1.

**2.1** An monatomic ideal gas at 300 K has a volume of 15 liters at a pressure of 15 atm. Calculate

a. The final volume of the system
b. The work done by the system
c. The heat entering or leaving the system
d. The change in the internal energy
e. The change in the enthalpy when the gas undergoes
   i. A reversible isothermal expansion to a pressure of 10 atm
   ii. A reversible adiabatic expansion to a pressure of 10 atm

The constant-volume molar heat capacity of the gas, $c_v$, has the value 1.5 $R$.

$P_i = 15 atm \quad V_i = 15L, \quad T_i = 300K, \rightarrow n = \frac{P_i V_i}{RT_i} = \frac{15 \cdot 15}{0.0806 \cdot 300} = 9.16$

i) reversible isothermal expansion to $P_j = 10$, (T = constant)

a. $P_i V_i = P_j V_j \quad , \quad V_j = \frac{P_i V_i}{P_j} = 22.5 L.$

b. $w = \int_{V_i}^{V_j} P\,dV = \int_{V_i}^{V_j} \frac{nRT}{V} dV = nRT \ln\left(\frac{V_j}{V_i}\right) = 9.26 kJ.$

c. $\Delta U = 0 \quad \therefore q = w = 9.26 kJ.$

d. $\Delta U = nC_v \Delta T \quad , \quad P_i V_i = P_j V_j \rightarrow nRT_i = nRT_j \rightarrow \Delta T = 0 \quad \therefore \Delta U = 0$

e. $\Delta H = \Delta U_p + P\Delta V = nC_p \Delta T = 0.$

a) 22.5L  b) 9.26kJ  c) 9.26kJ  d) 0  e) 0

ii) reversible adiabatic expansion to $P_j = 10$

$P_i V_i^{\gamma} = P_j V_j^{\gamma} \quad , \quad \gamma = \frac{5}{3} \quad V_j = \left(\frac{P_i V_i^{\gamma}}{P_j}\right)^{\frac{3}{5}} = 19.13 L$

$T_j = \frac{P_j V_j}{nR} = 254.7 K.$

$\Delta U = q - w = -w = nC_v \Delta T = 9.16 \cdot \frac{3}{2} R \cdot (300 - 254.7)$

$= 5.17 kJ$

$\Delta H = \gamma \Delta U = 8.62 kJ$

a) 19.13L  b) −5.17kJ  c) 0  d) 5.17kJ  e) 8.62kJ

2.

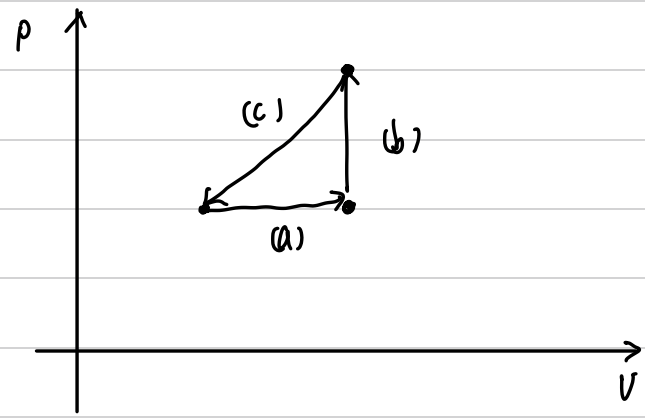
**2.2** One mole of a monatomic ideal gas, in the initial state $T = 273$ K, $P = 1$ atm, is subjected to the following three processes, each of which is conducted reversibly:

a. A doubling of its volume at constant pressure,
b. Then a doubling of its pressure at constant volume,
c. Then a return to the initial state along the path $P = 6.643 \times 10^{-4}V^2 + 0.6667$.

Calculate the heat and work effects which occur during each of the three processes.

