1) a)

[redacted]

$$\frac{dE}{dt} = \sum_i \dot{m}_i(t)\left(h_i(t) + p_i v_i(t) + \tfrac{1}{2}c_i^2(t)\right) + \sum_j \dot{Q}_j(t) - \sum_k \dot{W}_k(t)$$

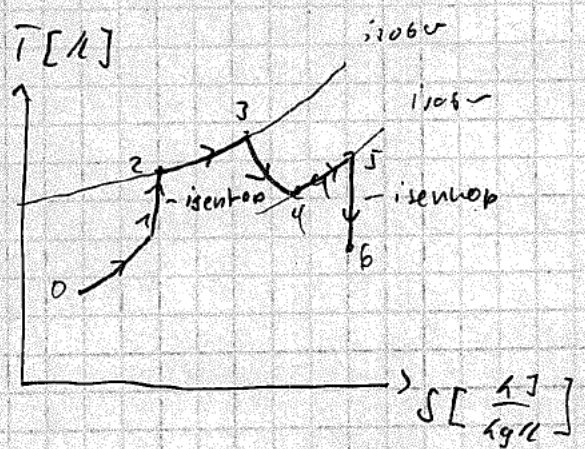
$$u_2 - u_1 = w_{ein} - w_{aus} = m_{ein}(h_{ein} - h_{aus}) + Q_{aus} + Q_{12}$$

b) $$\bar{T}_{AF} = \frac{\int_e^a \bar{T}\,ds}{s_a - s_e} = \frac{q_{rev}}{s_a - s_e}$$

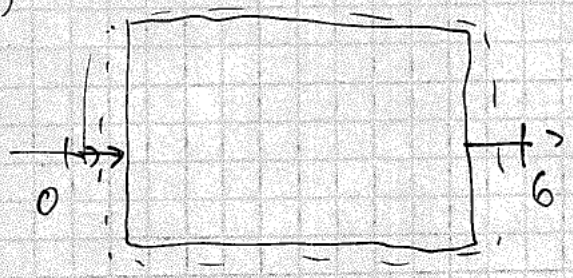
c) $$\frac{dS}{dt} = \sum_i \dot{m}_i(t) s_i(t) + \sum_j \frac{\dot{Q}_j}{\bar{T}_{AF}} + \dot{S}_{erz}$$

2)

a)




b)




$$\frac{dE}{dt} = \sum_i \dot{m}_i(t)\,(h_i(t) + h_{ci}(t) + p e_i(t)) + \sum_j \dot{Q}_j(t) - \sum_n \dot{W}_n(t)$$

$$0 = \dot{m}_{ges}\,(h_0 + k_0 - h_6 - k_6) \Rightarrow k_6 = h_0 - h_6 + k_0$$

$$k_0 = \frac{w^2}{2} = \frac{(700\,\frac{m}{s})^2}{2} = 20'000\,\frac{m^2}{s^2} \qquad \frac{w_6^2}{2} = h_0 - h_6 + k_0 \quad \overset{\text{auf welche Seite}}{\Longrightarrow} \text{Seite}$$

$$h_0 - h_6 = \int_{T_0}^{T_6} c_p^{ij}\,dT = 1{,}006\,\frac{kJ}{kgK}\,(-243{,}15K + 328{,}07K) = +85{,}4295\,\frac{kJ}{kg}$$

Für $T_6$ Schussdüse brauchen reversibel $\Rightarrow$ isentrop

$$\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{1{,}4-1}{1{,}4}} \Rightarrow T_6 = 431{,}9K\left(\frac{0{,}196bar}{0{,}56bar}\right)^{\frac{1{,}4-1}{1{,}4}} = \underline{328{,}07K}$$

$$w_6 = \sqrt{2\,(h_0 - h_6 + \tfrac{w_0^2}{2})}$$

$$\frac{m^2 kg}{s^2 kg} = \frac{Nm}{kg} = \frac{J}{kg}$$

$$= \sqrt{2\left(+85{,}4295\ \frac{kJ}{kg} + 20'000\ \frac{m^2 kg}{s^2 kg}\right)}$$

$$= \underline{\underline{459{,}19\ \frac{m}{s}}}$$

c)

$$e_{stat,6} = (h_6 - h_0 - T_0(s - s_0) + \tfrac{w_6^2}{2} + e_{p,6})$$

$$e_{stat,0} = (h_0 - h_0 - T_0(s_0 - s_0) + \tfrac{w_0^2}{2} + e_{p,0})$$

$$e_{stat,0} = \tfrac{w_0^2}{2} = 20'000\ \frac{m^2}{s^2} = 20'000\ \frac{m^2 kg}{s^2 kg}$$

$$= 20'000\ \frac{Nm}{kg} = \frac{20\,kJ}{kg}$$

$$h_6 - h_0 = \int_{T_0}^{T_6} c_p\,dT = 1{,}006\ \frac{kJ}{kg\,K}\,(328{,}07\,K - 243{,}15\,K)$$

