izpit 1991 pl. zvezek /102 + Elekt./13 ENT

5. 2 mola enoatomnega idealnega plina (c_v = 20 J/mol·K) adiabatno in ireverzibilno raztegnemo v vakuum iz začetnega stanja s temperaturo 310 K pri volumnu 30 dm^3 v končno stanje, kjer je tlak manjši. V tem procesu se entropija plina poveča za 8 J/K. Kakšen je končni volumen plina?

ΔS izračunamo pri nadomestni reverzibilni spremembi: reverzibilno izotermno razpenjanje

$c_v = 20$ J/mol·K

$T = 310$ K

$V_1 = 30\ dm^3$

$\Delta S = 8$ J/K

$$\left.\begin{matrix} A = 0 \\ Q = 0 \end{matrix}\right\} \Rightarrow \boxed{\Delta W_n = 0} \Rightarrow \boxed{\Delta T = 0}$$

$$dS \geq \frac{dQ}{T}$$

$$\boxed{dQ = T\,dS}$$

$$dW_n = dQ - p\,dV = 0 = c_v m\,dT$$

$$\boxed{dQ = p\,dV}$$

$$pV = \frac{m}{M}RT$$

$$\frac{p}{T} = \frac{m}{M}\frac{R}{V}$$

$$\boxed{dS = \frac{1}{T}\int dQ = \frac{p}{T}dV = \frac{p}{T}dV = \frac{m}{M}R\frac{dV}{V}}$$

$$\boxed{\Delta S = \frac{m}{M}R\ln\frac{V_2}{V_1}} \Rightarrow \boxed{V_2 = V_1 \cdot \exp\left[\frac{\Delta S \cdot M}{m \cdot R}\right]}$$

$$30 \cdot \exp\left[\frac{1000 \cdot 8}{2 \cdot 8314}\right] = 48.54$$

$$\boxed{V_2 = 48{,}54\ dm^3}$$

✓

1594

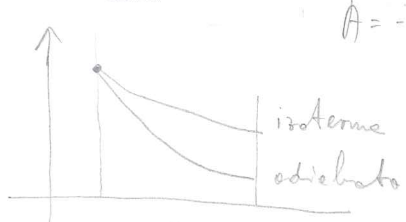
3. Maso 2 g enoatomnega idelanega plina (M = 12 kg/kmol) reverzibino razpnemo na dvakratni začetni volumen iz začetnega stanja pri tlaku 10^5 Pa in volumnu 4 l na dva načina, izotermno in adiabatno. V katerem procesu opravi plin večje delo ? Kolikšni sta spremembi entropije ? Odgovor argumentirajte z numeričnimi izračuni.

$A = -\int p\,dV$

$m = 2\,g$, $M = 12\,kg/kmol$

$V_2 = 2V_1$

$p_1 = 10^5\,Pa$, $V_1 = 4 \cdot 10^{-3}\,m^3$



$\Downarrow$

$|A_{ad}| < |A_{iz}|$

$p_1 V_1 = \frac{m}{M} R_1 T_1 \Rightarrow T_1 = \frac{p_1 V_1 M}{m R} = 289{,}16\,K$

$A_{iz} = -\int_{V_1}^{2V_1} p\,dV = -\int_{V_1}^{2V_1} \frac{m}{M} R T_1 \frac{1}{V}\,dV = -\frac{m}{M} R T_1 \ln\frac{2V_1}{V_1} = -277.26\,J$

$\Delta W_n = 0 = Q + A_{iz} \Rightarrow \Delta S_{iz} = \frac{Q}{T_1} = \frac{-A_{iz}}{T_1} = 0.958\,J/K$

$\Delta W_n = A_{ad} = c_v\, m\,(T_2 - T_1) = -220{,}3\,J$

$c_v = \frac{3}{2}\frac{R}{M}$

$c_p = c_v + \frac{R}{M} = \frac{5}{2}\frac{R}{M}$ $\Rightarrow \varkappa = \frac{c_p}{c_v} = \frac{5}{3}$

$T_2 = T_1 \frac{V_1^{\varkappa - 1}}{V_2^{\varkappa - 1}} = T_1 \left(\frac{1}{2}\right)^{\varkappa - 1} = 183\,K$

$\Delta S = \int \frac{dQ}{T} = 0$

Popit 1995 5.9.1991 ENT

3. Za koliko se spremeni entropija pol litra dvoatomnega idealnega plina, če ga pri nespremenjenem tlaku 10^5 Pa segrejemo s temperature 20° C na temperaturo 38° C ?

