Неделя 3.

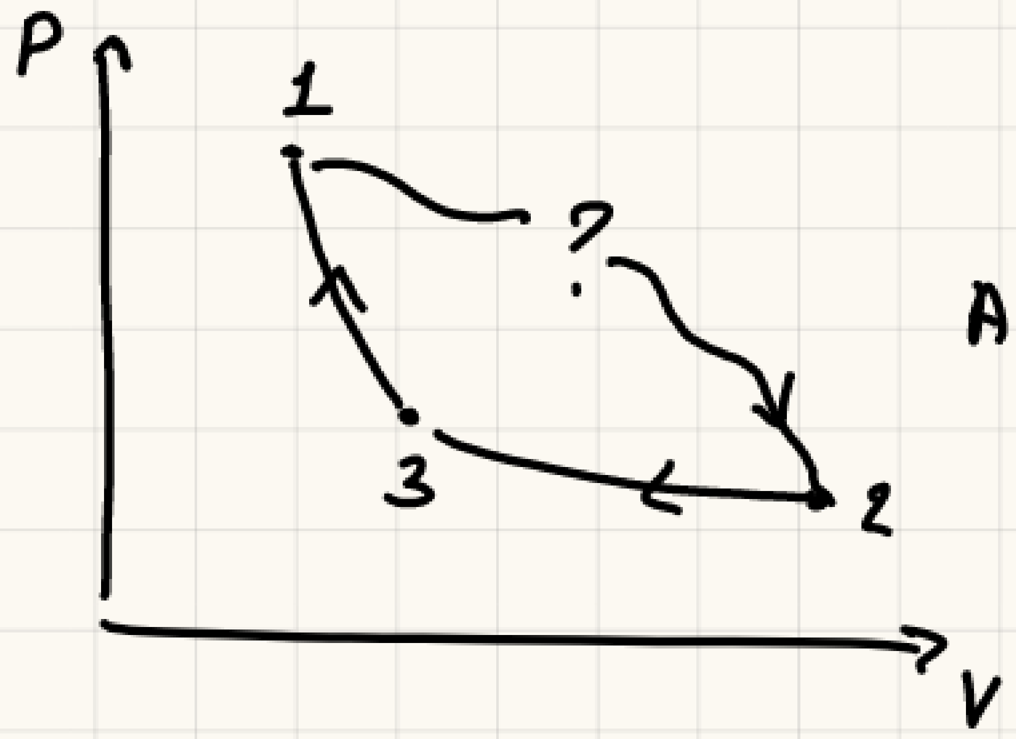
Изменение энтропии в необр. процессах
Термодинамические потенциалы

4.47

$\nu = 10$ моль
$i = 3$

$T_1 = 300K$
$T = 200K$
$A = 15$ кДж

$\Delta S - ?$



1-2: необр. расш. в пустой сосуд без подвода и отдачи тепла

A [2-3: изотерм. сжатие
3-1: адиабат. сжатие

2-3: $TdS = dU + PdV \overset{dU=0}{=\!=} PdV = dA \; ; \; TdS = dA$

$$A_{23} = T_2(S_3 - S_2) = -T\Delta S$$

3-1: $S_1 = S_3$

$$Q_{31} = A_{31} + \Delta U_{31} = 0 ; \quad A_{31} = \frac{3}{2}\nu R(T_1 - T_3) = \frac{3}{2}\nu R(T_1 - T)$$