$$= 85{,}429\ \frac{kJ}{kg}$$

$$s_6 - s_0 = \int_{T_0}^{T_6} \frac{c_p}{T}\,dT - R\ln\left(\frac{p_0}{p_0}\right)^0 = 1{,}006\ \frac{kJ}{kg\,K}\ln\left(\frac{328{,}07\,K}{243{,}15\,K}\right) = 0{,}3016\ \frac{kJ}{kg\,K}$$

$$e_{stat,6} = \left(85{,}429\ \frac{kJ}{kg} - 243{,}15\,K \cdot 0{,}3016\ \frac{kJ}{kg\,K} + \frac{(510\ \frac{m}{s})^2}{2}\right)$$

$$= 142{,}144\ \frac{kJ}{kg}$$

$$\Delta e_{stat} = e_{stat,6} - e_{stat,0} = \underline{\underline{122{,}145\ \frac{kJ}{kg}}}$$

[redacted]

2d)

$$\frac{dS}{dt}^{0} = \dot{m}_{ges}(s_0 - s_6) + \dot{s}_{er2}$$

aus 2c

$$\dot{s}_{er2} = \dot{m}_{ges}(s_6 - s_0) = 0{,}3076 \ \frac{kJ}{kg\,K}$$

$$\dot{E}_{x,verl} = T_0 \dot{s}_{er} = 243{,}15\,K \cdot 0{,}3076 \ \frac{kJ}{kg\,K} = \underline{\underline{73{,}334 \ \frac{kJ}{kg}}}$$

[redacted]

3a)

Zuerst muss der Druck im Gasbehälter berechnet werden:

Druck EW + Druck vom Gewicht + Druck Umgebung

$$p_K = \frac{F}{A} = \frac{32\,kg \cdot 9{,}81\,\frac{m}{s^2}}{\pi\,(5 \cdot 10^{-2}\,m)^2} = 39'969{,}36\,\frac{N}{m^2}$$

$$p_{EW} = \frac{F}{A} = \frac{0{,}12\,kg \cdot 9{,}81\,\frac{m}{s^2}}{\pi\,(5 \cdot 10^{-2}\,m)^2} = 124{,}904\,\frac{N}{m^2}$$

$$p_{amb} = 10^5\,\frac{N}{m^2}$$

$$p_{g,1} = p_K + p_{EW} + p_{amb} = 140'094{,}44\,\frac{N}{m^2} \Rightarrow$$

$$R = \frac{\bar{R}}{M} = \frac{8{,}314\,\frac{kJ}{kmol\,K}}{50\,\frac{kg}{kmol}} = 0{,}16628\,\frac{kJ}{kg\,K}$$

$$\Rightarrow p_{g,1} = 1{,}4\,bar$$

$$m_g = \frac{p_{g,1} \cdot V_{g,1}}{R \cdot T_{g,1}} = \frac{1{,}4 \cdot 10^5\,\frac{J}{m^3} \cdot 3{,}14 \cdot 10^{-3}\,m^3}{0{,}16628\,\frac{kJ}{kg\,K} \cdot 773{,}15\,K} = 3{,}419\,g$$

[redacted]

36)

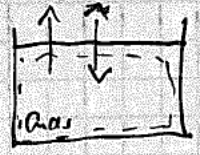
Das Eis-Wasser weist die Wasseranomalie auf, im Fest-Flüssig gebiet befindet sich eine Isotherme bis alles Eis (fest) weggeschmolzen ist. Also ist das EW immernoch $T_{EW,2} = 0°C$ somit muss auch das Gas $A$ $T_{g,2} = 0°C$, Thermodynamisches gleichgewicht.

$\underline{\underline{T_{g,2} = 0°C}}$

Die massen welche auf das Gas wirken sind ebenfalls die gleichen. somit $\underline{\underline{p_{g,2} = 1,46 bar}}$

$$p_{g,2} = \frac{m_g R T_{g,2}}{V_{g,2}}$$

3c




Energie bilanz um Systemgrenze:

$$\frac{dE}{dt} = \sum_j \dot{Q}_j \qquad \frac{dE}{dt} = \sum_j \dot{Q}_j - \sum_n \dot{W}_n$$

$$U_2 - U_1 = Q_{12} - W_{12}$$

Da wir keine Reibung haben ist $W_{12}$ = reversibel

$$W_{12} = \int_1^2 p\,dv$$

$$v_1 = \frac{V_{g,1}}{m_{g,1}} = \frac{3,14 \cdot 10^{-3} m^3}{3,419 \cdot 10^{-3} kg} = 0,918397 \frac{m^3}{kg}$$