$$\Delta S \geqq \int \frac{dQ}{T}$$

$V_z = 0{,}5\ dm^3 = 5 \cdot 10^{-4}\ m^3$

$p = 10^5\ Pa = konst$

$T_z = 20^\circ C = 293\ K$

$T_k = 38^\circ C = 311\ K$

$c_v = \frac{5}{2}\frac{R}{M}$

$c_p - c_v = \frac{R}{M} \Rightarrow c_p = \frac{7}{2}\frac{R}{M}$

$$\Delta S = \int_{T_z}^{T_k} \frac{dQ}{T} = \int_{T_z}^{T_k} \frac{c_p m\, dT}{T} = c_p \cdot m \cdot \ln\frac{T_k}{T_z} = \frac{7}{2}\frac{R}{M}\frac{p V_z M}{R T_z} \cdot \ln\frac{T_k}{T_z} =$$

$pV = \frac{m}{M} RT \Longrightarrow m = \frac{p V_z M}{R T_z}$

$$= \frac{7}{2} \cdot \frac{p V_z}{T_z} \cdot \ln\frac{T_k}{T_z} = 3{,}56 \cdot 10^{-2}\ J$$

$$\frac{7 \cdot 10^5 \cdot 5 \cdot 10^{-4}}{2 \cdot 293} \cdot \ln\frac{311}{293} =$$

2. Idealni plin z maso 0,58 kg v jeklenki segrejemo od 27°C na 327°C. Pri tem se entropija plina spremeni za 296,43 J/K. Molska masa plina je 28 kg/kmol. Izračunaj specifično toploto plina pri konstantnem volumnu in ugotovi, koliko atomov je v molekuli tega plina.

1992

$m = 0{,}58\ kg$

$T_1 = 300\ K$

$T_2 = 600\ K$

$\Delta S = 296{,}43\ J/K$

$M = 28\ kg/kmol$

$c_V = ?$

$V = konst \Rightarrow A = 0 \Rightarrow$

$dW_n = dQ = c_V m\, dT$

$$\Delta S = \int_{T_1}^{T_2} \frac{dQ}{T} = \int_{T_1}^{T_2} \frac{c_V m\, dT}{T} = m \cdot c_V \cdot \ln \frac{T_2}{T_1} \Rightarrow$$

$$c_V = \frac{\Delta S}{m \cdot \ln \frac{T_2}{T_1}} = 737.3\ J/(kg \cdot K)$$

✓

$$W_n = N \cdot x \cdot kT = \frac{N m_1}{m_1} \times \frac{k N_A}{N_A} T = m \cdot x \frac{R}{M} \cdot T$$

($N m_1 = m$, $k N_A = R$, $m_1 N_A = M$, $x \frac{R}{M} = c_V$)

$$c_V = x \cdot \frac{R}{M} \Rightarrow x = c_V \cdot \frac{M}{R} = 2{,}5 = \frac{5}{2}$$

✓

⇓

DVOATOMNA MOLEKULA

KOLOKVIJ 95/96

5. Enoatomni idealni plin (M = 12 kg/kmol) reverzibilno razpnemo na dvakrat večji volumen iz začetnega stanja pri tlaku 10^5 N/m^2 in volumnu 4 l na dva načina, izotermno in adiabatno. V katerem procesu je končni tlak večji in kdaj plin opravi večje delo ? Kolikšni sta spremebi notranje energije in entropije plina v obeh primerih ? Masa plina je 2 g. ← DODAJ !

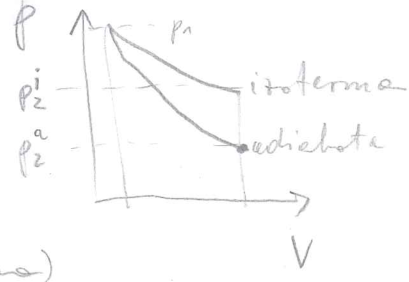
ENT

Sen 32/2.25

$p_1 = 10^5$ N/m^2 , $m = 2$ g

$V_1 = 4 \cdot 10^{-3}$ m^3

$M = 12$ kg



$\Rightarrow |A_a| < |A_i|$

(p_1, V_1, T_1) → $p_2 V_2 T_1$ (izotermno); $p_2' V_2 T_2'$ (adiabatno)

