7. Razredčeni plin vodika (H_2) mase 10 g, temperature 27°C in volumna V_1 najprej adiabatno raztegnemo na štirikratni začetni volumen ($4 \cdot V_1$), nato pa ga izotermno stisnemo na polovični začetni volumen ($V_1/2$). Za koliko se spremeni notranja energija plina vodika pri opisanem procesu ?

14. 9

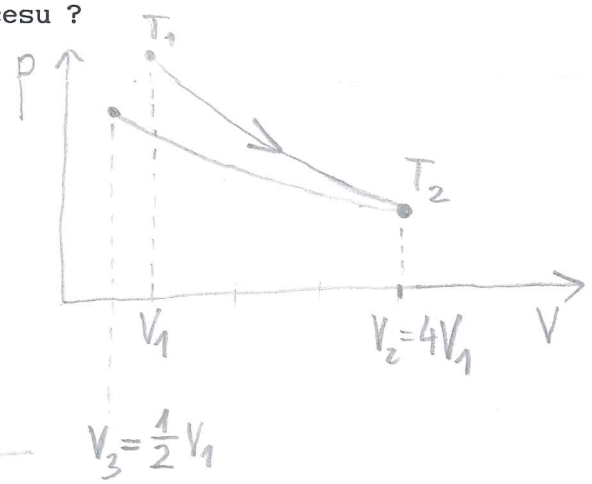
$m = 10\ g$

$T_1 = 300\ K$

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

$c_p = \frac{5}{2}\frac{R}{M} + \frac{R}{M} = \frac{7}{2}\frac{R}{M}$

$\kappa = \frac{c_p}{c_V} = \frac{7}{5} = 1.4$



$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\kappa - 1} = 172,3\ K$, $\Delta T = T_2 - T_1$

$\Delta W_n = c_V m \Delta T = \frac{5}{2}\frac{R}{M} m \Delta T = -13,27\ kJ$

1986

3. Enoatomni idealni plin pri temperaturi $T_1 = 27\ ^{\circ}C$ in tlaku $p_1 = 1,25\cdot10^6$ Pa ima volumen $V_1 = 4\cdot10^{-3}\ m^3$. Plinu izobarno dovedemo toploto $Q = 2\cdot10^4$ J. Kolikšna bosta končna temperatura in volumen plina?

4. Kolikšna je sprememba notranje energije (ΔW_n) in kolikšno delo je opravil plin (A) za izobarno spremebno stanja enoatomnega idelanega plina, ki je opisana pri prejšnji nalogi ?

$T_1 = 300\ K$

$p_1 = 1,25\cdot10^6\ Pa$

$V_1 = 4\cdot10^{-3}\ m^3$

$Q = 2\cdot10^4\ J$

$T_2, V_2, \Delta W_n, A$

$$c_p = c_v + \frac{R}{M} = \frac{3}{2}\frac{R}{M} + \frac{R}{M} = \frac{5}{2}\frac{R}{M} \quad (1.\ at.\ plin)$$

$p = konst. \quad p_1 = p_2$

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

$$\Delta T = \frac{Q}{m c_p} = \frac{Q R T_1 2 M}{p_1 V_1 M 5 R} = \frac{2 Q T_1}{5 p_1 V_1} = 481\ K$$

$$T_2 = T_1 + \Delta T = 781\ K = 508^{\circ}C$$

$$\frac{T_1}{V_1} = \frac{T_2}{V_2} \Rightarrow V_2 = \frac{T_2}{T_1} V_1 = 1,04\cdot10^{-2}\ m^3$$

3.

$$\Delta W_n = c_v m \Delta T = \frac{3}{2}\frac{R}{M}\frac{p_1 V_1 M}{R T_1}\Delta T = \frac{3}{2}\frac{p_1 V_1}{T_1}\Delta T = 1,2\cdot10^4\ J$$

$$\Delta W_n = A + Q \Rightarrow A = \Delta W_n - Q = -8000\ J$$

$$A = -\int_{V_1}^{V_2} p\, dV = p(V_1 - V_2)$$

4

1992

1. 5 g dvoatomnega idealnega plina reverzibilno in adiabatno stisnemo iz začetnega stanja pri temperaturi 20 ^{o}C in volumnu 6 dm^{3} na petkrat manjši končni volumen. Kolikšno delo moramo opraviti pri tem ? (M = 28 kg/kmol) A-L

OT.

