Ex.1

In[152]:= g := [**Earth** PLANET] [*gravity*] ✓ ;

ρ := [**water** CHEMICAL] [*mass density*] ⋯ ✓

T := 298 K ⋯ ✓ ; Δh := 1.2 cm ✓

R := R ⋯ ✓ ; m := 3 g/L ⋯ ✓

Δp = ρ * g * Δh

M = m (R * T) / (Δp) // UnitConvert

Out[155]= 1172.53 g/(cm s^2)

3)

	N_2	H_2	$\rightarrow$ NH_3
ΔG	0	0	-16.4
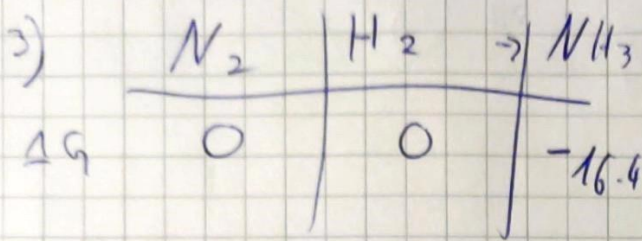
$\rightarrow \Delta G = -32.8 \ \frac{kJ}{mol}$

$n_{H_2} \cdot n_{N_2} \Rightarrow P_{H_2} = P_{N_2}$

$P_{NH_3} = \dfrac{\sqrt{k} \ P_{H_2}^2}{P_0}$

$1 atm = P_{N_2} + P_{H_2} + P_{NH_3} = 2 P_{H_2} + \dfrac{\sqrt{k} P_{H_2}^2}{P_0}$

$\Rightarrow P_{H_2} \approx \ 0.035 \ atm \Rightarrow P_{NH_3} - 1atm - 2 \cdot P_{H_2} \approx 0.93 \ atm$

b)

$~~~~~ n_{H_2} ~~ n_{N_2} ~~ \frac{PV}{RT} = 2 \cdot 10^{22} ~~~~ n_{NH_3} = 5.59 \cdot 10^{23}$

$PV = N k_B T \qquad \Delta P_{NH_3} = \dfrac{0.2 \ mol \ RT}{V} \approx 0.2 \ atm$

$\Rightarrow P_{H_2} = P_{N_2} \overset{=0.035 atm}{} \ , \ P_{NH_3} = 1.13 \ atm \qquad$, neues Gleichgewicht bei $\quad P_{H_2}^{neu} = P_{H_2} + 3x$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad P_{N_2}^{neu} = P_{N_2} + x$

$k = \dfrac{P_{NH_3}^2 \cdot P_0^2}{P_{N_2}^3 P_{H_2}} = \dfrac{(P_{NH_3} - 2x)^2 P_0^2}{(P_{N_2} + 3x)^3 (P_{N_2} + x)} \Rightarrow x \approx 0.0015 \ atm \qquad P_{NH_3}^{neu} = P_{NH_3} + 2x$

$\Rightarrow P_{N_2}^{neu} = 0.00365 \ atm \qquad P_{H_2}^{neu} \approx 0.0395 \ atm \qquad P_{NH_3}^{neu} \approx 0.927 \ atm$

c) $P_{H_2}^{neu} = 0.07 \ atm + 3x$

$P_{N_2}^{neu} = 0.07 \ atm + x \qquad \Rightarrow x \approx 0.008 \ atm$

$P_{NH_3}^{neu} = 1.86 \ atm - 2x$

$\Rightarrow P_{N_2}^{neu} \approx 0.064 \ atm \qquad P_{H_2}^{neu} \approx 0.046 \ atm \qquad P_{NH_3}^{neu} \approx 1.876 \ atm$

Reaktion läuft unter Druck „besser" ab. Gleichgewicht verschiebt sich richtung Produkt.

$$) \; 8 \; Z_A = \frac{Z_A}{N_A!}^{N_A} \qquad Z_{AB} = Z_A Z_B \qquad Z_A \cdot \frac{\cancel{V}^{N_A}}{\cancel{N_A \lambda_A}} \quad \ell n \, z_A = \frac{V}{\lambda_A^3}$$

$$F = -k_B T \, \ell n \, Z = -k_B T \left(\ell n \, z_A + \ell n \, z_B \right) =$$

$$= -k_B T \left(N_A \, \ell n \left(\frac{V}{\lambda_A^3} \right) - N_A \, \ell n \, N_A + N_A + N_B \, \ell n \left(\frac{V}{\lambda_B^3} \right) - N_B \, \ell n \, N_B + N_B \right) =$$

$$= -k_B T \left(N_A \ell n \left(\frac{V}{N_A \, \lambda_A^3} \right) + N_A + N_B \, \ell n \left(\frac{V}{N_B \lambda_B^3} \right) + N_B \right)$$

$$= -k_B T \left[N_A \left(\ell n \left(\frac{z_A}{N_A} \right) + 1 \right) + N_B \left(\ell n \left(\frac{z_B}{N_B} \right) + 1 \right) \right]$$

$$S = -\frac{\partial F}{\partial T} = \cancel{2z_A} - \cancel{\frac{F}{T}} + \cancel{Sz_A} - \frac{\partial F_A}{\partial T} - \frac{\partial F_B}{\partial T}$$

$$\frac{\partial F_A}{\partial T} = -\frac{F_A}{T} + k_B T N_A \frac{\partial}{\partial T} \left(\ell n(z_A) - \ell n(N_A) + 1 \right) = \qquad\qquad z_A = \frac{V}{\lambda_A^3} \quad, \; \lambda_A = \hbar \sqrt{\frac{2\pi}{m k_B T}}$$

$$= -\frac{F_A}{T} + k_B T N_A \frac{\partial \, \ell n(z_A)}{\partial T} = \qquad\qquad\qquad\qquad\qquad = \alpha(T)^{-\frac{1}{2}}$$

