Неделя 1.

Первое начало термодинамики. Теплоёмкость. Адиабатический и политропический процесс.

№1

$p, V = const$

$T_1 \to T_2$

$\Delta U - ?$

количество вещества в комнате изменилось

$pV = \nu_1 RT_1 = \nu_2 RT_2$; $\nu_1 T_1 = \nu_2 T_2$; $\nu_2 = \nu_1 \frac{T_1}{T_2}$

$\Delta U = \frac{i}{2}\nu_2 RT_2 - \frac{i}{2}\nu_1 RT_1 = \underline{\underline{0}}$

№2

$V_0 \to V_1 = 2V_0$

$T = const$

$T = 25°C = 298 K$

$\nu = 1$ моль

пусть p, V – в произв. момент

$\nu RT = p_0 V_0 = pV$; $p = \nu RT \cdot \frac{1}{V}$

$\delta A = p\,dV = \nu RT \frac{dV}{V}$

$A = \nu RT \int_{V_0}^{V_1} \frac{dV}{V} = \underline{\underline{\nu RT \ln \frac{V_1}{V_0}}} = 1 \cdot 8{,}314 \cdot 298 \cdot \ln 2 =$

$\underline{\underline{= 1{,}72 \text{ кДж}}}$

№3

$T = 273 K$

$\Delta T = 1 K$

$\Delta c_{зв} - ?$ (скорость звука)

$c_{зв} = \sqrt{\frac{\gamma RT}{\mu}}$; $dc_{зв} = \sqrt{\frac{\gamma R}{\mu}} \frac{dT}{2\sqrt{T}} = \underline{\underline{\frac{1}{2}\sqrt{\frac{\gamma R}{\mu}} \frac{dT}{\sqrt{T}}}}$

$\Delta c_{зв} \approx dc_{зв}(T) = \frac{1}{2}\sqrt{\frac{1{,}4 \cdot 8{,}314}{28{,}8 \cdot 10^{-3}}} \frac{1}{\sqrt{273}} = \underline{\underline{0{,}61 \frac{м}{с}}}$

1.100

$\nu = 1$ моль

$i = 5$

$\delta Q^{\nearrow} = 2dU$

p_1

$2V \to V$

$p_2 - ?$

$|\delta Q| = 2dU$

$U = \frac{i}{2}\nu RT$; $dU = \frac{i}{2}\nu R dT$

$\delta Q = \delta A + dU = p dV + \frac{i}{2}\nu R dT = -\frac{2i}{2}\nu R dT$

$p dV + \frac{15}{2}(p dV + V dp) = 0$

$\frac{17}{2} p dV + \frac{15}{2} V dp = 0$

$17 \frac{dV}{V} = -15 \frac{dp}{p}$

$17 \ln \frac{V_2}{V_1} = -15 \ln \frac{p_2}{p_1}$

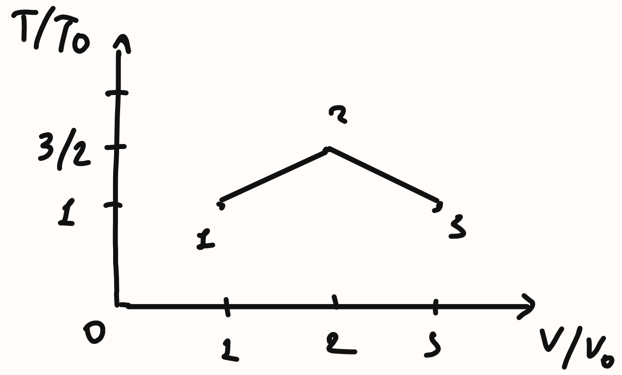
$$\cancel{f}\,17\ln 2 = \cancel{f}\,15 \ln\frac{p_2}{p_1}$$

$$\underline{\underline{p_2 = p_1 \cdot 2^{\frac{17}{15}} = 2{,}15\ p_1}}$$

T-1.

$\nu = 1$ моль

$\Delta C\ (б\ т.2) - ?$



$1 \to 2:$

$$\delta Q = C_{12}\,dT = dU + p\,dV =$$
$$= \frac{i}{2}\nu R\,dT + \nu RT\frac{dV}{V}$$

$1 \to 2$ (продолжение):

$$\frac{dT}{dV} = \frac{1/2}{1} = \frac{1}{2};$$

$$\frac{T}{T_0} = \frac{1}{2} + \frac{1}{2}\frac{V}{V_0}$$
$$2\frac{T}{T_0} - 1 = \frac{V}{V_0}$$
$$V = V_0\left(2\frac{T}{T_0} - 1\right)$$
$$dV = V_0\left(2\frac{dT}{T_0}\right) = \frac{2V_0}{T_0}\,dT$$

$$\delta Q = C_{12}\,dT = \frac{i}{2}\nu R\,dT + \nu RT\,\frac{\frac{2\cancel{V_0}}{T_0}\,dT}{\cancel{V_0}\left(\frac{2T - T_0}{\cancel{T_0}}\right)} =$$

$$= \nu R\left(\frac{i}{2}\,dT + \frac{2T\,dT}{2T - T_0}\right)$$

$$C_{12}(T) = \nu R\left(\frac{i}{2} + \frac{2T}{2T - T_0}\right)$$

$$\frac{T}{T_0} = \frac{5}{2} - \frac{1}{2}\frac{V}{V_0}$$
$$V = V_0\left(5 - 2\frac{T}{T_0}\right)$$
$$dV = V_0\left(-2\frac{dT}{T_0}\right) = -\frac{2V_0}{T_0}\,dT$$