2-3-1: $A = A^{ext} = -(A_{23} + A_{31})$

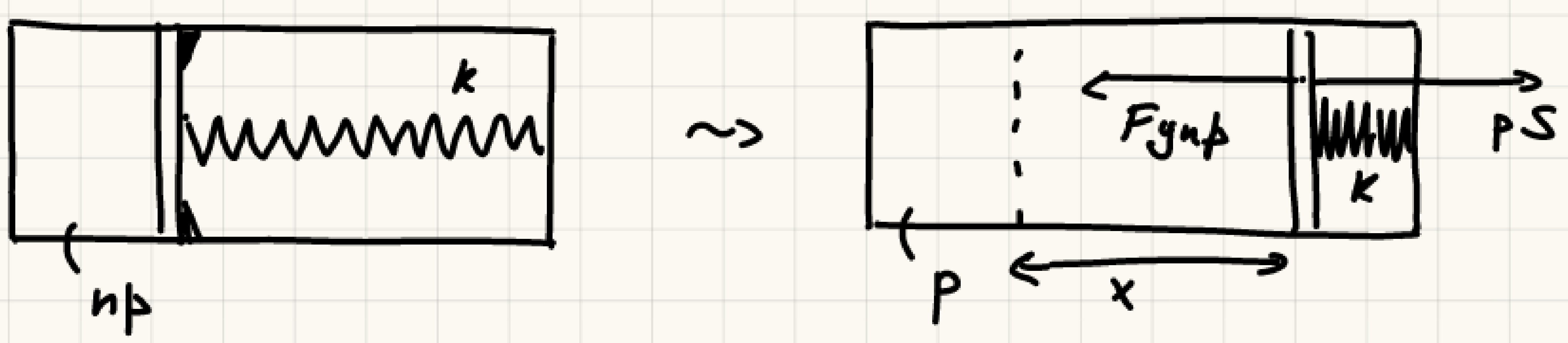
$$A_{23} = -A - A_{31} = -A - \frac{3}{2}\nu R(T_1 - T)$$

$$\Delta S = -\frac{A_{23}}{T} = \frac{A + \frac{3}{2}\nu R(T_1 - T)}{T} \approx 137 \frac{Дж}{K}$$

T-3

$\nu = 1$ моль
$i = 5$, иг } N_2

$n = 3$
$nP \to P$



$$\Delta S = \nu R \ln\frac{V_2}{V_1} + \nu \underbrace{c_V}_{\frac{5}{2}R} \ln\frac{T_2}{T_1} = \nu R\left(\ln\frac{V_2}{V_1} + \frac{5}{2}\ln\frac{T_2}{T_1}\right)$$

Пусть жесткость пружины — k.

$PS = kx \quad | \cdot x$

$$P\Delta V = kx^2 = k\left(\frac{\Delta V}{S}\right)^2$$

Ур-е состояния:

$$\left.\begin{aligned} nPV_1 &= \nu RT_1 \\ P(V_1+\Delta V) &= \nu RT_2 \end{aligned}\right\}: \quad \frac{T_2}{T_1} = \frac{V_1+\Delta V}{nV_1}; \quad n\frac{T_2}{T_1} = 1+\frac{\Delta V}{V_1}; \quad \Delta V = V_1\left(n\frac{T_2}{T_1}-1\right)$$

Теплоизоляция:

$$\nu c_V (T_1-T_2) = \frac{kx^2}{2} = \frac{k\Delta V^2}{2S^2} = \frac{1}{2}P\Delta V$$

$$5\underbrace{\nu RT_1}_{n\cancel{PV_1}}\left(1-\frac{T_2}{T_1}\right) = \cancel{PV_1}\left(n\frac{T_2}{T_1}-1\right)$$

$$5n - 5n\frac{T_2}{T_1} = n\frac{T_2}{T_1} - 1$$

$$5n+1 = 6n\frac{T_2}{T_1}$$

$$\frac{T_2}{T_1} = \frac{5n+1}{6n} \overset{n=3}{=\!=\!=} \frac{\cancel{16}8}{\cancel{18}\cdot 3} = \frac{8}{9}$$

$$\frac{V_2}{V_1} = \frac{V_1+\Delta V}{V_1} = n\frac{T_2}{T_1} = 3\cdot\frac{8}{9} = \frac{8}{3}$$

$$\Delta S = \nu R\left(\ln\frac{V_2}{V_1} + \frac{5}{2}\ln\frac{T_2}{T_1}\right) = \nu R\left(\ln\frac{8}{3} + \frac{5}{2}\ln\frac{8}{9}\right) = 7{,}15\ \frac{Дж}{К}$$

