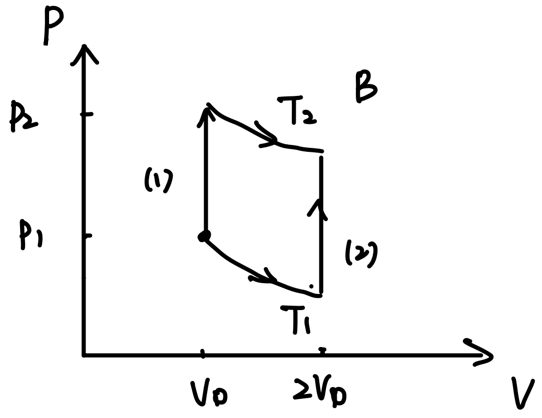
10-4 质量为 1 kg 的氧气, 其温度由 300 K 升高到 350 K 是在下列三种不同情况下发生的: (1) 体积不变; (2) 压强不变; (3) 绝热. 问该气体内能的改变各为多少?

均可使用理想气体内能公式:

$$\Delta E = \frac{m}{M} \cdot \frac{i}{2} R \Delta T = \frac{1000}{32} \cdot \frac{5}{2} \cdot 8.31 \times 50 = 3.25 \times 10^4 J$$

10-5 1 mol 氢, 在压强为 1 atm, 温度为 20 °C 时, 其体积为 V_0, 今使其经以下两种过程达到同一状态: (1) 先等体加热使其温度升高到 80 °C, 然后等温膨胀使体积变为原来的 2 倍; (2) 先等温膨胀到原体积的 2 倍, 然后等体加热到 80 °C. 试作出 $p-V$ 图 (在同一 p-V 图上画两过程的曲线), 并分别计算以上两种过程中气体吸收的热量、对外做功及内能的增量.



等体

$$Q_V = \frac{m}{M} C_{V,m} \Delta T$$

$$A_V = 0$$

$$\Delta E_V = \frac{m}{M} C_{V,m} \Delta T$$

等温

$$Q_T = A = \frac{m}{M} RT \ln \frac{V_2}{V_1}$$

$$A_V = \int_{V_0}^{2V_0} p\, dV = \frac{m}{M} RT \ln \frac{V_2}{V_1}$$

$$\Delta E = 0$$

(1). $Q_1 = Q_{V_1} + Q_{T_2} = \frac{5}{2} \cdot 8.31 \cdot 60 + 8.31 \cdot 353 \cdot \ln 2 = 3.28 \times 10^3\ J$

$A_1 = A_V = 2.03 \times 10^3\ J$ $\quad E_1 = \frac{m}{M} C_{V,m} \Delta T = 1.25 \times 10^3\ J.$

(2) $Q_2 = Q_{T_1} + Q_V = 8.31 \cdot 293 \cdot \ln 2 + \frac{5}{2} \cdot 8.31 \cdot 60 = 2.93 \times 10^3\ J$

$A_2 = A_V = 1.69 \times 10^3\ J$ $\quad E_2 = \frac{m}{M} C_{V,m} \Delta T = 1.25 \times 10^3\ J.$

10-7 一气缸内储有 10 mol 单原子理想气体, 在压缩过程中外界对气体作功 209 J, 使气体温度升高 1 K, 试计算气体吸收的热量、内能的增量和该过程中气体的摩尔热容.

解:

$$\Delta E = \frac{m}{M}\frac{i}{2}R\Delta T = 10\times\frac{3}{2}\times 8.31\times 1 = 124.65\ \mathrm{J}$$

$$Q = \Delta E + A = 124.65 - 209 = -84.35\ \mathrm{J}$$

$$C = \frac{Q}{\Delta T\cdot\frac{m}{M}} = -8.435\ \mathrm{J\cdot K^{-1}\cdot mol^{-1}}.$$

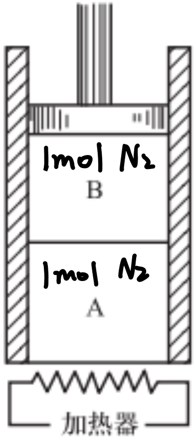
10-8 有一除底部外都是绝热的气筒, 被一位置固定的导热板隔成相等的两部分 A 和 B, 如题图 10-8 所示, 其中各盛有 1 mol 理想气体氮. 现将 336 J 的热量缓慢地由底部传给气体, 设活塞上的压强始终保持为 100 atm, 求 (1) A 部和 B 部气体温度的改变量以及各吸收的热量 (设导热板的热容量可忽略不计); (2) 将位置固定的导热板换成可自由滑动的绝热板, 重复上述讨论.

