^6 \text{ Pa}$

(d) Isothermal process at constant volume $\Rightarrow n'/P' = n/P$

$\Rightarrow n' = (P'/P)n = 0.10n \Rightarrow n_{\text{removed}} = n - n' = 277 \text{ moles}$

[Text 1.16] ⑤



Balance net pressure force (up)

against weight (down)

$\Rightarrow (P+dP)A - PA + \rho(A dz)g = 0$

$\Rightarrow dP/dz = -\rho g$

(b) Ideal gas law $\rightarrow PV = Nk_B T \Rightarrow N = PV/k_B T$

mass density $\rightarrow \rho = Nm_{\text{molecule}}/V = Pm_{\text{molec}}/k_B T$

$\Rightarrow dP/dz = -\alpha P$ where $\alpha \equiv m_{\text{molec}}g/k_B T$

(c) $dP/P = -\alpha dz \Rightarrow \ln(P/P(0)) = -\alpha z$

$\Rightarrow P = P(0)e^{-\alpha z}$

$\rho = \frac{\alpha}{g} P \Rightarrow \rho = \rho(0)e^{-\alpha z}$ with $\rho(0) = \frac{\alpha}{g} P(0)$

(d) choose $T = 20^\circ\text{C} = 293 \text{ K}$, $m_{\text{molec}} = 29 \text{ g} / N_A$ (problem 3)

$\Rightarrow \alpha = 1.167 \times 10^{-4} \text{ m}^{-1}$

Now for Ogden, $z = 1430 \text{ m} \rightarrow P = 0.85 \text{ atm}$

Leadville, $z = 3090 \text{ m} \rightarrow P = 0.70 \text{ atm}$

Mt. Whitney, $z = 4420 \text{ m} \rightarrow P = 0.60 \text{ atm}$

Mt. Everest, $z = 8850 \text{ m} \rightarrow P = 0.36 \text{ atm}$

[Text 1.19] ⑥

For O_2 , molar mass $M(O_2) = 32 \text{ g} = 32 \times 10^{-3} \text{ kg}$

For H_2 , molar mass $M(H_2) = 2 \text{ g} = 2 \times 10^{-3} \text{ kg}$

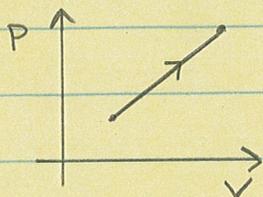
Choose $T = 20^\circ\text{C} = 293 \text{ K} \rightarrow v_{rms} = \sqrt{3RT/M}$

$\rightarrow v(O_2) = 478 \text{ m/s}$ and $v(H_2) = 1910 \text{ m/s}$

ratio $\rightarrow \underline{v(H_2)/v(O_2) = \sqrt{M(O_2)/M(H_2)} = 4}$

[Text 1.31] ⑦

①



②

$P = AV \Rightarrow P dV = AV dV$
 $\Rightarrow W = - \int_{V_{in}}^{V_f} P dV = - \frac{1}{2} AV^2 \Big|_{V_{in}}^{V_f}$

$\Rightarrow W = \frac{1}{2} [AV_{in} V_{in} - AV_f V_f] = \frac{1}{2} (P_{in} V_{in} - P_f V_f)$

Now $P_{in} = 1.013 \times 10^5 \text{ Pa}$, $V_{in} = 1.0 \times 10^{-3} \text{ m}^3$, $P_f = 3P_{in}$, $V_f = 3V_{in}$

$\Rightarrow W = \frac{1}{2} (1-9) P_{in} V_{in} = -4 P_{in} V_{in} \Rightarrow \underline{W = -405 \text{ J}}$

③ Monatomic gas $\Rightarrow \Delta U = \frac{3}{2} nR(\Delta T) = \frac{3}{2} (nRT_f - nRT_{in})$

Ideal gas law $\Rightarrow nRT_{in} = P_{in} V_{in}$ and $nRT_f = P_f V_f$

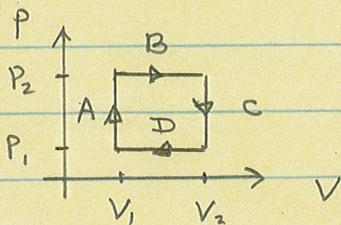
$\Rightarrow \Delta U = \frac{3}{2} (9-1) P_{in} V_{in} = 12 P_{in} V_{in} = -3W \Rightarrow \underline{\Delta U = 1216 \text{ J}}$

First law $\Rightarrow \Delta U = Q + W \Rightarrow \underline{Q = 1621 \text{ J}}$