5.32

$\nu = 1$ моль

$\Psi = -\frac{RT}{2}\ln(AT^3V^2)$

$c_p - ?$

$$S = -\left(\frac{\partial\Psi}{\partial T}\right)_V = -\frac{R}{2}\ln(AT^3V^2) + \frac{RT}{2}\frac{AV^2\cdot 3T^2}{AT^3V^2} = \frac{R}{2}\ln(AT^3V^2) + \frac{3}{2}R$$

$$P = -\left(\frac{\partial\Psi}{\partial V}\right)_T = \frac{RT}{\cancel{2}}\frac{1}{\cancel{AT^3V^2}}\cdot\cancel{AT^3\cdot 2}V = \frac{RT}{V} \Rightarrow V = \frac{RT}{P}$$

$$S = \frac{R}{2}\ln\left(AT^3\frac{R^2T^2}{P^2}\right) + \frac{3}{2}R = \frac{R}{2}\ln\left(\frac{AR^2T^5}{P^2}\right) + \frac{3}{2}R$$

$$c_p = T\left(\frac{\partial S}{\partial T}\right)_P = \cancel{T}\left(\frac{R}{2}\frac{\cancel{P^2}}{\cancel{AR^2T^5}}\cdot\frac{\cancel{AR^2}}{\cancel{P^2}}\cdot 5\cancel{T^4}\right) = \frac{5}{2}R$$

5.54

$f = \alpha T\left(\frac{L}{L_0} + \left(\frac{L_0}{L}\right)^2\right)$

$\alpha = 0{,}013\ \frac{Н}{К}$

$L_0 = 1м$

$(T_1 = 300К)$

1-2: $T = const$ растяжение до $L = 2м$

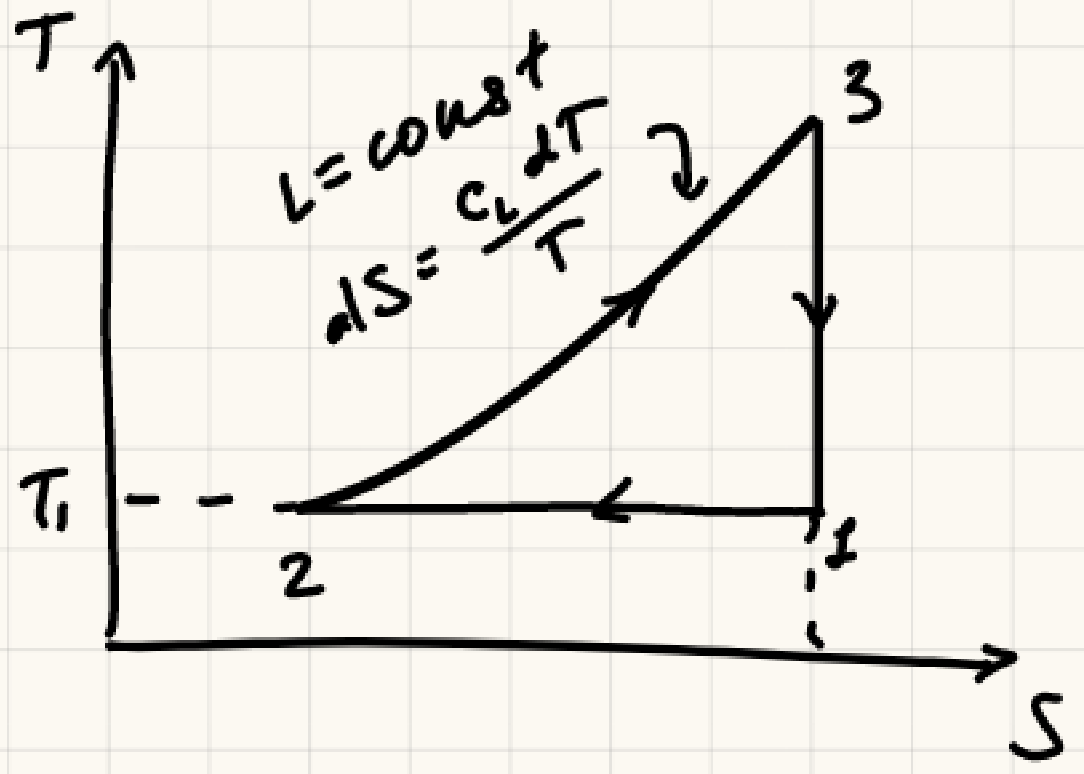
2-3: $L = const$ нагревание

3-1: $Q = 0$ сокращ. длины до L_0

• изобразить на $T(S)$ $\qquad$ $c_L = 1,2\ \frac{\text{Дж}}{\text{К}}$ (не зависит от T и ΔL)

• $Q_{\text{погл}}$ − ?, $Q_{\text{отд}}$ − ?