$V_2 = 2V_1$

$$p_1 V_1 = \frac{m}{M} R T_1 \Rightarrow T_1 = \frac{p_1 V_1 \cdot M}{m R} = \frac{10^5 \cdot 4 \cdot 10^{-3} \cdot 12}{2 \cdot 10^{-3} \cdot 8300} = 289.16 \text{ K}$$

izotermno: $p_1 V_1 = p_2 2V_1 \Rightarrow p_2 = p_1/2 = 0.5 \cdot 10^5$ N/m^2 $= p$

$$A_i = -\int_{V_1}^{2V_1} p\,dV = -\int_{V_1}^{2V_1} \frac{m}{M} R T_1 \frac{1}{V} dV = -\frac{m}{M} R T_1 \ln\frac{2V_1}{V_1} = -\frac{2 \cdot 10^{-3}}{12} \cdot 8300 \cdot 289.16 \cdot \ln 2 = -277.26 \text{ J}$$

$$\Delta W_n = 0 = Q + A_i \Rightarrow \Delta S = \frac{Q}{T_1} = \frac{-A_i}{T_1} = 0.958 \text{ J/K}$$

ADIABATNO:

$$\left.\begin{aligned} c_p - c_v &= \frac{R}{M} \\ c_v &= \frac{3}{2} R/M \end{aligned}\right\} \quad \left.\begin{aligned} c_p - \frac{3}{2} R/M &= \frac{R}{M} \\ c_p &= \frac{5}{2} \frac{R}{M} \end{aligned}\right\} \quad \frac{c_p}{c_v} = \frac{5 R\, 2M}{2M\, 3R} = \frac{10}{6} = 1.66 = \kappa, \quad V_2 = 2V_1$$

$$T_1 V_1^{\kappa-1} = T_2 (V_2)^{\kappa-1} \Rightarrow T_2 = \frac{T_1 V_1^{\kappa-1}}{V_2^{\kappa-1}} = T_1 \left(\frac{1}{2}\right)^{\kappa-1} = 183 \text{ K}$$

$$\Delta W_n = A_a = c_v m \cdot \Delta T = \frac{3}{2} \frac{R}{M} \cdot m \cdot \Delta T = -\frac{3 \cdot 8300 \cdot 2 \cdot 10^{-3} \cdot 106.16}{2 \cdot 12} = -220.3 \text{ J}$$

$\Delta T = (T_2 - T_1) = -106.16$

$$\Delta S = \int \frac{dQ}{T} = 0 \quad \left(\int dQ = 0 \text{ za adiabatno spremembo}\right)$$

$$p_1 V_1^\kappa = p_2 V_2^\kappa \Rightarrow p_2 = p_1 \left(\frac{V_1}{V_2}\right)^\kappa = p_1 \left(\frac{1}{2}\right)^\kappa = 0.316 \cdot 10^5 \frac{N}{m^2} = p$$

Kolokvij 93/94 (ENT)

1. Enoatomen idealen plin v jeklenki s prostornino 0,25 l ima pri temperaturi 20°C tlak 10^5 Pa. Za koliko se spremeni entropija in notranja energija plina v jeklenki, če ga segrejemo na 38°C ? (M = 28 kg/kmol)

$V_1 = 0.25 \cdot 10^{-3}\ m^3$

$T_1 = 293 K$

$p_1 = 10^5\ N m^{-2}$

$c_v = \frac{3}{2}\frac{R}{M}$

$T_2 = 311 K \Rightarrow \Delta T = 18 K$

$$\Delta S = \int_{T_1}^{T_2} \frac{dQ}{T} = \int_{T_1}^{T_2} \frac{c_v m\, dT}{T} = c_v m \ln\frac{T_2}{T_1} = 7.635 \cdot 10^{-3}\ J/K$$

$$p_1 V_1 = \frac{m}{M} R T_1 \Rightarrow m = p_1 V_1 \cdot M/(R \cdot T_1) = 2.88 \cdot 10^{-4}\ kg$$

$$m = \frac{10^5 \cdot 0.25 \cdot 10^{-3} \cdot 28}{8300 \cdot 293} = \frac{25 \cdot 28}{8300 \cdot 293} = 2.88 \cdot 10^{-4}\ kg$$

$$\frac{3}{2}\frac{8300}{28} \cdot 2.88 \cdot 10^{-4} \cdot \ln\frac{311}{293} = 76.35 \cdot 10^{-4}$$

$$\Delta W_n = c_v m \Delta T = \frac{3}{2}\frac{R}{M} \cdot m \cdot \Delta T = 2.3\ J$$

$$\frac{3}{2}\frac{8300}{28} \cdot 2.88 \cdot 10^{-4} \cdot 18 = 2.3\ J$$

Dvoatomni plin : $c_v = \frac{5}{2}\frac{R}{M}$

$\Delta W_n = 3.85\ J$ *

$\Delta S = 12.7 \cdot 10^{-3}\ J/K$

5. Dvoatomen idealen plin v jeklenki s prostornino 0,25 litra ima pri temperaturi 20°C tlak 10^5 Pa. Za koliko se spremeni entropija in notranja energija plina v jeklenki, če ga segrejemo na 38°C. (M = 28 kg/kmol)