2. Kolikšen je končni tlak pri adiabatni spremembi, ki je opisana pri prejšnji nalogi ? Kolikšna pa je sprememba entropije in notranje energije plina ? A-L

$m = 5\,g$, $M = 28\,kg/kmol$

$T_1 = 293\,K$

$V_1 = 6 \cdot 10^{-3}\,m^3$

$V_2 = V_1/5$

$c_v = \frac{5}{2}\frac{R}{M}$, $c_p = \frac{7}{2}\frac{R}{M}$

$\varkappa = \frac{c_p}{c_v} = \frac{7}{5} = 1.4$

(1) $Q = 0 \Rightarrow A = \Delta W_n = c_v m \Delta T = \frac{5}{2}\frac{R}{M} m (T_2 - T_1) = 981.2\,J$

$T_1 V_1^{\varkappa-1} = T_2 V_2^{\varkappa-1} \Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\varkappa-1} = T_1 \cdot 5^{0.4} = 557.8\,K$

$A = -\int_{V_1}^{V_2} p\,dV = \left[+p_1 V_1^{\varkappa} \frac{1}{\varkappa-1}\right] V^{(1-\varkappa)}\Big|_{V_1}^{V_2}$

(2) $p_1 V_1^{\varkappa} = p_2 V_2^{\varkappa} \Rightarrow p_2 = p_1 \left(\frac{V_1}{V_2}\right)^{\varkappa} = \frac{1}{V_1}\frac{m}{M} R T_1 (5)^{\varkappa} = 6{,}89 \cdot 10^{5}\,Pa$

$p_1 = \frac{1}{V_1}\frac{m}{M} R T_1$

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

$\Delta W_n = A = 981.2\,J$

1992

6. V cilindru preseka 1 cm^2 je z batom mase 0,3 kg zaprt enoatomen plin z volumnom 2 dm^3. Bat in stene posode so toplotno izolirani. Bat se lahko giblje po cilindru skoraj brez trenja. Zunanji tlak je 10^5 Pa. Kolikšen je nihajni čas bata pri majhnih odmikih ? Cilinder je postavljen vertikalno. $g = 10\ \mathrm{m\,s^{-2}}$

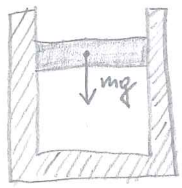
$S = 10^{-4}\ \mathrm{m^2}$

$m = 0{,}3\ \mathrm{kg}$

$V_0 = 2 \cdot 10^{-3}\ \mathrm{m^3}$

$p_0 = 10^5\ \mathrm{Pa}$

$t_0 = ?$



$p_{n0} S = p_0 S + mg$

$\Downarrow$

$$p_{n0} = p_0 + \frac{mg}{S}$$

enoatomen plin : $c_v = \frac{3}{2}\frac{R}{M}$, $c_p = \frac{5}{2}\frac{R}{M}$ $\Big|$ $\varkappa = \frac{c_p}{c_v} = \frac{5}{3} = 1{,}66$

$$pV^{\varkappa} = \text{konst.}$$

$\Delta V = S x \qquad x \ll 1$

$\Downarrow$

$$p \varkappa V^{\varkappa - 1} dV + V^{\varkappa} dp = 0 \Rightarrow \Delta p = -\frac{p \varkappa V^{\varkappa-1}}{V^{\varkappa}} = -\frac{p\varkappa}{V}\Delta V$$

$$= -\varkappa \frac{p_{n0}}{V_0} S x$$

$$m\ddot{x} = S \Delta p = -\varkappa \frac{p_{n0}}{V_0} S^2 x$$

$$\ddot{x} = -\underbrace{\varkappa \frac{p_{n0} \cdot S^2}{m V_0}}_{\left(\frac{2\pi}{t_0}\right)^2} \cdot x$$

$\Downarrow$

$$t_0 = 2\pi \cdot \sqrt{\frac{m V_0}{\varkappa \cdot p_{n0} \cdot S^2}} = 2\pi \sqrt{\frac{m V_0}{\varkappa \cdot S^2 \left(p_0 + \frac{mg}{S}\right)}} = 3.31\,\mathrm{s}$$

SED

1TD, 19

Toplota - dolo pri izotermnem stiskanju

1.1

3) Koliko dela opravimo, čeizotermno stisnemo 5 kg idealnega plina z molsko maso 29 kg.kmol^{-1} pri temperaturi 0^{o}C od tlaka 10^{5}N.m^{-2} na 5.10^{5} N.m^{-2}. (Splošna plinska konstanta R = 8,3.10^{3} J.kmol^{-1}.K^{-1}).