Für $v_{g2}$:

$$v_{g2} = \frac{mRT}{p} = \frac{3{,}419 \cdot 10^{-3}\,kg \cdot 0{,}16628\,\frac{kJ}{kg\,K} \cdot 273{,}15\,K}{1.4 \cdot 10^{2}\,\frac{kJ}{m^3}}$$

$$= 1{,}109 \cdot 10^{-3}\,m^3$$

$$v_{g2} = \frac{1{,}109 \cdot 10^{-3}\,m^3}{3{,}419 \cdot 10^{-3}\,kg} = 0{,}324364\,\frac{m^3}{kg}$$

$$w_{12} = \int_1^2 p\,dv = p\,(v_2 - v_1) = 1.4 \cdot 10^{2}\,\frac{kJ}{m^3}\,($$

$$= 1{,}4 \cdot 10^{2}\,\frac{kJ}{m^3}\left(0{,}324364\,\frac{m^3}{kg} - 0{,}918397\,\frac{m^3}{kg}\right) = -83{,}164\,\frac{kJ}{kg}$$

$$W_{12} = w_{12} \cdot m_g = -83{,}164\,\frac{kJ}{kg} \cdot 3{,}419 \cdot 10^{-3}\,kg = -0{,}28434\,kJ$$

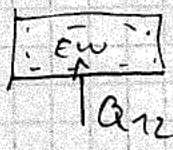
$$u_2 - u_1 = \int_1^2 c_v^{pg}(T_2 - T_1) \cdot m_g = 0{,}633\,\frac{kJ}{kg\,K}\,(273{,}15\,K - 773{,}15\,K) \cdot 3{,}419 \cdot 10^{-3}\,kg$$

$$= -1{,}0821\,kJ$$

$$Q_{12} = u_2 - u_1 + W_{12} = -1366{,}4\,kJ$$

$$|Q_{12}| = 1366{,}4\,kJ$$

3d)




$\frac{dE}{dt} = \sum_j \dot{Q}_j - \sum_k \dot{W}_k$ ($\dot{W}_k = 0$, da keine Volumenänderungsarbeit)

$U_2 - U_1 = Q_{12}$

$u_1 = u_f + x(u_g - u_f)$ Druck im EW bei Zustand 1: aus vorheriger Aufgabe bekannt

$p_{amb} + p_e = 1{,}4$ bar (gemessen)

Aus Tab 1:

$u_1 = -0{,}045 \frac{kJ}{kg} + 0{,}6\left(-333{,}458 \frac{kJ}{kg} + 0{,}045 \frac{kJ}{kg}\right)$

$= -200{,}09 \frac{kJ}{kg}$ $\quad U_1 = u_1 \cdot m_{EW} = -20 \frac{kJ}{kg} = -20\,kJ$

$U_2 = Q_{12} + U_1 = 1366{,}4\,J - 20\,kJ = -18{,}63364\,J$

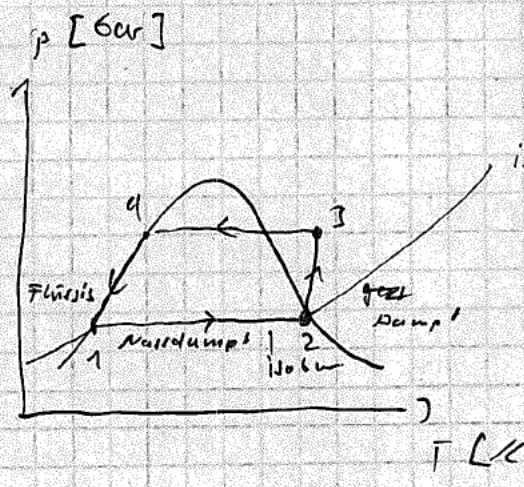
$x = \frac{u_2 - u_f}{u_g - u_f} \overset{\text{Tab 1}}{=} \frac{-18{,}63361\,J + 0{,}045 \frac{kJ}{kg} \cdot 0{,}1\,kg}{0{,}1\,kg\left(-333{,}458 \frac{kJ}{kg} + 0{,}045 \frac{kJ}{kg}\right)}$

$= 0{,}5587$

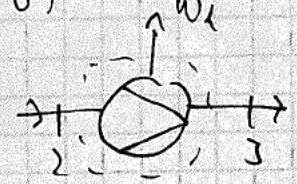
$m_{2E,j} = x_{2E,j} \cdot m_{EW} = 0{,}5587 \cdot 0{,}1\,kg = \underline{\underline{55{,}87\,g}}$

[redacted]

4a)




4b)




$$\frac{dE}{dt} = \sum_i \dot{m}_i \left( h_i + k_{e,i}(t) + p_{e,i}(t) \right) + \sum_j \dot{Q}_j(t) - \sum_n \dot{W}_n(t)$$

(0, stationär; 0; 0; 0, adiabat)

$x_2 = 1$ $\quad p_3 = 8\,bar$

$T_i =$

$$0 = \dot{m}_{R134a} (h_2 - h_3) - \dot{W}_t$$

c)


$p_q = 8\,bar$

$x_q = 0$ $\quad h_q = h_f = 93{,}42 \frac{kJ}{kg}$

$h_1 = 93{,}42 \frac{kJ}{kg}$ isenthalp

$$x_1 = \frac{h_1 - h_f}{h_g - h_f}$$

d)

$$\varepsilon_1 = \frac{|\dot{Q}_{zu}|}{|\dot{W}_t|} = \frac{|\dot{Q}_{zu}|}{|\dot{Q}_{ab}| - |\dot{Q}_{zu}|}$$