Ch. 19

Q6. (a) ΔE_{int} depends only on initial & final state.
→ path independent.
$\therefore\ 1 = 2 = 3 = 4$

(b) $W = \int_{V_i}^{V_f} p\,dV$ → area below path.

$\therefore\ 4 > 3 > 2 > 1$

(c) $\Delta E_{int} = Q - W$
→ $Q = \Delta E_{int} + W$
Since ΔE_{int} is the same for all paths,
$4 > 3 > 2 > 1$

71.E. Along path A,
$W_A = \int_1^4 p\,dV = 40 \cdot \int_1^4 dV = 120\text{ J}$

Along path B,
$W_B = \int_1^4 p\,dV = \int_1^4 (50 - 10V)\,dV = 50 \cdot (4-1) - \frac{10}{2}(4^2 - 1^2)$
$= 75\text{ J}$

($\because$ Path B is a straight line passing through two points (1m^3, 40 Pa) & (4m^3, 10 Pa).
We can write $p = a + bV$ and find a & b.)

Along path C,
$W_c = \int_1^4 p\,dV = 10 \int_1^4 dV = 30\text{ J}$.

76E. Since ΔE_{int} depends only on states (initial & final), in cyclical processes $\Delta E_{int} = 0$. (if we consider a complete cycle.)

$\therefore \quad 0 = Q - W$

$\rightarrow \quad Q = W$

Along $A \rightarrow B$,

$$W_{AB} = \int_1^4 p\,dV = \int_1^4 \left(\frac{10}{3} + \frac{20}{3}V\right) dV$$

$$= 60\text{ J}$$

Along $B \rightarrow C$

$$W_{BC} = \int_4^1 p\,dV = 30\int_4^1 dV = -90\text{ J}$$

Along $C \rightarrow A$, $W_{CA} = \int_1^1 p\,dV = 0$

$\therefore \quad Q = W = 60\text{J} - 90\text{J} + 0\text{J} = -30\text{J}$

$\rightarrow$ the gas loses 30J of energy in the form of heat.

Ch. 20

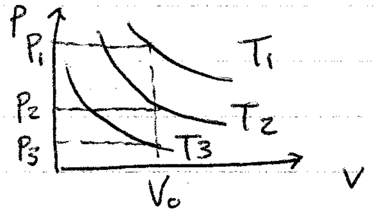
Q1. The pressure of the gas increased but less than doubled.

$P_1V = nR(293K)$

$P_2V = nR(313K)$

$$\rightarrow \quad \frac{P_2}{P_1} = \frac{313}{293} < 2.$$

Q6.



$T_1 > T_2 > T_3$

$$\frac{PV}{T} = nR = \text{constant}.$$

At any given volume V_0, we have

$$\frac{P_1V_0}{T_1} = \frac{P_2V_0}{T_2} = \frac{P_3V_0}{T_3} = \text{constant}.$$

If $T_1 > T_2 > T_3$, then $P_1 > P_2 > P_3$ as we expect from the above graph.

$\therefore$ Points 1, 2, 3, 4 are in lower temperature.

Q11. (a) Same

(b) $\frac{PV}{T} = \text{constant}.$

increases

(c) For adiabatic processes, $PV^{\gamma} = \text{constant}$, where $\gamma = \frac{C_P}{C_V} > 1$.

$\therefore$ P decreases as V increases.

(d) $\frac{PV}{T} = \text{const.} \Rightarrow$ T increases.

Q13. ΔE_{int} along path abc and along ac are the same, since initial state & final state are the same for each paths.

Path ab is an isothermal process.
Since $\Delta E_{int} = nC_v \Delta T$, $\Delta E_{int} = 0$ for path ab.
Path ac is adiabatic. So $Q = 0$.
Then $\Delta E_{int} = -W$ ← first law of thermodynamics.
$\therefore$ $\Delta E_{int} = -4J$.
⇒ Overall $\Delta E_{int} = -4J$

Q15. (a) For adiabatic processes,
$pV^{\gamma} = $ const. where $\gamma = \frac{C_p}{C_v}$

$$\gamma_{mono} = \frac{5R/2}{3R/2} = 1.67$$

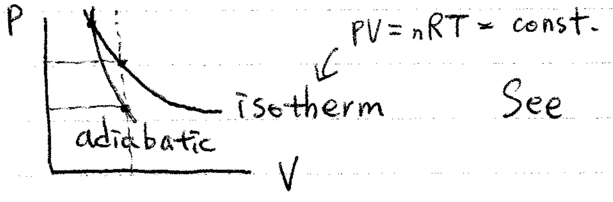
$$\gamma_{dia} = \frac{7R/2}{5R/2} = 1.4$$

$$\gamma_{poly} = \frac{4R}{3R} = 1.3$$

⇒ $\gamma_{mono} > \gamma_{dia} > \gamma_{poly}$.

which means for a given volume change,
$P_{mono} < P_{dia} < P_{poly}$

Therefore, 1 = polyatomic, 2 = diatomic, 3 = monoatomic.