④ Add heat to this system so that T increases

[Text 1.34] ⑧

①



steps A and C isochoric $\Rightarrow \underline{W_A = W_C = 0}$

steps B and D isobaric

$\Rightarrow \underline{W_B = P_2(V_1 - V_2)}$ $\underline{W_D = P_1(V_2 - V_1)}$

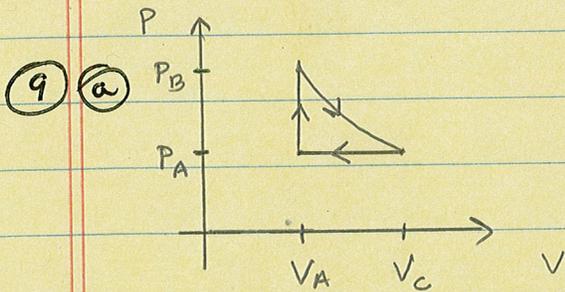
$\Delta U = \frac{5}{2} nR(\Delta T) = \frac{5}{2} \Delta(PV)$

$\Rightarrow \Delta U_A = \frac{5}{2} (P_2 - P_1) V_1 \Rightarrow Q_A = \frac{5}{2} (P_2 - P_1) V_1$
 $\Delta U_B = \frac{5}{2} P_2 (V_2 - V_1) \Rightarrow Q_B = \frac{7}{2} P_2 (V_2 - V_1)$
 $\Delta U_C = \frac{5}{2} (P_1 - P_2) V_2 \Rightarrow Q_C = \frac{5}{2} (P_1 - P_2) V_2$
 $\Delta U_D = \frac{5}{2} P_1 (V_1 - V_2) \Rightarrow Q_D = \frac{7}{2} P_1 (V_1 - V_2)$

Set 1

- (8) (b) Step B \rightarrow piston expands, heat added
 Step C \rightarrow fixed volume, heat removed
 Step D \rightarrow piston contracts, heat removed

(c) $W_{total} = (P_1 - P_2)(V_2 - V_1) < 0 \rightarrow$ gas does work on outside
 $Q_{total} = \frac{5}{2}(P_2 - P_1)(V_1 - V_2) + \frac{7}{2}(P_2 - P_1)(V_2 - V_1)$
 $\rightarrow Q_{total} = (P_2 - P_1)(V_2 - V_1) = -W_{total} > 0$
 \rightarrow heat transfer into the gas
 $\Delta U_{total} = \frac{5}{2}(P_2 - P_1)(V_1 - V_2) + \frac{5}{2}(P_2 - P_1)(V_2 - V_1) = 0$
 $\rightarrow \underline{\underline{\Delta U_{total} = 0}}$ around closed cycle



(b) $P_A = 2.0 \times 10^5 \text{ Pa}$, $P_B = 2P_A$
 $V_A = 4.0 \text{ m}^3$, $n = 200 \text{ moles}$

$\Rightarrow T_A = P_A V_A / nR = 481 \text{ K}$
 $T_B = T_C = 2T_A = 962 \text{ K}$

(c) $P_C = P_A \Rightarrow V_C = nRT_C / P_A = nR(2T_A) / P_A = 2V_A$
 $\Rightarrow \underline{\underline{V_C = 8.0 \text{ m}^3}}$

(d) Step 1 isochoric $\Rightarrow W_1 = 0$
Step 2 isothermal $\Rightarrow W_2 = nRT_B \ln(V_A / V_C) = -nRT_B \ln 2$
 $\Rightarrow \underline{\underline{W_2 = -1.11 \times 10^6 \text{ J}}}$
Step 3 isobaric $\Rightarrow W_3 = P_A(V_C - V_A) \rightarrow \underline{\underline{W_3 = 8.0 \times 10^5 \text{ J}}}$
 $\Rightarrow \underline{\underline{W_{total} = -3.09 \times 10^5 \text{ J}}}$

(e) $Q_1 = nC_V \Delta T = \frac{3}{2}nR(T_B - T_A) \rightarrow \underline{\underline{Q_1 = 1.20 \times 10^6 \text{ J}}}$
 Step 2 isothermal $\Rightarrow \underline{\underline{Q_2 = -W_2 = +1.11 \times 10^6 \text{ J}}}$
 $Q_3 = nC_P \Delta T = \frac{5}{2}nR(T_A - T_C) \rightarrow \underline{\underline{Q_3 = -2.00 \times 10^6 \text{ J}}}$
 $\Rightarrow \underline{\underline{Q_{total} = +3.09 \times 10^5 \text{ J}}}$

(f) $\Delta U = Q + W = 0$ as expected for closed cycle
 \rightarrow first law satisfied