$\quad = Q^{\swarrow} \qquad\quad = Q^{\nearrow}$



1 − 2: $dS = -\left(\frac{\partial f}{\partial T}\right)_L dL$ $\quad (T = const)$

$$\Delta S_{12} = -\int_{L_0}^{L}\left(\frac{\partial f}{\partial T}\right)_L dL = -a\int_{L_0}^{L}\left(\frac{L}{L_0} - \frac{L_0^2}{L^2}\right)dL =$$

$$= -a\left(\frac{L^2}{2L_0} + \frac{L_0^2}{L} - \frac{3}{2}L_0\right) = -0{,}013\ \frac{\text{Дж}}{\text{К}}$$

$$\Delta Q_{12} = T_1 \Delta S_{12} = \underline{\underline{-3{,}9\ \text{Дж}}} = Q^{\nearrow}$$

2 − 3: $\Delta S_{23} = c_L \ln\frac{T_3}{T_1} = -\Delta S_{12}$; $\quad \left(\frac{T_3}{T_1}\right)^{c_L} = e^{-\Delta S_{12}}$; $\quad T_3 = T_1 e^{-\frac{\Delta S_{12}}{c_L}} = 303{,}26\ \text{К}$

$$\Delta Q_{23} = c_L(T_3 - T_1) = \underline{\underline{3{,}92\ \text{Дж}}} = Q^{\swarrow}$$

№7

теплоизол.

$m = 10$ г (H_2, ИГ)

$V \to 2V$

ΔS − ?

$$\underline{\underline{\Delta S}} = \nu c_v \ln\cancel{\frac{T'}{T}} + \nu R \ln\frac{2V}{V} = \frac{m}{M}R\ln 2 \approx \underline{\underline{28{,}8\ \text{Дж/К}}}$$

№8

$m = 90$ г

$M = 330$ г

$T_0 = 273$ К

$T_1 = 373$ К

$\lambda = 330$ Дж/г

$c_{Al} = 0{,}9\ \frac{\text{Дж}}{\text{г}\cdot\text{К}}$

$c_B = 4{,}18\ \frac{\text{Дж}}{\text{г}\cdot\text{К}}$

ΔS − ?

$$\underbrace{m\lambda + c_B m(T - T_0)}_{Q\ \text{отд}} = \underbrace{c_{Al} M(T_1 - T)}_{Q\ \text{получ}}$$

$$T = \frac{c_{Al} M T_1 + c_B m T_0 - m\lambda}{M c_{Al} + m c_B} = 273\ \text{К} = T_0$$

$$\Delta S_{Al} = \int_{T_1}^{T}\frac{c_{Al} M\, dT}{T} = c_{Al} M \ln\frac{T_0}{T_1} \approx -92{,}7\ \frac{\text{Дж}}{\text{К}}$$

$$\Delta S_\lambda = \frac{m\lambda}{T_0} \approx 108{,}8\ \frac{\text{Дж}}{\text{К}}$$

$$\rightarrow \underline{\underline{\Delta S}} = \Delta S_\lambda + \Delta S_{Al} \approx \underline{\underline{16{,}1\ \frac{\text{Дж}}{\text{К}}}}$$

9

ΔF - ?

ΔG - ?

$m = 1кг$

$T = 298 K$

$P_1 = 1 мбар$

$P_2 = 2 мбар$

$P_1 \to P_2$

$$F = U - TS = \nu c_v T - TS = (\nu c_v - S)T$$

$$G = U - TS + PV = U - T + \nu RT = (\nu c_v - S + \nu R)T = (\nu c_p - S)T$$

$$V = \frac{\nu RT}{P}$$

$$S = \nu c_v \ln T + \nu R \ln V + C$$
$$= \nu c_v \ln T + \nu R \ln T - \nu R \ln p + C =$$
$$= \nu c_p \ln T - \nu R \ln P + C$$

изотерм.:

$$\Delta F = T(S_1 - S_2) = \nu R \ln \frac{P_2}{P_1} = \frac{m}{\mu} R \ln \frac{P_2}{P_1}$$

$$\Delta G = T(S_1 - S_2)$$