$T_i = 273k$, $P_i = 1$ atm $V_i$, $n_i = 1 \longrightarrow$ ? heat, work effect.

a) $V_j = 2V_i$, $P_j = P_i$ b) $P_i = 2P_i$, $V_j = V_i$, c. $P = 6.648 \times 10^{-4}V^2 + 0.6667$




$V_i = \frac{n_i RT}{P_i} = 22.4$

(a) $\Delta U = nC_v\Delta T$, $T_j/T_i = \frac{P_jV_j}{P_iV_i} = 2$, $T_j = 546k$

$= \frac{3}{2}R \cdot 273 = 3.40kJ$.

$w = P\Delta V = 1atm \cdot 22.4L = 22.4\ atm\cdot L \cdot \frac{10^5 N/m^2}{1atm} \times \frac{1m^3}{10^3 L}$

$= 2.24kJ$

$q = \Delta U + w = 5.64kJ$

$\therefore w = 2.24kJ$ $q = 5.64kJ$ $\Delta U = 3.4kJ$

(b) $P_i = 1atm$ $V_i = 44.8$ $n = 1$ $T_i = 546k$

$P_j = 2atm$ $V_j =$ 〃 〃 $T_j = 1092k$.

$\Delta U = nC_v\Delta T = \frac{3}{2}R \cdot 546 = 6.81kJ$

$\Delta U = q - w$, $w = 0$, $\Delta U = q = 6.81kJ$

$\therefore w = 0$, $q = 6.81kJ$, $\Delta U = 6.81kJ$

(c) $P = 6.648 \times 10^{-4}V^2 + 0.6667$ $P_i = 2atm$ $V_i = 44.8L$, $n = 1$ $T_i = 1092k$.

$T_{initial} = T_{final} \rightarrow \Delta U = nC_v\Delta t = \frac{3}{2}R \cdot 819 = 10.21kJ$.

$w = \int P\,dV = \left[6.648 \times 10^{-4} \cdot 1/3 \cdot V^3 + 0.6667V\right]_{44.8}^{22.4} \cdot 10^{-1} \frac{kJ}{atm\cdot L} = -3.24kJ$

$q = \Delta U + w = 6.91kJ$

$\therefore w = -3.24kJ$, $q = 6.91kJ$, $\Delta U = 10.21kJ$.

3.

**3.1** The initial state of 1 mole of a monatomic ideal gas is $P = 10$ atm and $T = 300$ K. Calculate the change in the entropy of the gas for

a. An isothermal decrease in the pressure to 5 atm
b. A reversible adiabatic expansion to a pressure of 5 atm
c. A constant-volume decrease in the pressure to 5 atm

$P_i = 10atm$ 、 $T_i = 300k$ 、 $n = 1mol.$ $V_i = \frac{nRT_i}{P_i} = 2.46L$

a.) $P_f = 5atm$ 、$V_i = 4.92L$ 、$T_f = 300\ k$ (isothermal)

① $dS = \frac{dq}{T}$

② Isothermal 、$\Delta U = 0$ 、 $q = w$

$w = \int p dV = \int \frac{nRT}{V} dV = nRT \ln\left(\frac{V_f}{V_i}\right)$

② ← ① $\Delta S = \int \frac{dq}{T} = nR \ln \frac{V_f}{V_i} = 16.82 J/K.$

b) adiabatic : $\Delta q = 0 \rightarrow \Delta S = \int \frac{dq}{T} = 0.$

c) constant volume 、decrease in pressure of $P_f = 5atm$

$\Delta V = 0 \rightarrow w = 0 \rightarrow dq = \Delta U = nC_v dT$

$\Delta S = \int \frac{dq}{T} = \int_{300}^{150} nC_v / T \, dT = -nC_v \ln 2 = -\frac{3}{2} R \ln 2 = -8.64\ J/K.$

4.