$$A = \int_{V_2}^{V_1} p\,dV$$ pri izotermni spremembi velja:

$$pV = mRT = p_1V_1 \quad \text{ali} \quad p = \frac{mRT}{V}$$ zato dobimo

$$A = mRT \int_{V_2}^{V_1} \frac{1}{V}\,dV = mRT \ln\frac{V_1}{V_2}$$

$$A = mRT \ln\frac{V_1}{V_2} = p_1V_1 \ln\frac{V_1}{V_2} = p_1V_1 \ln\frac{p_2}{p_1}$$

$$= -p_1V_1 \ln\frac{V_2}{V_1}$$

$$A = mRT \ln\frac{V_1}{V_2}$$
$$A = -mRT \ln\frac{V_2}{V_1}$$

$$A = mRT \ln\frac{p_2}{p_1}$$
$$A = -mRT \ln\frac{p_1}{p_2}$$

$$A = mRT \ln\frac{p_2}{p_1} = \frac{5\,kg \cdot kmol \cdot 8{,}3 \cdot 10^{3}\,J \cdot 273\,K \cdot 1{,}6094}{29\,kg \cdot kmol \cdot K} = 6{,}287 \cdot 10^{5}\,J$$

$\ln 5 = 1{,}6094$

$6{,}287 \cdot 10^{5}$

$62{,}87 \cdot 10^{4}$

$6{,}287 \cdot 10^{5} = 628700$

$62{,}87 \cdot 10^{4} = 628700$

rupert 1991 FIZIKA I

1. Liter idealnega dvoatomnega plina s temperaturo 0°C pri tlaku 10^5 Pa izredno hitro stisnemo na polovico začetne prostornine. Plin nato pri konstantnem tlaku počasi ohladimo nazaj na temperaturo 0°C. Kakšna je končna prostornina plina ? Nekateri podatki so odveč! FI

$V_3 = ?$, $V_1 = 10^{-3}\ m^3$

dvoatomni plin:

$$\chi = \frac{c_p}{c_V} = 1.4$$

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

adiabata:

$$V_1, T_1 \longrightarrow \frac{V_1}{2}, T_2 \Rightarrow \frac{T_1}{T_2} = \left(\frac{V_1/2}{V_1}\right)^{\chi-1}$$

p = konst.:

$$\frac{V_1}{2}, T_2 \longrightarrow V_3, T_1 \Rightarrow \frac{T_1}{V_3} = \frac{T_2}{(V_1/2)}$$

$$\Downarrow$$

$$V_3 = \frac{T_1}{T_2} \cdot \frac{V_1}{2} = \left(\frac{1}{2}\right)^{\chi-1} \cdot \left(\frac{V_1}{2}\right) = \left(\frac{1}{2}\right)^{\chi} \cdot V_1 =$$

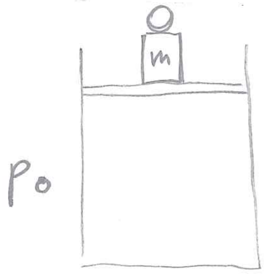
$$= 0{,}379 \cdot 10^{-3}\ m^3$$

1992

1. Valjasto posodo, napolnjeno z enoatomnim plinom, zapira zelo lahek in tanek bat. Temperatura plina je enaka temperaturi zraka zunaj posode, ki je enaka 20°C. Presek posode je 1 dm^2, bat pa miruje 1 m nad dnom. Na bat položimo utež z maso 10 kg. Za koliko centimetrov se premakne bat takoj, ko položimo utež na bat ? Kolikšno delo opravi utež na plinu v tem kratkem času ? Stene posode niso izolirane. Zunanji zračni tlak je $p_0 = 10^5$ Pa.

2. Nadaljavanje 1. naloge :

Za koliko centimetrov pa se še premakne bat v primeru, če počakamo dalj časa? Kolikšna je skupna končna sprememba notranje energije plina v batu potem, ko se bat spusti na svojo končno ravnovesno višino ? Čas štejemo od trenutka, ko položimo utež na bat. Plin v batu obravnavamo kot idealni plin.