$\Delta S = 1{,}27 \cdot 10^{-2}\ JK^{-1}$

$V = 0.25 \cdot 10^{-3}\ m^3$

$T_1 = 293\ K$, $\Delta T = 18\ K$, $T_2 = 311\ K$

$p_1 = 10^5\ K$

$c = \frac{5}{2}\frac{R}{M}$

$dW_n = dQ - p\,dV$ ($dV = 0$)

$dW_n = dQ$

$\Delta S = \int_{T_1}^{T_2} \frac{dQ}{T} = \int_{T_1}^{T_2} \frac{c_v m\, dT}{T} = c_v m \ln\frac{T_2}{T_1} = 1{,}27 \cdot 10^{-2}\ J/K$

$p_1 V = \frac{m}{M} R T_1 \Rightarrow m = \frac{p_1 V M}{R T_1} = \frac{10^5 \cdot 0.25 \cdot 10^{-3} \cdot 28 \cdot 2}{8300 \cdot 293} \Rightarrow$

$m = \frac{25 \cdot 28}{8300 \cdot 293} = 0{,}288 \cdot 10^{-3}\ kg$

$c_v = \frac{5}{2}\frac{R}{M}$

$c_v m \ln\frac{T_2}{T_1} = \frac{5 \cdot 8{,}300}{2 \cdot 28} \cdot 0.288 \ln\frac{311}{293} = 1.27 \cdot 10^{-2}\ J/K$

$\Delta W_n = c_v m \Delta T = \frac{5}{2}\frac{R}{M} \cdot m \cdot \Delta T \Rightarrow$

$\Delta W_n = \frac{5}{2}\frac{8{,}300}{28} \cdot 0.288 \cdot 18 = 3.84\ J$

6. V zmes 10 kg vode in 1 kg ledu dodamo 15 kg vode pri T = 350 K. Kolikšna je sprememba entropije ? (q_t = 335 kJ/kg)

$m_{v1} = 10\ kg \quad (T_{v0} = 273\ K)$

$m_L = 1\ kg$

$m_{v2} = 15\ kg \quad (T_v = 350\ K)$

$$c_p m_{v2} (T_v - T_z) = m_L \cdot q_t + (m_L + m_{v1}) c_p (T_z - T_{v0})$$

$$c_p T_z (m_{v2} + m_L + m_{v1}) = c_p m_{v2} T_v - m_L q_t + T_{v0} c_p (m_L + m_{v1})$$

$$T_z = \frac{m_{v2} \cdot c_p \cdot T_v + (m_L + m_{v1}) c_p T_{v0} - m_L q_t}{c_p (m_{v2} + m_L + m_{v1})} = 314.4\ K$$

$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_L = 992.2\ J/K$$

$$\Delta S_1 = (m_{v1} + m_L) c_p \cdot \ln \frac{T_z}{T_{v0}} = 6523.75\ J/K$$

$$\Delta S_2 = m_{v2} \cdot c_p \ln \frac{T_v}{T_z} = -6758\ J/K$$

$$\Delta S_L = \frac{m_L q_t}{T_{v0}} = 1227\ J/K$$

kolokvij 80/81

ENT

3. V toplotno izolirani posodi zmešamo 1 kg ledu s temperaturo 0°C in 20 kg vode s temperaturo 5°C. Kolikšna je sprememba entropije celotnega sistema ? (talilna toplota ledu $3{,}32 \cdot 10^5$ J/kg, specifična toplota vode =4200J/kgK) (M-Ž)

$m_e = 1\,kg$, $T_e = 273$ K

$m_v = 20\,kg$, $T_v = 278$ K

$$c_p m_v (T_v - T_z) = m_e \cdot \lambda_{tal} + c_p m_e \cdot (T_z - T_e)$$

$$-c_p m_v \cdot T_z + c_p m_v T_v = m_e \cdot \lambda_{tal} + c_p m_e T_z - c_p m_e \cdot T_e$$

$$c_p (m_v T_v + m_e T_e) - m_e \lambda_{tal} = T_z (c_p m_e + c_p m_v)$$

$$T_z = \frac{c_p (m_v T_v + m_e T_e) - m_e \cdot \lambda_{tal}}{(c_p m_e + c_p m_v)} = \frac{4200(20 \cdot 278 + 273) - 3.32 \cdot 10^5}{4200(21)} = \underline{\underline{274\ K}}$$

$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3 = \underline{\underline{13.9\ J/K}}$$