**3.4** Calculate the change in the enthalpy and the change in entropy when 1 mole of SiC is heated from 25°C to 1000°C. The constant-pressure molar heat capacity of SiC varies with temperature as

$$c_p = 50.79 + 1.97\times10^{-3}T - 4.92\times10^{6}T^{-2} + 8.20\times10^{8}T^{-3}\ \text{J/mole}\cdot\text{K}$$

① $\Delta H = \int nC_p\,dT$ , $n=1$ , $T_f=1273$ $T_i=289$

$= \left[50.79T + \frac{1}{2}\times1.97\times10^{-3}T^2 + 4.92\times10^{6}T^{-1} - \frac{1}{2}\cdot 8.20\times10^{8}T^{-2}\right]_{289}^{1273}$

$= 4.30\text{kJ/mol}$

② $\Delta S = \int \frac{dq}{T}$

- entropy는 상태함수 → 경로 상관 X.

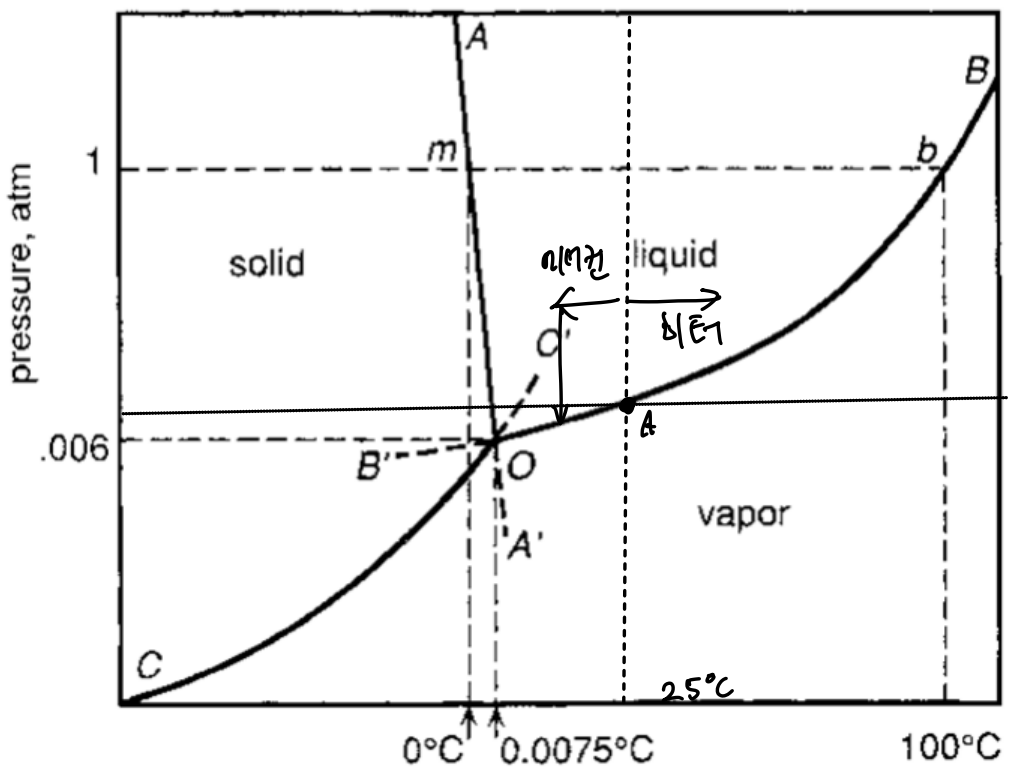
$q = \Delta U + w = \Delta U + p\Delta V = \Delta H$

$\Delta S = \int \frac{dq}{T} = \int \frac{\Delta H}{T}dT = \int 50.79 + \frac{1}{2}\times1.97\times10^{-3}T + 4.92\times10^{6}T^{-2} - \frac{1}{2}\cdot 8.20\times10^{8}T^{-3}\,dT$

