

Øving 9 - Erlend Sørli

1) $U = \frac{3}{2} RT \Rightarrow \Delta U = \frac{3}{2} R \Delta T, C_V = \frac{q_V}{\Delta T}$

$\Delta U = q + w$, konstant volum gir $w=0$

$\Delta U = q_V$
 $\Rightarrow C_V = \frac{\Delta U}{\Delta T} = \frac{3}{2} R \frac{\Delta T}{\Delta T} = \frac{3}{2} R$

$q_P = C_P \cdot \Delta T \Rightarrow C_P = \frac{q_P}{\Delta T}$

$q_P = \Delta H = \Delta U + p \Delta V$

$n \Delta U = R \Delta T$ ← Ideelle gasser

/antar 1 mol

$q_P = \Delta U + n R \Delta T = \frac{3}{2} R \Delta T + R \Delta T$

$C_P = \frac{\frac{3}{2} R \Delta T + R \Delta T}{\Delta T} = \frac{3}{2} R + R = \frac{5}{2} R$

$C_V = \frac{3}{2} R$ $C_P = \frac{5}{2} R$

2) $S = K_b \cdot \ln W$

$S_1 = K_b \cdot \ln 100 = 1,380 \cdot 10^{-23} \cdot \ln 100 = 6,36 \cdot 10^{-23} \text{ J/K} \cdot 1 \text{ bil}$

$S_2 = K_b \cdot \ln (100 \cdot 99) = 1,27 \text{ J/K} \cdot 2 \text{ biler}$

1 bil $6,36 \cdot 10^{-23} \text{ J/K}$ 2 biler $= 1,27 \cdot 10^{-22}$

3) I) sukrose, det er et større molekyl, og har flere tilstander en glukose

II) S stiger med stigende energi/T $\Rightarrow \text{H}_2\text{O}$ ved 0°C

III) gass har $S \gg S_{\text{væske}} \Rightarrow \text{H}_2\text{S (g)}$ ved 25°C

IV) De alike, likt trykk og temperatur, ideelle gasser.
HCl er størst iht. SI

4) I: 5 mol gass $\rightarrow$ 1 mol $\Rightarrow \Delta S < 0$

$\Delta S = \sum S^\circ(\text{prod}) - \sum S^\circ(\text{reakt}) = (189 - (131 + \frac{1}{2} \cdot 205)) \text{ J/(K} \cdot \text{mol)}$

$\Delta S = -44,5 \text{ J/(K} \cdot \text{mol)}$

II: 3 mol gass $\rightarrow$ 2 mol $\Rightarrow \Delta S < 0$

$\Delta S = (2 \cdot 239 - 3 \cdot 205) \text{ J/(K} \cdot \text{mol)}$

$\Delta S = -137 \text{ J/(K} \cdot \text{mol)}$

III: NO er sammen sett, og vil vekselvirke i beholder s.a. antall tilstander øker $\Rightarrow \Delta S > 0$

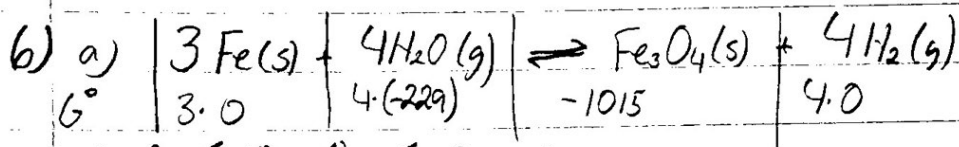
$\Delta S = (2 \cdot 211 - (192 + 205)) \text{ J/(K} \cdot \text{mol)}$

$\Delta S = 25 \text{ J/(mol} \cdot \text{K)}$

5) a) Konstant volum: $q_p = C_p \cdot \Delta T = 28,95 \cdot (350 - 298) \text{ kJ/mol} = 1,51 \text{ kJ/mol}$
 Konstant tryk: $q_v = C_v \cdot \Delta T = 37,27 \cdot (350 - 298) \text{ kJ/mol} = 1,94 \text{ kJ/mol}$
 $q_p = 1,51 \text{ kJ/mol}$, $q_v = 1,94 \text{ kJ/mol}$

b) $S = S^\circ + \Delta S = S^\circ + C_p \cdot \ln\left(\frac{T_2}{T_1}\right) = (213,64 + 5,99) \text{ J/(Kmol)}$
 $S = 219,6 \text{ J/(Kmol)}$