(1) A 等体. B 等压.

$Q_A = \Delta E_A = \frac{i}{2} R \Delta T.$

$Q_B = \frac{m}{M} C_{p,m} \Delta T$

$= \frac{i+2}{2} R \Delta T.$



题图 10-8

$Q_A + Q_B = 336.\ J$

$\Rightarrow \Delta T = 6.74K.$

$Q_A = \frac{\frac{5}{2}}{6} \cdot Q = 140\ J$

$Q_B = \frac{\frac{7}{2}}{6} \cdot Q = 196\ J$

(2) A 等压. B 绝热

$Q_A = \frac{i+2}{2} R \Delta T$

$Q_B = 0$

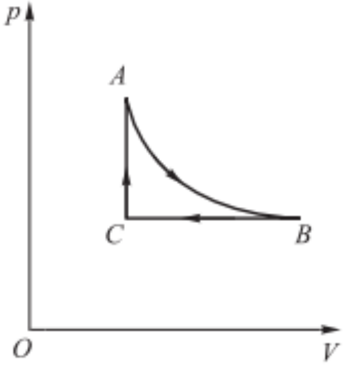
$\Rightarrow \Delta T = \frac{Q}{\frac{i+2}{2} R} = \frac{336}{\frac{7}{2} \cdot 8.31} = 11.55\ K.$

$Q_A = Q = 336\ J$

$Q_B = 0\ J$

10-9 一定量理想气体作如题图 10-9 所示的循环, 试填入下表内各空格应有的数值.

过程	Q	W	ΔE	η
AB (等温)	100 J	100J	0	
BC (等压)	−126J	−42 J	−84 J	
CA (等体)	84J	0	84J	
$ABCA$	58J	58J	0	



题图 10-9

$\Delta E_{AB} = 0$

$W_{AB} = Q_{AB} = 100J$

$Q_{BC} = W + \Delta E = -126J$

循环有 $\Delta E = 0$

$\Delta E_{CA} = -(\Delta E_{AB} + \Delta E_{BC}) = 84J$

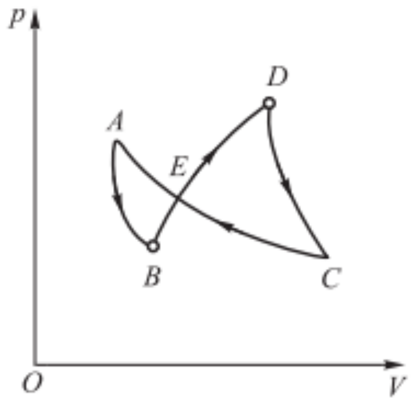
等体 $W_{CA} = 0$

$Q_{CA} = \Delta E_{CA} = 84J$

$Q_{ABCA} = Q_{AB} + Q_{BC} + Q_{CA} = 58J.$

$\eta = \frac{A}{Q_1} = \frac{58}{100+84} = 31.5\%$

10-10 题图 10-10 所示的循环过程中, AB, DC 是绝热过程, CEA 是等温过程, BED 是任意过程. 已知图中 EDC 和 EAB 所包围的面积对应的功分别为 80 J 和 40 J, CEA 过程中系统放热为 100 J, 求 BED 过程系统吸收的热量.



题图 10-10

解:

对外做功 $A = 80 - 40 = 40J$.

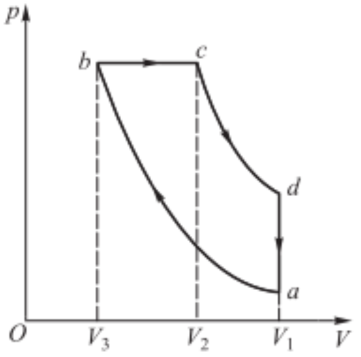
$(E \to D \to C$ 顺时针 $A > 0$. $E \to A \to B$. 逆时针 $A < 0)$.