$p_0 = 10^5$ Pa

$S = 10^{-2}\,m^2$

$T_0 = 293\,K$

$\kappa = 1{,}66$

$m = 10\,kg$

$l_0 = 1\,m$

$g = 10\,ms^{-2}$

$$p_1 = p_0 + \frac{mg}{S}$$

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

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

$$\kappa = \frac{c_p}{c_v} = \frac{5}{3} = 1{,}66$$

(1)

$$p_0 V_0^{\kappa} = p_1 V_1^{\kappa}$$

$$V_0 = S \cdot l_0 \qquad V_1 = S \cdot l_1$$

$$l_1 = l_0 \left(\frac{p_0}{p_1}\right)^{1/\kappa} = l_0 \left[\frac{p_0}{p_0 + \frac{mg}{S}}\right]^{1/\kappa} = 0{,}944\,m$$

$$\Rightarrow \Delta h = 5{,}6\ cm \quad ✓$$

$$Q = 0 \Rightarrow A = \Delta W_n = c_v m \Delta T = \frac{3}{2}\frac{R}{M}\left(\frac{p_0 V_0}{T_0}\frac{M}{R}\right)\Delta T = \frac{3}{2}\frac{p_0 V_0}{T_0}(T_1 - T_0) \Rightarrow$$

$$p_0 V_0 = \frac{m}{M} R T_0 \Rightarrow m = \frac{p_0 V_0 M}{T_0 R}$$

$$A = 58.15\ J \quad ✓$$

$$T_0 V_0^{\kappa-1} = T_1 V_1^{\kappa-1} \Rightarrow T_1 = T_0 \left(\frac{V_0}{V_1}\right)^{\kappa-1} = T_0 \left(\frac{l_0}{l_1}\right)^{\kappa-1} = 304.36\ K \quad ✓$$

(2)

$$p_0 V_0 = p_1 \tilde{V}_1 \Rightarrow \tilde{l}_1 = l_0 \frac{p_0}{p_1} = l_0 \cdot \frac{p_0}{p_0 + \frac{mg}{S}} = 0{,}91\ m \quad ✓$$

$$\Rightarrow \Delta \tilde{h} = 9\ cm \quad ✓$$

$$\Delta W_n = c_v m \Delta T = 0 \quad ✓$$

$$A = -\int_{V_1}^{V_2} p\,dV = +\left[p_1 V_1^{\kappa} \frac{1}{\kappa - 1} V^{(1-\kappa)}\right]_{V_1}^{V_2}$$

6. 3 g enoatomnega idealnega plina adiabatno razpnemo iz začetnega stanja pri tlaku 10^5 Pa in volumnu 6 dm^3 na trikrat večji končni volumen. Kolikšno delo opravi plin ? (M = 12 kg/kmol)

$m = 3 g$

$p_1 = 10^5 Pa$

$V_1 = 6 \cdot 10^{-3} m^3$

$V_2 = 3 V_1$

$M = 12 kg/kmol$

$A = ?$

$$\left\{ \begin{array}{l} c_v = \frac{3}{2}\frac{R}{M} \\ c_p = c_v + \frac{R}{R} = \frac{5}{2}\frac{R}{M} \end{array} \right\} \Rightarrow \kappa = \frac{c_p}{c_v} = \frac{5}{3} = 1,66$$

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

$$T_1 V_1^{\kappa-1} = T_2 V_2^{\kappa-1} \Rightarrow T_2 = T_1 \cdot \left(\frac{V_1}{V_2}\right)^{\kappa-1} = 139 \text{ K}$$

$$A = \Delta W_n = c_v m \Delta T = \frac{3}{2}\frac{R}{M} \cdot m \cdot (T_2 - T_1) = -467 \text{ J}$$

-3

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

6. Oceni delo pare in spremembo notranje energije pri izparitvi 1 kg vode pri 100°C in konstantnem tlaku 10^5 Pa. Izparilna toplota vode je $2{,}26 \cdot 10^6$ J·kg^{-1}. Paro obravnavamo kot idealni plin.