ΔS_1 – taljenje ledu; ΔS_2 – segrevanje vode, ki nastane iz ledu; ΔS_3 – ohlajanje vode

$$\underline{\underline{\Delta S_1}} = \frac{m_e \cdot \lambda_{tal}}{T_e} = \underline{\underline{1216\ J/K}}$$

$$\underline{\underline{\Delta S_2}} = m_e \cdot c_p \cdot \ln \frac{T_z}{T_e} = m_e c_p \ln \frac{274}{273} = \underline{\underline{15{,}3\ J/K}}$$

$$\underline{\underline{\Delta S_3}} = m_v \cdot c_p \ln \frac{T_z}{T_v} = m_v \cdot c_p \cdot \ln \frac{274}{278} = \underline{\underline{-1217{,}4\ J/K}}$$

5. Za koliko se spremeni entropija 1 kg ledu s temperaturo - 20°C, če ga segrevamo toliko časa, da imamo na koncu vodo s temperaturo 60°C. Talilna toplota ledu = $3,36 \cdot 10^5\ J \cdot kg^{-1}$, specifična toplota ledu je $2,1 \cdot 10^3\ J \cdot kg^{-1} \cdot K^{-1}$, $c_{p,vode} = 4200\ J \cdot kg^{-1} \cdot K^{-1}$.

FOR

$T_0 = 273\ K$, $m = 1\ kg$

$T_z = +253\ K$

$T_k = 333\ K$

q_t, c_{pe}, c_{pH_2O}

$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3$$

ΔS_1 ↑ segrevanje ledu na 0°C; ΔS_2 ↑ taljenje ledu; ΔS_3 ↑ segrevanje vode

$$\Delta S = \int_{T_1}^{T_2} \frac{c_p m\, dT}{T} = m c_p \ln \frac{T_2}{T_1}$$

$$\Delta S_1 = m c_{pe} \ln \frac{T_0}{T_z} = 158\ J/K$$

$$\Delta S_2 = \frac{m q_t}{T_0} = 1230\ J/K$$

$$\Delta S_3 = m c_{pH_2O} \ln \frac{T_k}{T_z} = 834\ J/K$$

$$\Delta S = 2223\ J/K$$

Sprememba entropije (T.D) — elektrotehnika 1991 — BNT

13. 1 mol idelanog plina (c_V= 25,12 J/mol.K, c_p= 33,44 J/mol.K) adijabatski in ireverzibilno rasteže se u vakuum od početnog stanja kod temperature 340 K i tlaka 5.10^5 Pa do konačnog stanja, gdje je zapremina dvaput veća. Odrediti promenu entropije. (R = 8300 J/K).

enoatom id. plin: $\varkappa = \frac{c_p}{c_v} = \frac{5}{3} = 1,67$

b) ADIABATNI razteg plina v vakuum:

$$A = 0, \quad Q = 0 \Rightarrow \Delta W_n = 0$$

① $T_1 = T_2 = 340\,K$

② $\Delta W_n = 0$

③ ireverzibilna je prava sprememba: $dS > \frac{dQ}{T}$ $\quad dQ \neq T\,dS \quad \leftarrow \quad dS = \frac{dQ}{T}$ reverzibilno

SPREMEMBO ENTROPIJE IZRAČUNAMO PRI NADOMESTNEM REVERZIBILNEM IZOTERMNEM RAZPENJANJU PLINA: Strnad str. 235, ker je ENTROPIJA ENOLIČNA FUNKCIJA STANJA: Strnad str. 231

$$dW_n = dQ - p\,dV$$

$$dW_n = T\,dS - p\,dV$$

$$c_v m\,dT = T\,dS - p\,dV \Rightarrow dS = c_v m \frac{dT}{T} + \frac{p}{T} dV$$

$$pV = \frac{m}{M} RT \Rightarrow \frac{p}{T} = \frac{m}{M} R \frac{1}{V}$$

$$dS = c_v m \frac{dT}{T} + \frac{m}{M} R \frac{dV}{V}$$

če $dT = 0 \Longrightarrow$

$$dS = \frac{m}{M} R \frac{dV}{V}$$

$$\Delta S = \frac{m}{M} R \int_{V_1}^{V_2} \frac{dV}{V} = \frac{m}{M} R \ln \frac{V_2}{V_1} = 5.7628\ J/K$$

0.001 8314 J/K ln 2

do tu
1 skup. EL š.l. 1996

kolokvij 90/91

ENT

2. Encatomen idealen plin v jeklenki s prostornino 1/4 litra ima pri temperaturi 20 °C tlak 10^5 Pa. Za koliko se spremeni entropija in notranja energija plina v jeklenki, če ga segrejemo na 38 °C? (M = 28 kg/kmol).