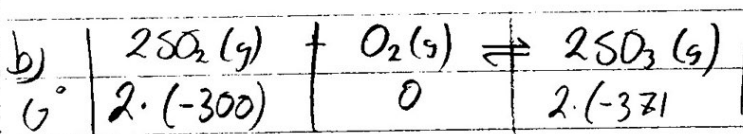
c) $S = S_{350K} + S_{1 \text{ atm} \rightarrow 1,174 \text{ atm}}$ $\left[nR \ln \frac{V_2}{V_1} = nR \ln \frac{P_1}{P_2} = -nR \ln \frac{P_2}{P_1} \right]$
 $= 219,6 \text{ J/(Kmol)} + nR \ln \frac{V_2}{V_1}$
 $= 219,6 \text{ J/(Kmol)} - nR \ln \frac{P_2}{P_1} = 219,6 \text{ J/(Kmol)} - R \cdot \ln \frac{1,174}{1}$
 $= 218,3 \text{ J/(Kmol)}$



$\Delta G^\circ = \sum G^\circ(\text{prod}) - \sum G^\circ(\text{reakt})$

$\Delta G^\circ = -99 \text{ kJ/mol} \Rightarrow \Delta G^\circ = -RT \ln K \Rightarrow \ln K = \frac{-\Delta G^\circ}{RT} = 39,96$
 $\Rightarrow K = 2,26 \cdot 10^{17}$

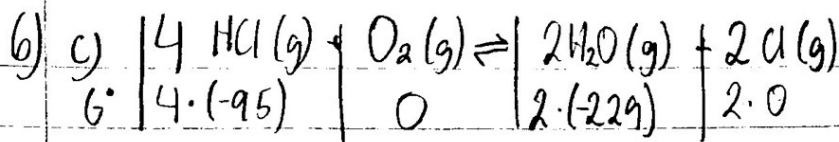
$\Delta G^\circ = -99 \text{ kJ/mol}$ $\wedge K = 2,26 \cdot 10^{17}$



$\Delta G^\circ = \sum G^\circ(\text{prod}) - \sum G^\circ(\text{reakt}) = -142 \text{ kJ/mol}$

$\Delta G^\circ = -142 \text{ kJ/mol} \Rightarrow \Delta G^\circ = -RT \ln K \Rightarrow \ln K = \frac{-\Delta G^\circ}{RT} = 57,31$
 $\Rightarrow K = 7,76 \cdot 10^{24}$

$\Delta G^\circ = -142 \text{ kJ/mol}$ $\wedge K = 7,76 \cdot 10^{24}$



$$\Delta G^\circ = \sum G^\circ(\text{prod}) - \sum G^\circ(\text{reakt}) = -78 \text{ kJ/mol}$$

$$\Rightarrow \ln K = \frac{-\Delta G^\circ}{RT} = 31,48$$

$$\Rightarrow K = 4,70 \cdot 10^{13}$$

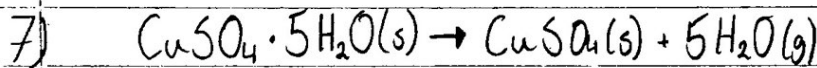
$$\Delta G^\circ = -78 \text{ kJ/mol} \quad \text{I} \quad K = 4,70 \cdot 10^{13}$$

$$d) \quad p_{\text{SO}_2} = 1,0 \cdot 10^{-4} \text{ atm}, \quad p_{\text{O}_2} = 0,2 \text{ atm}, \quad p_{\text{SO}_3} = 0,1 \text{ atm}, \quad p^\circ = 1 \text{ bar} = 0,9869 \text{ atm}$$

$$Q = \frac{\left(\frac{p_{\text{SO}_3}}{p^\circ}\right)^2}{\left(\frac{p_{\text{SO}_2}}{p^\circ}\right)^2 \left(\frac{p_{\text{O}_2}}{p^\circ}\right)} = \frac{p_{\text{SO}_3}^2}{p_{\text{SO}_2}^2 \cdot p_{\text{O}_2}} \cdot p^\circ = 4,93 \cdot 10^6$$

$$Q = 4,93 \cdot 10^6 \ll 7,76 \cdot 10^{24} = K$$

$\Rightarrow$ Spontan mot høyre



$$\text{Spontan n r } \Delta G \leq 0 \Rightarrow \Delta H - \Delta S \cdot T \leq 0$$