FOR

$m = 1\,kg$ $\quad M_{H_2O} = 18\,kg/kmol$

$T = 373\,K$

$p = 10^5\,Pa$

$\underline{q_i = 2{,}26 \cdot 10^6\,J/kg}$

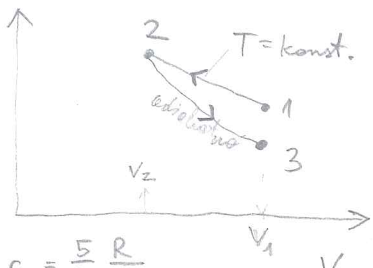
$$pV = \frac{m}{M} RT \Rightarrow V = \frac{m}{M \cdot p} \cdot R \cdot T = \underline{\underline{1{,}72\,m^3}}$$

$$A = -p\Delta V = -pV = \underline{\underline{-1{,}72 \cdot 10^5\,J}}$$

$$\underline{\underline{\Delta W_n}} = Q_{izp} - p\Delta V = 2{,}26 \cdot 10^6\,J - 0{,}172 \cdot 10^6\,J = \underline{\underline{2{,}08 \cdot 10^6\,J}}$$

2. 9 l kisika O_2 pri T = 300 K in p = 10^5 Pa izotermno stisnemo na prostornino 3 l, potem pa adiabatno razpnemo nazaj na prostornino 9 l. Prikažite ta proces na pV diagramu. Izračunajte delo, ki ga opravimo, spremembo notranje energije in spremembo entropije plina. Molska masa kisika O_2 : M_{O_2} = 32 kg/kmol.

$$\left.\begin{array}{l} p_1 = 10^5\ \text{Pa},\ V_1 = 9\cdot 10^{-3}\ \text{m}^3 \\ T_1 = 300\ \text{K} \\ V_2 = 3\cdot 10^{-3}\ \text{m}^3 \end{array}\right\} T = \text{konst} \qquad M = 32\ \text{kg/kmol}$$



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

dvoatomni plin: $\varkappa = \frac{c_p}{c_v} = \frac{7}{5} = 1.4$, $c_v = \frac{5}{2}\frac{R}{M}$ $\qquad pV = \frac{m}{M}RT$

① T = konst.

$$A_1 = -\int_{V_1}^{V_2} p\,dV = -\int_{V_1}^{V_2} \frac{m}{M}RT_1\frac{dV}{V} = \frac{m}{M}RT_1 \ln\frac{V_1}{V_2} = p_1V_1 \ln\frac{V_1}{V_2} = \underline{989\ \text{J}}$$

$\boxed{\Delta W_n = Q + A = 0}$, $\quad \Delta S = \frac{Q}{T_1} = \frac{-A}{T_1} = \underline{-3.3\ \text{J/K}}$

② S = konst.

$$\Delta W_n = Q^{=0} + A \Rightarrow \Delta W_n = A_2 = c_v m \Delta T = \frac{5}{2}\frac{R\cdot m}{M}(T_2 - T_1) =$$

$$T_1 V_2^{\varkappa-1} = T_2 V_1^{\varkappa-1} \qquad = \frac{5}{2}\frac{Rm}{M}T_1\left[\left(\frac{V_2}{V_1}\right)^{\varkappa-1} - 1\right] =$$

$$T_2 = T_1\left(\frac{V_2}{V_1}\right)^{\varkappa-1} \qquad \left(\frac{Rm}{M}T_1 = p_1V_1\right)$$

$$= \frac{5}{2}p_1V_1\left[\left(\frac{V_2}{V_1}\right)^{\varkappa-1} - 1\right] = \underline{-800\ \text{J}}$$

skupaj:

$A = A_1 + A_2 = \underline{189\ \text{J}}$

$\Delta W_n = \underline{-800\ \text{J}}$

$\Delta S = \underline{-3{,}3\ \text{J/K}}$

4. Dva litra dvoatomnega idealnega plina s temperaturo 20°C in tlakom 10^5 Pa adiabatno stisnemo na polovično prostornino. Koliko dela pri tem opravimo ? Kolikšna je sprememba notranje energije plina ?

1993

$V_1 = 2 \cdot 10^{-3}\,m^3$, $p_1 = 10^5\,Pa$, $T_1 = 293\,K$

$V_2 = V_1/2 = 10^{-3}\,m^3$

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

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

$T_2 = T_1 (2)^{\kappa-1} = 293 \cdot 2^{0.4} = 386.6\,K$

$\Delta W_n = Q + A$, $Q = 0 \Rightarrow \Delta W_n = A = c_v m \Delta T$

$\Delta T = 93.6$

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

$= \frac{5}{2} \cdot \left(\frac{p_1 V_1}{T_1}\right)(T_2 - T_1) = \frac{5 \cdot 10^5 \cdot 2 \cdot 10^{-3} \cdot 93.6}{2 \cdot 293} = \frac{10^{+3}}{2 \cdot 273} = 160\,J$

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

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

$\kappa = \frac{c_p}{c_v} = \frac{7}{5} = 1.4$