1a) 2nd law of thermodynamics - trivial

b) 3rd law of thermodynamics - trivial

c) reversible change => $\Delta S = 0$

d) $dA = -p\,dV - S\,dT$

$$\frac{\partial}{\partial T}\left(\frac{\partial A}{\partial V}\right) = \frac{\partial}{\partial V}\left(\frac{\partial A}{\partial T}\right) \Rightarrow -\frac{\partial p}{\partial T} = -\frac{\partial S}{\partial V} \quad \square$$

e) $$\eta = \frac{T_h - T_c}{T_h} = \frac{1200-300}{1200} = \frac{9}{12} = \frac{3}{4} \Rightarrow W_{max} = \frac{3}{4}\cdot 2kJ = 1.5kJ \quad \square$$

f) $$\Delta \ln \Omega = \frac{\Delta E}{kT} \qquad k = 1.38\cdot 10^{-23}\,JK^{-1}, \quad T = 300K$$

2eV: $\Delta E = 2\cdot 1.6\cdot 10^{-19}\,J$

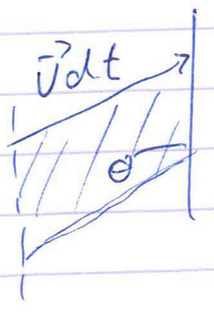
$$\Delta \ln \Omega = \frac{2\cdot 1.6\cdot 10^{-19}\,J}{1.38\cdot 10^{-23}\,JK^{-1}\,300K} = 77.29$$

$\Delta \Omega = 3.7\cdot 10^{33}$

$3.3\cdot 10^{-6}$ eV: $\Delta \ln \Omega = 0{,}000128$

$\Delta \Omega = 1.00013$

g)



$A\cdot v\,dt\cos\theta$: number of molecules hitting the wall.
unit time and unit area
=> $v\cos\theta$ to be multiplied with $f(v)$, $\frac{1}{2}$ because of two directions, n: density

additional factor v causes preference for fast (hot) particles!

h) particle flow through a plane

thermal energy: $C \cdot T = \frac{3}{2} k T$ for ideal gas

transported energy: $C \cdot \Delta T = C \cdot \frac{\partial T}{\partial z} \cos\theta \, \lambda$

$$J_x = \int_0^\infty \int_0^\pi -C \frac{\partial T}{\partial z} \cos\theta \, \lambda \, v \cos\theta \, n f(v) \frac{1}{2} \sin\theta \, d\theta \, dv$$

i) $pV = nRT$ $\quad n = \frac{pV}{RT} = \frac{6.258 \cdot 10^4 \, Pa \cdot 0.001 \, m^3}{8.31 \, JK^{-1} mol^{-1} \cdot 373 \, K}$

$= 0.0202 \, \frac{mol}{m^3}$

i) rev. isotherm. exp.: $\Delta S_1 = nR \ln\left(\frac{V_f}{V_i}\right) = -0.116 \, J/K$

ii) reversible const V cooling: $\Delta S_2 = \frac{3}{2} nR \ln\left(\frac{T_f}{T_i}\right) = -0.057 \, J/K$

$\Rightarrow \Delta S_{total} = -0.173 \, J/K$ (for the system)

rev.: $\rightarrow \Delta S_{sur} = +0.173 \, J/K$

2) a) B is isothermally compressed

$$\Rightarrow w = -\int_{V_i}^{V_f} p\,dV = -nRT\int_{V_i}^{V_f} \frac{1}{V}\,dV$$

(with $p = \frac{nRT}{V}$)

$$= -nRT \ln\frac{V_f}{V_i} = -nRT \ln{1/2} = +3456\ J$$

$w_A = -w_B$

b) $\Delta U_B = 0$ for an isothermal volume change of an ideal gas

c) $\Delta U_B = \Delta Q_B + \Delta W_B \Rightarrow \Delta Q_B = -\Delta W_B = -3456\ J$

K

d) reversible process $\Rightarrow p_f^A = p_f^B$ $\qquad pV = nRT$

$\Rightarrow$ pressure doubles in B (isotherma)

$p_f^A = p_f^B = 2\,p_A$

$V_f^A = 1.5\,V_A \qquad \frac{T_f^A}{T_A} = \frac{p_f^A V_f^A}{p_A V_A} = 2 \cdot 1.5 = 3$

$T_f^A = 3 \cdot T_A = 900\,K \qquad \Delta U_A = n\,C_{V,m}\,\Delta T = 2 \cdot 20 \cdot 600$
$= 24000\,J$

e) $\Delta Q_A = \Delta U_A - \Delta W_A = 24000 + 3456 = 27.456\,J$

3 a)

$dU = C_v dT = dW$

$C_v \frac{dT}{T} = -p dV = -\frac{RT}{V} dV$

$\ln \frac{T_2}{T_1} = -\frac{R}{C_v} \ln \frac{V_2}{V_1} = \ln \left(\frac{V_2}{V_1}\right)^{-\frac{R}{C_v}}$

$T_2 = T_1 \cdot \left(\frac{V_2}{V_1}\right)^{-\frac{R}{C_v}}$ ☒

$\frac{C_v}{R} = \frac{5}{2} \Rightarrow T_B = T_A \cdot \frac{2V_A}{V_A}^{-\frac{2}{5}} = 227.4K$

$p_B = \frac{nRT_B}{V_B} = 0.38 P_A = \left(\frac{1}{2}^{2/5} \cdot \frac{1}{2}\right) PA$

b)

$P_C = P_A$, $V_C = V_B = 2V_A$ $P_C V_C = 2 P_A V_A = RT_C$
$= 2RT_A$

$T_C = 2T_A = 600K$

d)

$A \Rightarrow B$: adiabatic, $\Delta Q = 0 \Rightarrow \Delta U_{AB} = C_v(T_B - T_A)$
$= \Delta W_{AB}$
$= -1509 J$

$B \to C$: $\Delta W = 0$ (no expansion)

$\Delta U = C_v (T_C - T_B) = \Delta Q_{BC} = 7745 J$

$C \to A$: $\Delta H = \Delta U_{CA} + \Delta(pV) = \Delta U_{CA} + R(T_A - T_C)$
$= C_p (T_A - T_C)$

$\Rightarrow U_3 = C_v (T_A - T_C) = \Delta Q_{CA} + \Delta W_{CA}$

$\Delta W_{CA} = -P_0(V_A - V_C) = P_0 V_0 = RT_A = 2494 J$

$\Delta Q_{CA} = C_v(T_A - T_C) - RT_A = C_v(T_A - 2T_A) - RT_A$
$= -\frac{7}{2} T_A = -8730 J$

$\Delta U_{total} = 0$