$M = 28$ kg /

$c_v = \frac{3}{2}\frac{R}{M}$

$dW_n = dQ$

$V_1 = 0.25 \cdot 10^{-3}\ m^3$

$T_1 = 293$ K

$p_1 = 10^5\ N/m^2$

$T_2 = 311$ K

$\Delta T = T_2 - T_1 = 18$ K

$$\Delta S = \int_{T_1}^{T_2} \frac{dQ}{T} = c_v \cdot m \cdot \ln \frac{T_2}{T_1} = 7{,}635 \cdot 10^{-3}\ J/K$$

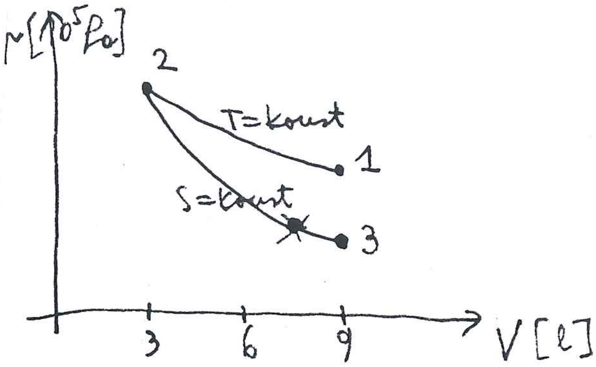
$$p_1 V_1 = \frac{m}{M} R T \Rightarrow m = \frac{p_1 V_1 \cdot M}{R \cdot T_1}$$

$$\Delta W_n = c_v \cdot m \cdot \Delta T = 2.3\ J$$

$\frac{3}{2}\frac{R}{M}$

6

5. Koliko vodne pare s temperaturo 100°C moramo napeljati v izolirano posodo v kateri je 1 kg ledu s temperaturo 0°C, da se bo ravno ves led stalil ? Za koliko se spremeni skupna entropija ?
($q_{tal} = 3{,}3\cdot 10^5$ J/kg, $q_{izp} = 2{,}27\cdot 10^6$ J/kg)



1.) T = konst

$$A = -\int p\,dV = -\int_{V_1}^{V_2} \frac{m}{M} R T_1 \frac{dV}{V} = -\frac{m}{M} R T_1 \ln\frac{V_2}{V_1}$$

$$pV = \frac{m}{M} RT$$

$$\Delta W_n = 0\ , \quad \Delta S = \frac{Q}{T_1} = -\frac{A}{T_1} = \frac{m}{M} R \ln\frac{V_2}{V_1}$$

2.) S = konst

$$\Delta W_n = \overset{=0}{Q} + A \Rightarrow$$

$$A = m c_V \Delta T = \Delta W_n = m c_V \left(T_2 \left(\frac{V_2}{V_3}\right)^{\kappa-1} - T_2\right)$$

$$T_2 V_2^{\kappa-1} = T_3 V_3^{\kappa-1}$$

$$\kappa = \frac{c_p}{c_V} = \frac{7}{5} \text{ za dvoatomen plin}$$

$$c_V = \frac{5}{2}\frac{R}{M}$$

skupaj: $$A = -\frac{m}{M} R T_1 \ln\frac{V_2}{V_1} + m\cdot\frac{5}{2}\frac{R}{M} T_2 \left(\left(\frac{V_2}{V_3}\right)^{\kappa-1} - 1\right)$$

$$p_1 V_1 = \frac{m}{M} R T_1 \qquad p_2 V_2 = \frac{m}{M} R T_2 = p_1 V_1$$

$$A = -p_1 V_1 \ln\frac{V_2}{V_1} + \frac{5}{2} p_1 V_1 \left(\left(\frac{V_2}{V_3}\right)^{\kappa-1} - 1\right) = -188\ \mathrm{J}$$

(989; -800; $\frac{1}{3}$)

$$\Delta W_n = m\cdot\frac{5}{2}\frac{R}{M} T_2 \left(\left(\frac{V_2}{V_3}\right)^{\kappa-1} - 1\right) = \frac{5}{2} p_1 V_1 \left(\left(\frac{V_2}{V_3}\right)^{\kappa-1} - 1\right) = -800 \ (\text{~~482~~})$$

$$\Delta S = \frac{m}{M} R \ln\frac{V_2}{V_1} = \frac{p_1 V_1}{T_1} \ln\frac{V_2}{V_1} = -330\ \frac{\mathrm{J}}{\mathrm{K}}$$

6. 5 molov idealnega plina v cilindru izotermno reverzibilno razpnemo od tlaka $4\cdot10^5$ Pa na tlak 10^5 Pa. Valj je v termalnem ravnovesju z okolico s temperaturo 311 K. Valj in bat sta zelo dobra prevodnika toplote. Določi spremembo notranje energije in entropije plina v batu ? Kolikšno delo opravi plin ?