$Q_{AB} = Q_{DC} = 0$

$Q_{BED} = A + |Q_{CEA}| = 140J$

10-13 理想的狄塞尔内燃机的工作循环由两个绝热过程 ab 和 cd, 一个等压过程 bc 及一个等容过程 da 组成 (题图 10-13), 试证明此热机的效率为

$$\eta = 1 - \frac{\left(\frac{V_3}{V_2}\right)^{\gamma} - 1}{\gamma\left(\frac{V_1}{V_2}\right)^{\gamma-1}\left(\frac{V_3}{V_2} - 1\right)}.$$



题图 10-13

解: $Q_{ab} = Q_{cd} = 0.$

放热 $Q_2 = Q_{da} = \frac{m}{M} C_{V,m} \Delta T_2$

吸热: $Q_1 = Q_{bc} = \frac{m}{M} C_{p,m} \Delta T_1.$

da. 等体 $V = const.$ $\Delta T_2 = \frac{(P_a - P_d)V_1}{R\frac{m}{M}}$

bc 等压. $P = const$ $\Delta T_1 = \frac{P_b(V_2 - V_3)}{R \cdot \frac{m}{M}}$

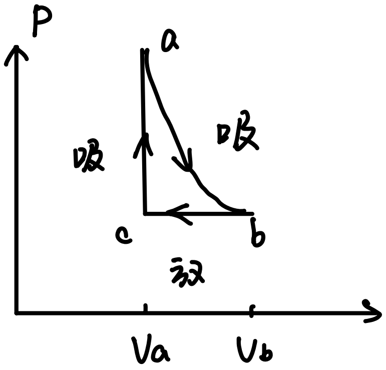
$$\frac{|\Delta T_2|}{\Delta T_1.} = \frac{(P_d - P_a) \cdot V_1}{P_b \cdot (V_2 - V_3).}$$

$$\left(\frac{P_a}{P_b}\right) = \left(\frac{V_b}{V_a}\right)^{\gamma} = \left(\frac{V_3}{V_1}\right)^{\gamma} \qquad \left(\frac{P_d}{P_b}\right) = \left(\frac{P_d}{P_c}\right) = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

$$\eta = 1 - \frac{|Q_2|}{Q_1} = 1 - \frac{|\Delta T_2|}{\gamma \Delta T_1} = 1 - \frac{\left[\left(\frac{V_2}{V_1}\right)^{\gamma} - \left(\frac{V_3}{V_1}\right)^{\gamma}\right] P_b \cdot V_1}{\gamma \cdot P_b (V_2 - V_3)}$$

$$= 1 - \frac{\left[\left(\frac{V_3}{V_1}\right)^{\gamma} - \left(\frac{V_2}{V_1}\right)^{\gamma}\right] V_1}{\gamma (V_3 - V_2)} = 1 - \frac{\left[\left(\frac{V_3}{V_2}\right)^{\gamma} - 1\right].}{\gamma \cdot \left(\frac{V_1}{V_2}\right)^{\gamma-1}\left(\frac{V_3}{V_2} - 1\right)}$$

10-15 单原子理想气体经历一循环过程, 如题图 10-15 所示. 其中 ab 为等温过程, bc 为等压过程, ca 为等体过程. 图中 $V_b = 6.00L, V_a = 3.00L$, 求此循环的效率.



解: $Q_{ca} = \frac{m}{M} C_{V,m} \Delta T. = \frac{i}{2} V_a (P_a - P_c).$

$Q_{ab} = P_a V_a \ln \frac{V_b}{V_a}$

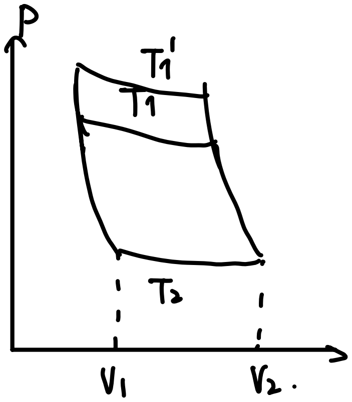
$Q_{bc} = \frac{m}{M} C_{p,m} \Delta T = \frac{i+2}{2} P_c (V_a - V_b).$

$$\eta = 1 - \frac{|Q_{bc}|}{Q_{ca} + Q_{ab}} = 1 - \frac{\frac{i+2}{2} P_c (V_b - V_a)}{P_a V_a \ln \frac{V_b}{V_a} + \frac{i}{2} V_a (P_a - P_c)}$$

$$\frac{P_c}{P_a} = \frac{P_b}{P_a} = \frac{V_a}{V_b} = \frac{1}{2} \qquad = 1 - \frac{\frac{5}{2} \cdot 3 \cdot (\frac{P_c}{P_a}).}{3 \cdot \ln 2 + \frac{3}{2} \cdot 3 \cdot (1 - (\frac{P_c}{P_a}))} = 1 - \frac{3.75}{3\ln 2 + 2.25} = 13.38\%$$

10-17 理想气体准静态卡诺循环, 当热源温度为 100 °C, 冷却器温度为 0 °C 时, 做净功为 800 J. 今若维持冷却器温度不变, 提高热源的温度, 使净功增为 1.60×10^3 J, 并设该两个循环都工作于相同的两条绝热线之间, 求 (1) 热源的温度是多少? (2) 效率增大到多少?