$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad z_A = \frac{\frac{N k_B T}{P}}{\left(\alpha (T)^{\frac{1}{2}} \right)^3} =$$

$$= -\frac{F_A}{T} + k_B T N_A \frac{1}{z_A} \gamma \frac{5}{2} T^{\frac{3}{2}} = \qquad\qquad\qquad\qquad = \gamma \, T^{\frac{5}{2}} \quad , \; \gamma = \frac{N_A k_B}{P \hbar^3 \sqrt{2\pi}}^3$$

$$= + k_B N_A \left(\ell n (z_A) - \ell n(N_A) + 1 \right) + \frac{5 k_B T}{2} \frac{N_A}{z_A} T^{\frac{3}{2}} \cancel{N_A k_B} \frac{V}{\lambda^3} \cdot$$

$$= k_B N_A \left(\ell n \left(\frac{z_A}{N_A} \right) + \frac{5}{2} \right)$$

$$\rightarrow S = S_A + S_B = k_B \left[N_A \left(\ell n \left(\frac{z_A}{N_A} \right) + \frac{5}{2} \right) + N_B \left(\ell n \left(\frac{z_B}{N_B} \right) + \frac{5}{2} \right) \right]$$

$$U = F + ST \quad U_A = F_A + S_A T = -k_B T N_A \left(\ell n \left(\frac{z_A}{N_A} \right) + 1 \right) + k_B T N_A \left(\ell n \left(\frac{z_A}{N_A} \right) + \frac{5}{2} \right) = \frac{3}{2} N_A k_B T$$

$$\rightarrow U = U_A + U_B = \frac{3}{2} k_B T (N_A + N_B)$$

$$P = -\frac{\partial F}{\partial V} \qquad P_A = -\frac{\partial F_A}{\partial V} = + k_B T N_A \frac{\partial}{\partial V} \left(\ell n(V) - \ell n(\lambda_A^3 N_A) + 1 \right) = \frac{k_B T N_A}{V}$$

$$\rightarrow P = \frac{k_B T}{V} (N_A + N_B)$$

$$H = U + PV \qquad H_A = \frac{3}{2} N_A k_B T + k_B T N_A = \frac{5}{2} k_B T N_A \qquad \rightarrow H = \frac{5}{2} k_B T (N_A + N_B)$$
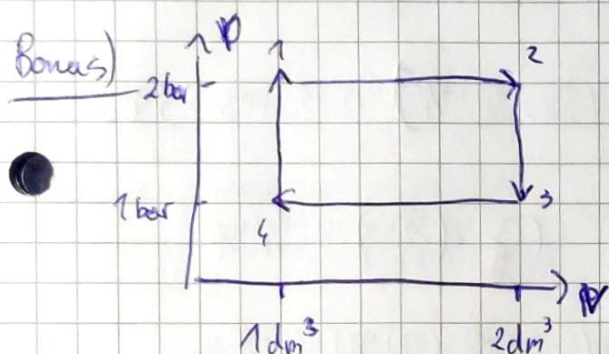
$$G = F + pV \qquad G_A = -k_B T \, N_A \left(\ln\left(\frac{z_A}{N_A} \right) + 1 \right) + k_B T N_A = -k_B T N_A \ln\left(\frac{z_A}{N_A} \right)$$

$$G = -k_B T \left[N_A \ln\left(\frac{z_A}{N_A} \right) + N_B \ln\left(\frac{z_B}{N_B} \right) \right]$$

$$C_V = \left(\frac{\partial U}{\partial T} \right)_{V} \qquad\qquad C_V^A = \frac{3}{2} N_A k_B$$

$$C_V = \frac{3}{2} (N_A + N_B) k_B$$

Bonus)

$$T = \frac{pV}{N k_B}$$

$$C_V = \frac{5}{2} N k_B \qquad C_V T = \frac{5}{2} pV$$

$$\Delta W_{12} = \int_1^2 -p \, dV = -2 \text{ bar} \cdot 1 \text{ dm}^3 = \Delta Q_{12}$$

$$\Delta Q_{23} = C_V (T_3 - T_2) = \frac{5}{2}(-2) \text{ bar dm}^3 = -5 \text{ bar dm}^3$$

$$\Delta W_{34} = +1 \text{ bar} \cdot 1 \text{ dm}^3$$

$$\Delta Q_{41} = C_V (T_1 - T_4) = \frac{5}{2} \text{ bar dm}^3$$

$$\eta = \frac{\Delta W_{12} + \Delta W_{34}}{\Delta Q_{23} + \Delta Q_{41}} = \frac{-1 \text{ bar dm}^3}{-\frac{5}{2} \text{ bar dm}^3} = \frac{2}{5}$$

Es geht viel Energie in Wärme verloren, Isotherme und adiabatische Prozesse sind da besser (wie im Carnot Zyklus).