$= \left[50.79T + \frac{1}{2}\times1.97\times10^{-3}T^2 - 4.92\times10^{6}T^{-1} + \frac{1}{4}\cdot 8.20\times10^{8}T^{-2}\right]_{289}^{1273}$

$= 6.16\text{kJ/K}$

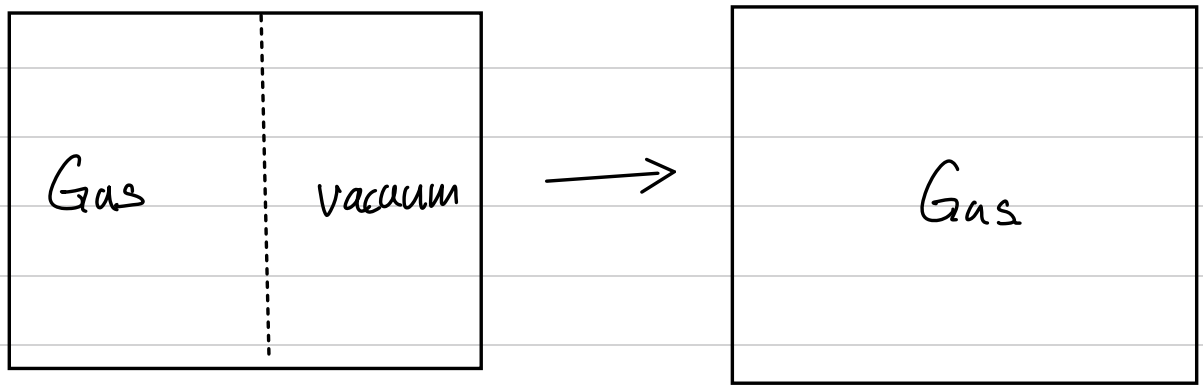
5.




Answer: 찬 바람을 나오게 하는 것이 현명하다.

→ 대기압은 1atm 이나, 이중에서 water의 partial volume은 매우 낮다.
대략 차 안의 조건이 A라 가정시 $H_2O$의 상태는 vapor이 우세한 상태로,
차가운 상태인 창과 접촉시 liquid로 우세하게되어 김이 서리게 된다.
만약 T를 내리기위해 에어컨을 켜면 liquid가 우세한 상태로 바뀌어
vapor의 partial pressure이 낮아져 김 서림이 덜해진다

6.




- statistical 관점 : $\Delta S = k_B \ln \Omega_2/\Omega_1$ 으로 정의한다.
$\Omega_1$ 이 gas 입자가 공간 내에 존재하는 경우의 수이므로,
2배의 공간이 존재시 $\Omega_2 > \Omega_1$
$\therefore \Delta S = k_B \ln \Omega_2/\Omega_1 > 0$ → 자발적으로
gas가 확산된다.

- dynamics 관점 : isolate되므로 $\Delta U = \Delta H = 0$ 이만 irreversible 하므로
q와 w를 직접적용할 수는 없으나

$\Delta S = \frac{q_{irreversible}}{T} + \Delta S_{irr} = \frac{q_{rev}}{T}$ 일 때.

reversible adiabatic 경로로 생각시

$q_{rev} = RT \ln \frac{V_2}{V_1} > 0$ 이 자발적이다.

반응의 즉 초기에 irreversible한 경우에서 reversible 해석
가능한 경우의 존재 (전후이 일어나지 않을)가 있다 가정시
$\Delta S > 0$ 으로 자발적.

## 7. Microscopically reversible, Macroscopically irreversible.

- Macroscopic: P, T state
  Microscopic: 분자들의 각각의 특성.

- Microscopic state의 경우 분자의 속력을 따지는 경우로, 실제로는 분자의 속력을 모두 알 수 없는 random 에게 reversible한 상태와 유사하다.
- Macroscopic state의 경우 방향성이 존재하며, 이로 인해 irreversible 한 상태라고 할 수 있다.