$$\Rightarrow \text{N r } \Delta S \cdot T \geq \Delta H$$

Stoff	$\Delta H^\circ \text{ (kJ/mol)}$	$S^\circ \text{ (J/(K \cdot mol))}$
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O (s)}$	-2280	300
$\text{CuSO}_4 \text{ (s)}$	-771	109
$5 \text{ H}_2\text{O (g)}$	$5 \cdot (-242)$	$5 \cdot 189$

$$\Delta H^\circ = ((-771 + 5 \cdot (-242)) - (-2280)) \text{ kJ/mol} = 299 \text{ kJ/mol}$$

$$\Delta S^\circ = ((109 + 5 \cdot 189) - 300) \text{ J/(K \cdot mol)} = 754 \text{ J/(K \cdot mol)}$$

$$\Delta S \cdot T \geq \Delta H$$

$$T \geq \frac{\Delta H}{\Delta S} = \frac{299000 \text{ J/mol}}{754 \text{ J/(K \cdot mol)}} = 397 \text{ K}$$

$$\underline{T \geq 397 \text{ K}}$$

8) a) Hva $\text{Ag}_2\text{SO}_4(\text{s}) \rightleftharpoons 2\text{Ag}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$

$\Delta H^\circ (\text{kJ/mol})$	-715	$2 \cdot 106$	-909
$S^\circ (\text{J/K}\cdot\text{mol})$	200	$2 \cdot 73$	19
$\Delta G^\circ (\text{kJ/mol})$	-614	$2 \cdot 77$	-744

For alle ΔX gjelder: $\sum \Delta X^\circ(\text{prod}) - \sum \Delta X^\circ(\text{reakt}) = \Delta X$

$$\Rightarrow \Delta X = (2 \cdot \dot{X}(\text{Ag}^+) + \dot{X}(\text{SO}_4^{2-})) - \dot{X}(\text{Ag}_2\text{SO}_4)$$

Dette gir svarene: $\Delta H^\circ = 19 \text{ kJ/mol}$, $\Delta S^\circ = -35 \text{ J/K}\cdot\text{mol}$, $\Delta G^\circ = 28 \text{ kJ/mol}$

b) $\Delta G^\circ = -RT \ln K = -RT \ln K_{sp} \Rightarrow \ln K_{sp} = \frac{-28 \text{ kJ/mol}}{R \cdot 298 \text{ K}} = -11,3$

$$K_{sp} = e^{\ln K_{sp}} = 1,24 \cdot 10^{-5}$$

$$K_{sp}(\text{Ag}_2\text{SO}_4) = [\text{Ag}^+]^2 [\text{SO}_4^{2-}] \quad X = [\text{SO}_4^{2-}] \Rightarrow [\text{Ag}^+] = 2X$$

$$= 4X^2 \cdot X = 4X^3$$

$$X = \sqrt[3]{1,24 \cdot 10^{-5} / 4} = 0,01458, X = [\text{SO}_4^{2-}] = [\text{Ag}_2\text{SO}_4]$$

$$M_n(\text{Ag}_2\text{SO}_4) = (2 \cdot 107,9 + 32,07 + 4 \cdot 16) \text{ g/mol} = 311,87 \text{ g/mol}$$

$$= M_n[\text{Ag}_2\text{SO}_4] = c \cdot M_n = 0,01458 \text{ mol/L} \cdot 311,87 \text{ g/mol}$$

$$= 4,6 \text{ g/L}$$

$$\underline{K_{sp} = 1,2 \cdot 10^{-5} \wedge l = 4,6 \text{ g/L}}$$

c) Forventer økende løselighet, $\Delta H > 0 \Rightarrow$ endoterm rx.
Mer varme løser dermed mer salt.

$$\Delta G^\circ = \Delta H^\circ - \Delta S \cdot T = 19000 \text{ J/mol} - (-35 \text{ J/(mol}\cdot\text{K)}) \cdot 373 \text{ K}$$

$$= 32055 \text{ J/mol} = 32 \text{ kJ/mol}$$

$$\ln K_{sp} = \frac{-32 \text{ kJ/mol}}{R \cdot 373 \text{ K}} = -10,34 \Rightarrow K_{sp} = e^{-10,34} = 3,25 \cdot 10^{-5}$$

$$\text{fra b)} \Rightarrow [\text{Ag}_2\text{SO}_4] = \sqrt[3]{3,25 \cdot 10^{-5} / 4} = 0,02 \text{ mol/L}$$

$$l = 0,02 \text{ M} \cdot 311,8 \text{ g/mol} = 6,3 \text{ g/L}$$

$$\underline{l = 6,3 \text{ g/L}}$$