1594

5 molov

$T = 311\ K$

$p_1 = 4\cdot10^5\ N/m^2$

$p_2 = 10^5\ N/m^2$

$\{\Delta W_n, \Delta S, A\} = ?$

reverzibilno

$dS = \frac{dQ}{T} \Rightarrow dQ = T\,dS$

$dW_n = dQ + dA$

$\Downarrow$

$dW_n = T\,dS + dA = c_v m\,dT = 0$

$\Downarrow$

$dA = -p\,dV \longrightarrow T\,dS = -dA = p\,dV$

$\Downarrow$

$dS = \frac{1}{T}p\,dV$

$pV = \frac{m}{M}RT$

$V = \frac{m}{M}RT\frac{1}{p}$

$\Downarrow$

$dV = -\frac{m}{M}RT\frac{1}{p^2}dp$

$\Downarrow$

$$\Delta S = -\int_{p_1}^{p_2}\frac{1}{T}\cdot p\cdot\frac{m}{M}RT\frac{1}{p^2}dp = \frac{m}{M}R\int_{p_2}^{p_1}\frac{dp}{p} \Rightarrow$$

$$\Delta S = \frac{m}{M}R\ln\frac{p_1}{p_2} = \frac{m}{M}R\ln 4 = 57.53\ J/K$$

$\Delta W_n = 0$

$T\,dS = -dA \Rightarrow \Delta A = -\frac{1}{T}\Delta S = -0.185\ J$

izpit 1991

6. Pet molov enoatomnega idealnega plina se adiabatno in ireverzibilno raztegne v vakuum na trikraten volumen. Kolikšna je sprememba entropije pri opisanem procesu ? FI

$M = (\ ) kg/kmol$

$\frac{m}{M} = \frac{5}{1000}$ kmol

$V_2 = 3V_1$

$\Delta S = ?$

ireverzibilno: $dS > \frac{dQ}{T}$

reverzibilno: $dS = \frac{dQ}{T}$

$\Delta W_n = c_v m \Delta T$

$\Delta W_n = \Delta A + \Delta Q = 0 \Rightarrow \Delta T = 0$

$\Delta A \to 0$ (ker raztegne v vakuum), $\Delta Q \to 0$ (ker adiabatno)

$T = konst$

nadomestna izotermna sprememba:

$$dS = \frac{dQ}{T}$$

$$dW_n = dQ - p\,dV$$

$$dQ = dW_n + p\,dV$$

$$dQ = c_v m\,dT + p\,dV = p\,dV \quad (c_v m\,dT = 0)$$

$$dS = \frac{p}{T}\,dV$$

$$pV = \frac{m}{M} RT \Rightarrow \frac{p}{T} = \frac{1}{V}\frac{m}{M}R$$

$$\Delta S = \frac{m}{M} \cdot R \cdot \int_{V_1}^{V_2} \frac{dV}{V} = \frac{m}{M} \cdot R \ln \frac{V_2}{V_1} =$$

$$= \frac{m}{M} \cdot R \cdot \ln 3 = 45.67 \ J/K$$

$R = 8314\ J/(kmol\,K)$

8. 4 kg helijevega plina He izotermno stisnemo, pri čemer se tlak poveča od 0,1 Pa na 4 Pa. Kolikšno delo smo morali opraviti za stiskanje plina ? Kolikšne so spremembe notranje energije, entropije in entalpije (entalpija $H = W_n + p \cdot V$) plina pri opisanem procesu ? (m_{He} = 4 a.e.m.)

(T=14K) 1992

$m = 4\ kg$

$M = 4\ kg/kmol$

T = 14 K

zač.: $p_1 = 0{,}1\ Pa$

kon.: $p_2 = 4\ Pa$

$pV = \frac{m}{M}RT \Rightarrow dV = -\frac{m}{M}RT\frac{1}{p^2}dp$

$A = -\int_{p_1}^{p_2} p\,dV = \frac{m}{M}RT \ln\frac{p_2}{p_1} = 429 \cdot 10^3\ J$

$\Delta W_n = 0$

$dW_n = 0 = dQ - p\,dV \Rightarrow dQ = p\,dV$

$\Delta S = \int \frac{dQ}{T} = \frac{1}{T}\int p\,dV = -306 \cdot 10^2\ J/K$

$dH = dW_n + d(pV) = 0 \Rightarrow \Delta H = 0$ (kjer $dW_n = 0$, $d(pV) = 0$)

T = 300 K

$p_1 = 0{,}1\ kPa$

$p_2 = 4\ kPa$

$A = 9193 \cdot 10^3\ K$

$\Delta S = -306 \cdot 10^2\ J/K$

7

kolokvij 90/91

ENT

3. V toplotno izolirani posodi zmešamo 1 kg ledu s temperaturo 0 °C in 20 kg vode s temperaturo 5 °C. Kolikšna je sprememba entropije celotnega sistema? (talilna toplota ledu 3,32.10[5] J/kg, specifična toplota vode =4200 J/kgK).