(b)


See Fig. 20-14

$P_{isotherm}$ would be more than $P_{adiabatic}$.

adiabatic graph is more steeper because $PV^{\gamma} = $ const. & $\gamma > 1$

5P. Since the molar mass of the ink is $M = 18\,g/mol$, the number of molecules in $m = 1\mu g = 10^{-6}\,g$ of ink is

$$N = \frac{m N_A}{M} = \frac{(10^{-6}\,g)\cdot(6.02\times10^{23}\,mol^{-1})}{18\,g\cdot mol^{-1}}$$

$$\simeq 3\times10^{16}$$

The number of creatures in our galaxy, with the assumption made in the problem, is about

$$N' = (5\times10^{9})\cdot(10^{11}) = 5\times10^{20}$$

So the statement was wrong by a factor of about 20,000

11E. $PV = nRT$

$P_1V_1 = nRT_1$

$P_2V_2 = nRT_2$

$$\rightarrow \frac{P_2V_2}{P_1V_1} = \frac{T_2}{T_1} \quad \therefore \quad P_2 = \frac{V_1}{V_2}\cdot\frac{T_2}{T_1}\cdot P_1$$

$$P_2 = \frac{1000\,in.^3}{1020\,in.^3}\cdot\frac{300\,K}{273\,K}\cdot 24\,lb/in^2$$

$$= 27.0\,lb/in^2$$

18P. (a) $PV = nRT$

$$n = \frac{(2.5\,kPa)\cdot(1.0\,m^3)}{(8.31\,J/mol\cdot K)\cdot(200K)} = 1.5\,mol$$

(b) $$T_B = \frac{(7.5kPa)\cdot(3.0\,m^3)}{(1.5mol)\cdot(8.31\,J/mol\cdot K)}$$

(c) $$T_c = \frac{(2.5\,kPa)\cdot(3.0m^3)}{(1.5\,mol)\cdot(8.31\,J/mol\cdot K)} = 6.0\times10^2\,K$$

(d) $\Delta E_{int} = Q - W$

$\Delta E_{int} = 0$ for the cyclic process abca.

$Q = W = \frac{1}{2}(V_c - V_a)(P_b - P_a)$ ← area of triangle abc

$= \frac{1}{2}\cdot 2\cdot 5\times10^3 = 5\times10^3$ (J)

$$(\because\ W = \underbrace{\int_{V_a}^{V_b} pdV}_{\oplus} + 0 + \underbrace{\int_{V_c}^{V_a} pdV}_{\ominus}$$

$$= \underbrace{\int_{V_a}^{V_b} pdV}_{\oplus} - \underbrace{\int_{V_a}^{V_c} pdV}_{\oplus}$$ = area of triangle abc.)

31E. $V_{rms} = \sqrt{\frac{3RT}{M}}$, M : molar mass

$$\sqrt{\frac{3RT_{H_2}}{M_{H_2}}} = \sqrt{\frac{3RT_{He}}{M_{He}}}$$

$$\to T_{He} = \frac{M_{He}}{M_{H_2}}\cdot T_{H_2} = \frac{4\,g/mol}{2\,g/mol}\cdot(20+273)$$

$$= 586\,K$$

$$= 313\,°C$$

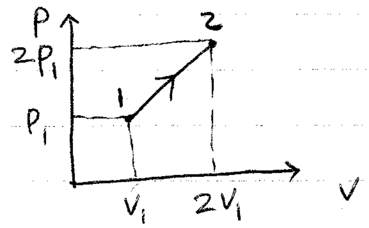
37E. $U = mgh$

$\overline{K} = \frac{3}{2}kT$

$$\Rightarrow \quad \frac{U}{\overline{K}} = \frac{2mgh}{3kT} = \frac{2\cdot(0.032\text{kg}/N_A)\cdot(9.8\,\text{m/s}^2)(0.1\text{m})}{3\cdot(R/N_A)\cdot(273\text{K})}$$

$$= 9.2\times10^{-6} \qquad k = \frac{R}{N_A}$$

64P.



And it is given that

$$p_1V_1 = nRT_1 \qquad \text{——} \quad (*)$$

(a) The straight line can be expressed as

$$p - p_1 = \frac{2p_1 - p_1}{2V_1 - V_1}(V - V_1)$$

$$\Rightarrow \quad p = \frac{p_1}{V_1}V$$

Using $(*)$, we have

$$p = \frac{nRT_1}{V_1^2}\cdot V$$

Now, $$W = \int_{V_1}^{2V_1} p\,dV = \frac{nRT_1}{V_1^2}\int_{V_1}^{2V_1} V\,dV = \frac{3}{2}\,nRT_1$$

(b) At point 2, $(2p_1)\cdot(2V_1) = nRT_2$.