$2 \to 3:$

$$C_{23}(T) = \nu R\left(\frac{i}{2} + T\,\frac{-\frac{2\cancel{V_0}}{\cancel{T_0}}}{\frac{\cancel{V_0}}{\cancel{T_0}}(5T_0 - 2T)}\right) =$$
$$= \nu R\left(\frac{i}{2} - \frac{2T}{5T_0 - 2T}\right)$$

$$\underline{\underline{\Delta C}} = C_{23}(T) - C_{12}(T) = \nu R\left(-\frac{2T}{5T_0 - 2T} - \frac{2T}{2T - T_0}\right) \quad \underline{\underline{T = \tfrac{3}{2}T_0}}$$

$$= -\nu R \cdot 3\cancel{T_0}\left(\frac{1}{2\cancel{T_0}} + \frac{1}{2\cancel{T_0}}\right) = \underline{\underline{-3\nu R}} \overset{\nu = 1\text{ моль}}{=\!=} \underline{\underline{-3R}}$$

1.75

$He : H_2 = 2:1$ (m)

$p_1 = 8$ атм

$p_2 = 1$ атм

$T_1 = 600$ K

$T_2 - ?$

адиабат.

$$\nu_{He} = \frac{2m_1\text{частиц}}{\mu_{He}} = \frac{\cancel{2}m_1}{\cancel{2}\mu_{H_2}} = \frac{m_1}{m_{H_2}} = \nu_{H_2} \overset{\text{пусть}}{=\!=}: \nu$$

пусть $He - A$, $H_2 - B$

$$\delta Q = \delta A + dU =$$
$$= p_A\,dV + p_B\,dV + \frac{3}{2}(p_A\,dV + V\,dp_A) + \frac{5}{2}(p_B\,dV + V\,dp_B)$$

(1) $\frac{5}{2}p_A dV + \frac{7}{2}p_B dV + \frac{3}{2}V dp_A + \frac{5}{2}V dp_B = 0$

(2) $pV^n = const$ $\qquad \longmapsto \quad pV^{\frac{3}{2}} = const$

$$n = \frac{C_p}{C_v} = \frac{7+5}{5+3} = \frac{\cancel{12}^{3}}{\cancel{8}_{2}} = \frac{3}{2}$$

$$p_1V_1^n = p_2V_2^n \;; \quad \frac{p_1}{p_2} = \left(\frac{V_2}{V_1}\right)^n \;; \quad V_2 = V_1\left(\frac{p_1}{p_2}\right)^{\frac{1}{n}} = V_1\left(\frac{p_1}{p_2}\right)^{\frac{2}{3}}$$

$$: \begin{cases} p_1V_1 = 2\nu RT_1 \\ p_2V_2 = 2\nu RT_2 \end{cases}$$

(3) $$\frac{T_2}{T_1} = \frac{p_2V_2}{p_1V_1} = \frac{p_2}{p_1}\cdot\left(\frac{p_1}{p_2}\right)^{\frac{2}{3}} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{3}}$$

$$\underline{\underline{T_2}} = T_1\left(\frac{p_2}{p_1}\right)^{\frac{1}{3}} = 600\,K\cdot\left(\frac{1}{8}\right)^{\frac{1}{3}} = \underline{\underline{300\,K}}$$

1.83

I_2

$T = 600\,K$

$c_p = 0{,}14 \frac{Дж}{г\cdot К}$

$A = 126{,}9$

$\alpha - ?$

$$\overset{1-\alpha}{I_2} \rightleftarrows \overset{\alpha}{I^{\bullet}} + \overset{\alpha}{I^{\bullet}}$$

$$c_p = \frac{\delta Q}{m\,dT}$$

пусть количество вещества I_2 до диссоциации – ν

Тогда при T:

$\nu(I_2) = \nu(1-\alpha)$

$\nu(I^{\bullet}) = 2\alpha\nu$

$$c_p = \frac{(1-\alpha)c_p(I_2)\cancel{\nu} + 2\alpha\, c_p(I^{\bullet})\cancel{\nu}}{\underbrace{m}_{2\mu\cancel{\nu}}} = \frac{(1-\alpha)\frac{7}{2}R + 2\alpha\cdot\frac{5}{2}R}{2\mu} =$$

$$= \frac{7 - 7\alpha + 10\alpha}{4\mu/R} = \frac{7+3\alpha}{4\mu/R}$$

$$\underline{\underline{\alpha}} = \frac{\frac{4\mu c_p}{R} - 7}{3} = \frac{\frac{4\cdot 126{,}9\cdot 0{,}14}{8{,}314} - 7}{3} = \underline{\underline{0{,}52}}$$