~~(q_{tal} 3,3.10[5] J/kg, c_p~~

$T_l = 273$ K , $T_v = 278$ K

$m_l = 1$ kg , $m_v = 20$ kg

$$c_p \cdot m_v (T_v - T_z) = m_l \, q_{tal} + c_p \cdot m_l \cdot (T_z - T_l)$$

⇓

$$\boxed{T_z = 274 \text{ K}}$$

$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3 = 13{,}9 \text{ J/K}$$

ΔS_1 ↓ taljenje

ΔS_2 ↓ segrevanje vode iz ledu

ΔS_3 ↓ hlajenje vode

$$\Delta S_1 = m_l \, q_{tal} / T_l = 1216 \text{ J/K}$$

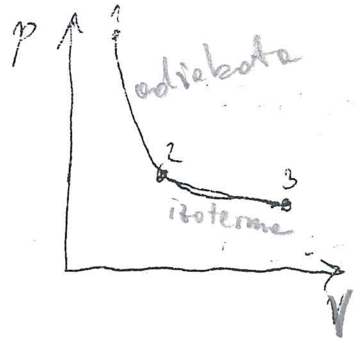
$$\Delta S_2 = m_l \cdot c_p \cdot \ln \frac{274}{273} = 15{,}39 \text{ J/K}$$

$$\Delta S_3 = m_v \cdot c_p \cdot \ln \frac{274}{278} = -1217{,}4 \text{ J/K}$$

(6)

6) Helij z molekulsko maso 4 kg/kmol je zaprt v posodi z volumnom 1 dm^3 pri tlaku 10^5 Pa in temperaturi 35° C. Najprej ga razpnemo adiabatno tako, da se volumen poveča na 2 dm^3. Iz tega stanja pa ga nato raztegnemo še izotermno tako, da je končni volumen 4 dm^3. Kolikšni sta celotni spremembi notranje energije in entropije? Razmerje specifičnih toplot je $\frac{5}{3}$. 1996

$$c_v = \frac{3}{2}\frac{R}{M}$$
$$c_p = c_v + \frac{R}{M} = \frac{5}{2}\frac{R}{M}$$
$$\varkappa = \frac{c_p}{c_v} = \frac{5}{3}$$



$M = 4\,kg/kmol$
$V_1 = 1\,dm^3$
$p_1 = 10^5\,Pa$
$T_1 = 308\,K$
$V_2 = 2\,dm^3$
$V_3 = 4\,dm^3$
$\varkappa = \frac{5}{3}$

$$p_1V_1 = \frac{m}{M}RT_1 \Rightarrow m = \frac{p_1V_1M}{RT_1}$$

adiabata

$$T_1V_1^{\varkappa-1} = T_2V_2^{\varkappa-1}$$
$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\varkappa-1} = 194\,K$$

$$\Delta W_{12} = m c_v (T_2 - T_1) =$$
$$= \frac{p_1V_1M}{RT_1}\frac{3R}{2M}T_1\left(\left(\frac{V_1}{V_2}\right)^{\varkappa-1} - 1\right) =$$
$$= \frac{3}{2}p_1V_1\left[\left(\frac{V_1}{V_2}\right)^{\varkappa-1} - 1\right] = -55{,}5\,J$$

$$\int dQ = 0 \Downarrow \Delta S_{12} = 0$$

Izoterma: $dW_n = 0 = dQ + dA \Rightarrow Q = -A_{23} \Rightarrow \Delta S_{23} = \int \frac{dQ}{T_2} = \frac{-A_{23}}{T_2}$

$$A_{23} = -\int_{V_2}^{V_3} p\,dV = -\underbrace{\frac{m}{M}RT_2}_{p_2V_2}\int_{V_2}^{V_3}\frac{dV}{V} = p_2V_2 \ln\frac{V_2}{V_3}$$

$$\Delta S_{23} = \frac{-A_{23}}{T_2} = \frac{p_2V_2}{T_2}\ln\frac{V_3}{V_2} = \frac{p_1V_1}{T_1}\cdot\ln\frac{V_3}{V_2} = 0{,}23\,J/K$$

$$\frac{m}{M}R = \frac{p_1V_1}{T_1}$$

$$\Delta W_{23} = 0$$

$$\Delta W = \Delta W_{12}$$
$$\Delta S = \Delta S_{23}$$