$$\Delta E_{int} = \frac{3}{2}nRT_2 - \frac{3}{2}nRT_1$$

$$= \frac{3}{2}\cdot 4p_1V_1 - \frac{3}{2}nRT_1 = \frac{3}{2}\cdot 4nRT_1 - \frac{3}{2}nRT_1$$

$$= \frac{9}{2}nRT_1$$

(c) $Q = \Delta E_{int} + W$

$$= \frac{9}{2}nRT_1 + \frac{3}{2}nRT_1 = 6nRT_1$$

(d) The molar specific heat would be

$$C = \frac{Q}{n\Delta T} = \frac{6\cancel{n}RT_1}{\cancel{n}(T_2 - T_1)}$$

$$= \frac{6RT_1}{\frac{(2P_1)(2V_1)}{nR} - T_1}$$

$$= \frac{6RT_1}{4T_1 - T_1} = 2R$$

70P. (a) For constant pressure process,

$$Q = nC_p\Delta T$$

For a diatomic ideal gas, $C_p = \frac{7}{2}R$.

$$\therefore Q = n\frac{7}{2}R\Delta T = \frac{7}{2}\cdot(4\,\text{mol})\cdot(8.31\,\text{J/mol}\cdot\text{K})\cdot(60\,\text{K})$$
$$= 6.98\times10^{3}\,\text{J}$$

(b) For any process, $\Delta E_{int} = nC_V\Delta T$

For a diatomic gas, $C_V = \frac{5}{2}R$

$$\therefore \Delta E_{int} = \frac{5}{2}\cdot(4\,\text{mol})\cdot(8.31\,\text{J/mol}\cdot\text{K})\cdot(60\,\text{K})$$
$$= 4.99\times10^{3}\,\text{J}$$

(c) $W = Q - \Delta E_{int}$ (first law of thermodynamics)
$= 1.99\times10^{3}\,\text{J}$

(d) $\Delta K = \underset{\uparrow}{\frac{3}{2}}nR\Delta T = \frac{3}{2}\cdot(4\,\text{mol})(8.31\,\text{J/mol}\cdot\text{k})\cdot(60\,\text{k}) = 2.99\times10^{3}\,\text{J}$

even if we are dealing with a diatomic gas, since we want to find "translational" kinetic energy, the factor is $3/2$.

82P. (a) Isothermal. $(T_1 = T_2)$

$$P_1 V_1 = P_2 V_2 = nRT_1$$

$$P_2 = \frac{V_1}{V_2} P_1 = \frac{1}{4}\cdot(32\,\text{atm}) = 8\ \text{atm}$$

$$W = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{nR\boxed{T_1}\overset{\text{constant here}}{\longleftarrow}}{V}\,dV = nRT_1 \cdot \ln\frac{V_2}{V_1}$$

$$= P_1 V_1 \ln\frac{V_2}{V_1} = (32\,\text{atm})\cdot(1.01\times10^{5}\ \text{Pa/atm})\cdot(1\times10^{-3}\ \text{m}^3)\ln\frac{4}{1}$$

$$= 4.4\times10^{3}\ \text{J}$$

(b) Adiabatic & Monatomic. $(Q=0\ \&\ C_V = \frac{3}{2}R)$

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$\Rightarrow P_2 = \left(\frac{V_1}{V_2}\right)^{\gamma}\cdot P_1 = \left(\frac{1}{4}\right)^{5/3}\cdot(32\,\text{atm}) = 3.2\ \text{atm}$$

$$\frac{pV}{T} = \text{constant.}$$

$$\Rightarrow T_2 = P_2 V_2 \cdot \frac{T_1}{P_1 V_1} = \frac{(3.2\,\text{atm})(4\text{L})}{(32\,\text{atm})(1\text{L})}\cdot 300\text{K} = 120\text{K}$$

$$Q = 0 \Rightarrow W = -\Delta E_{int} = -\frac{3}{2}nR\Delta T$$

$$= -\frac{3}{2}(P_2V_2 - P_1V_1)$$

$$= -\frac{3}{2}\left[(32\,\text{atm})(4\,\text{L}) - (32\,\text{atm})(1\,\text{L})\right]\cdot(1.01\times10^{5}\ \text{Pa/atm})\cdot\times(10^{-3}\ \text{m}^3/\text{L})$$

$$= 2.9\times10^{3}\ \text{J}$$

(c) Adiabatic & Diatomic

every procedure in (b) ~~are~~ can be used here. with $\gamma = 1.4$ & $C_v = \frac{5}{2}R$.

$$P_2 = \left(\frac{V_1}{V_2}\right)^{\gamma} \cdot P_1 = \left(\frac{1L}{4L}\right)^{1.4} \cdot 32\,atm = 4.6\,atm$$

$$T_2 = \frac{P_2 V_2}{P_1 V_1} \cdot T_1 = \frac{(4.6\,atm)(4L)}{(32\,atm)\cdot(1L)} = 170\,K$$

$$W = \overset{0}{\cancel{Q}} - \Delta E_{int} = -\frac{5}{2} nR\Delta T$$

$$= -\frac{5}{2}(P_2V_2 - P_1V_1)$$

$$= 3.4 \times 10^3\,J$$