Øving 9 - Erlend Sørlie

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 $W = 0$

$\Delta U = q_v$

$\Rightarrow C_v = \frac{\Delta U}{\Delta T} = \frac{3}{2}R\frac{\Delta T}{\Delta T} = \underline{\frac{3}{2}R}$

$q_p = C_p \cdot \Delta T \Rightarrow C_p = \frac{q_p}{\Delta T}$

$q_p = \Delta H = \Delta U + p\Delta V$ $\quad pV = RT$ ← Ideelle gasslov

$q_p = \Delta U + nR\Delta T = \frac{3}{2}R\Delta T + R\Delta T$. / antar 1 mol

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

$\underline{C_v = \frac{3}{2}R \quad C_p = \frac{5}{2}R}$

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

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

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

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

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

II) S stiger med stigende energi/T => H_2O ved 0°C

III) gass har $S \gg S_{væske}$ => H_2S (g) ved 25°C

IV) De ulike, likt trykk og temperatur, ideelle gasser.
HCl er størst i.h.t. SI

4) I: 1,5 mol gass → 1 mol => $\Delta S < 0$

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

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

II: 3 mol gass → 2 mol => $\Delta S < 0$

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

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

III: NO er sammensatt, og vil vekselvirke i beholder s.a. antall tilstander øker $-\Delta S$

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

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

5) a) Konstant volum: $q_p = C_p \cdot \Delta T = 28,95 \cdot (350-298)\ kJ/mol = 1,51\ kJ/mol$

Konstant trykk: $q_v = c_v \cdot \Delta T = 37,27 \cdot (350-298)\ kJ/mol = 1,94\ kJ/mol$

$q_p = 1,51\ kJ/mol$, $q_v = 1,94\ kJ/mol$

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

$S = 219,6\ J/(K \cdot mol)$

c) $S = S_{350K} + S_{1\ atm \to 1,174\ atm}$

$= 219,6\ J/(K \cdot mol) + nR \ln \frac{V_2}{V_1}$

$= 219,6\ J/(K \cdot mol) - nR \ln \frac{p_2}{p_1} = 219,6\ J/(K \cdot mol) - R \cdot \ln \frac{1,174}{1}$

$= 218,3\ J/(K \cdot mol)$

$pV = nRT \Rightarrow V$

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

6) a)

	$3\,Fe(s)$	+	$4H_2O(g)$	$\rightleftharpoons$	$Fe_3O_4(s)$	+	$4H_2(g)$
G°	3 · 0		4 · (-229)		-1015		4 · 0

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

$\Delta G^\circ = -99\ kJ/mol \Rightarrow \Delta G^\circ = -RT \ln K \Rightarrow \ln K = \frac{\Delta G^\circ}{RT} = 39,96$

$\Rightarrow K = 2,26 \cdot 10^{17}$

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

b)

	$2SO_2(g)$	+	$O_2(g)$	$\rightleftharpoons$	$2SO_3(g)$
G°	2 · (-300)		0		2 · (-371

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

$\Delta G^\circ = -142\ kJ/mol \Rightarrow \Delta G^\circ = -RT \ln K \Rightarrow \ln K = \frac{-\Delta G^\circ}{RT} = 57,31$

$\Rightarrow K = 7,76 \cdot 10^{24}$

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

6) c)

	$4\,HCl(g)$	$O_2(g)$	$\rightleftharpoons$	$2H_2O(g)$	$2\,Cl(g)$
G°	$4\cdot(-95)$	0		$2\cdot(-229)$	$2\cdot 0$

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

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

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

$\Delta G^\circ = -78\ kJ/mol \quad 1 \quad K = 4{,}70\cdot 10^{13}$

d) $p_{SO_2} = 1{,}0\cdot 10^{-4}$ atm, $p_{O_2} = 0{,}2$ atm, $p_{SO_3} = 0{,}1$ atm, $p^\circ = 1$ bar $= 0{,}9869$ atm

$$Q = \frac{\left(\frac{p_{SO_3}}{p^\circ}\right)^2}{\left(\frac{p_{SO_2}}{p^\circ}\right)^2\left(\frac{p_{O_2}}{p^\circ}\right)} = \frac{p_{SO_3}^2}{p_{SO_2}^2 \cdot p_{O_2}} \cdot p^\circ = 4{,}93\cdot 10^6$$

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

$\Rightarrow$ Spontan mot høyre

7) $CuSO_4\cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(g)$

Spontan når $\Delta G \leq 0 \Rightarrow \Delta H - \Delta S\cdot T \leq 0$

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

Stoff	ΔH° (kJ/mol)	S° (J/(K·mol))
$CuSO_4\cdot 5H_2O(s)$	-2280	300
$CuSO_4(s)$	-771	109
$5H_2O(g)$	$5\cdot(-242)$	$5\cdot 189$

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

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

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

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

$T \geq 397\ K$

8) a)

Hva	$Ag_2SO_4(s)$	$\rightleftharpoons$	$2\,Ag^+(aq)$	+	$SO_4^{2-}(aq)$
ΔH° (kJ/mol)	-715		2 · 106		-909
S° (J/K·mol)	200		2 · 73		19
ΔG° (kJ/mol)	-618		2 · 77		-744

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

$\Rightarrow \Delta X = (2 \cdot X^\circ(Ag^+) + X^\circ(SO_4^{2-})) - X^\circ(Ag_2SO_4)$

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

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

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

$K_{sp(Ag_2SO_4)} = [Ag^+]^2[SO_4^{2-}]$ $\quad X = [SO_4^{2-}] \Rightarrow [Ag^+] = 2x$

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

$x = \sqrt[3]{1{,}24 \cdot 10^{-5}/4} = 0{,}014578,\ X = [SO_4^{2-}] = [Ag_2SO_4]$

$M_m(Ag_2SO_4) = (2 \cdot 107{,}9 + 32{,}07 + 4 \cdot 16)\ g/mol = 311{,}87\ g/mol$

$= M_m \cdot [Ag_2SO_4] = c \cdot M_m = 0{,}014578\ mol/L \cdot 311{,}87\ g/mol$

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

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

c) Forventer økende løselighet, $\Delta H > 0 \Rightarrow$ endoterm rx.

Mer varme løser dermed mer salt.

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

$= 32\,055\ J/mol = 32\ kJ/mol$

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

fra b) $\Rightarrow [Ag_2SO_4] = \sqrt[3]{3{,}25 \cdot 10^{-5}/4} = 0{,}02\ mol/L$

$l = 0{,}02\ M \cdot 311{,}9\ g/mol = 6{,}3\ g/L$

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