解:



(1) $\eta_c = 1-\dfrac{T_2}{T_1} = \dfrac{A}{A+|Q_2|}$.

$Q_2 = A_2 = \dfrac{m}{M} RT_2 \ln\dfrac{V_1}{V_2}$. Q_2 在这一过程中不变.

$|Q_2| = \dfrac{AT_1}{\Delta T} - A = \dfrac{800\cdot 373}{100} - 800 = 2184\,\text{J}$.

$T_1' = \dfrac{T_2}{1-\dfrac{A'}{A'+|Q_2|}} = \dfrac{273}{1-\dfrac{1600}{1600+2184}} = 473\ \text{K} = 200^\circ\text{C}$

(2) $\eta_c' = 1-\dfrac{T_2}{T_1'} = 42.28\%$

10-19 容器的两边分别储有 80 °C 的水和 20 °C 的水, 经过一段时间, 从热的一边向冷的一边传递了 4.2×10^3 J 的热量, 假定水量足够多, 以致两边的水温不变, 求该过程系统的熵变.

解:

$$dS = |dQ|\left(\frac{1}{T_B}-\frac{1}{T_A}\right).$$

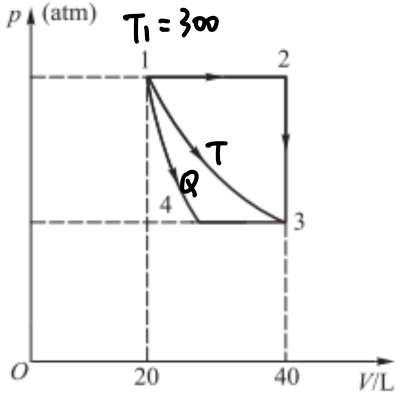
$$= 4.2\times10^3\cdot\left(\frac{1}{293}-\frac{1}{353}\right) = 2.44\ \mathrm{J/K}.$$

10-21 如题图 10-21 所示, 1 mol 理想气体在初态 1 时温度 $T_1 = 300$ K, 经不同过程到达终态 3, 其中 $1 \to 2, 4 \to 3$ 均为等压过程, $2 \to 3$ 为等体过程, $1 \to 3$ 为等温过程, $1 \to 4$ 为绝热过程, 试分别由三条路径计算熵变 $S_3 \to S_1$:

(1) $1 \to 2 \to 3$;

(2) $1 \to 3$;

(4) $1 \to 4 \to 3$.



题图 10-21

解: (1)

$$\Delta S = \int \frac{m}{M} C_{p,m} \cdot \frac{\Delta T}{T} + \int \frac{m}{M} C_{V,m} \cdot \frac{\Delta T}{T} = \int \frac{m}{M} C_{p,m} \frac{dT}{T} + \int \frac{m}{M} \cdot C_{V,m} \frac{dT}{T}$$

$$= R \cdot \int_{V_1}^{V_2} \frac{dV}{V} + C_{V,m} \int_{T_3}^{T_1} \frac{dT}{T} = R \cdot \ln \frac{V_2}{V_1} = 5.76\ J/K.$$

(2).

$$\Delta S = \int \frac{\delta Q}{T} = \int_{V_1}^{V_2} \frac{p\, dV}{T} = \int_{V_1}^{V_2} \frac{\frac{m}{M} RT\, dV}{VT}$$

$$= R \cdot \ln \frac{V_2}{V_1} = 5.76\ J/K.$$

(3).

$$\Delta S = \int \frac{\delta Q}{T} = \int \frac{\delta Q_{43}}{T} = \int_{V_4}^{V_3} \frac{\frac{m}{M} C_{p,m}\, dV}{V}$$

$$= C_{p,m} \cdot \ln \frac{V_2}{V_4} = C_{p,m} \ln \frac{V_2}{(V_1^{\gamma-1} V_2)^{\frac{1}{\gamma}}}$$

$$= C_{p,m} \cdot \frac{\gamma-1}{\gamma} \cdot \ln \frac{V_2}{V_1} = R \cdot \ln \frac{V_2}{V_1} = 5.76\ J/K.$$

绝热线上. $\frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$

等压过程 $\frac{V_4}{V_3} = \frac{T_4}{T_3} = \frac{T_4}{T_1}$.

$\Rightarrow V_4 = (V_1^{\gamma-1} V_2)^{\frac{1}{\gamma}}$