Factors affecting solubility

CH101 Fall 2009
Boston University

Solubility determined by (Dill/3e pp 208)

$\Delta G_{dissolve}$ = …

$\Delta E_{dissolve}$ (surroundings) + ΔE_{org} (system)

If $\Delta G_{dissolve} < 0$ → ***soluble***

If $\Delta G_{dissolve} > 0$ → ***insoluble***

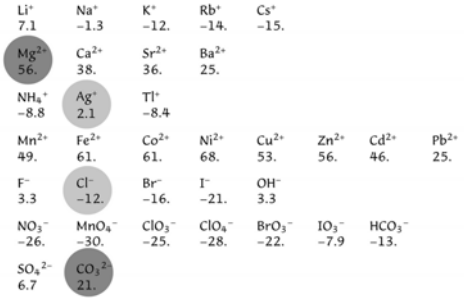
We can predict $\Delta E_{dissolve}$

Table 2.3 ***Lattice and hydration energies (in kJ·mol^{-1}) for some ionic compounds.***

The entries where the cation row and anion columns intersect are $\Delta E_{lattice}$ and $\Delta E_{hydration}$ values for the compound. For example, 2440 kJ·mol^{-1} is $\Delta E_{lattice}$ for $MgBr_2$.

	Anion					
	Cl^-		Br^-		I^-	
Cation	$\Delta E_{lattice}$	$\Delta E_{hydration}$	$\Delta E_{lattice}$	$\Delta E_{hydration}$	$\Delta E_{lattice}$	$\Delta E_{hydration}$
Li^+	861	−898	818	−867	759	−822
Na^+	787	−784	751	−753	700	−708
K^+	717	−701	689	−670	645	−625
Ag^+	916	−850	903	−819	887	−774
Mg^{2+}	2524	−2679	2440	−2626	2327	−2540
Ca^{2+}	2260	−2337	2176	−2285	2074	−2194
Sr^{2+}	2153	−2205	2075	−2142	1963	−2053
	S^{2-}		CO_3^{2-}			
Mg^{2+}	3406	−3480	3122	−3148		
Ca^{2+}	3119	−3140	2804	−2817		
Sr^{2+}	2974	−3030	2720	−2725		

We can predict ΔE_{org} (ion)



Dill/3e p 211

$MgCO_3$: ΔE_{org} makes $\Delta G_{dissolve} > 0$

$\Delta E_{dissolve} = \Delta E_{lattice} + \Delta E_{hydration}$
$= +3122$ kJ/mol $- 3148$ kJ/mol
$= -26$ kJ/mol

$\Delta E_{org} = \Delta E_{org}(Mg^{2+}) + \Delta E_{org}(CO_3^{2-})$
$= +56$ kJ/mol $+ 21$ kJ/mol
$= +77$ kJ/mol

$\Delta G_{dissolve} = \Delta E_{dissolve} + \Delta E_{org}$
$= -26$ kJ/mol $+ 77$ kJ/mol
$= +51$ kJ/mol → insoluble!!!

AgCl: $\Delta E_{dissolve}$ makes $\Delta G_{dissolve} > 0$

$\Delta E_{dissolve} = \Delta E_{lattice} + \Delta E_{hydration}$
$= +916$ kJ/mol $- 850$ kJ/mol
$= +66$ kJ/mol

$\Delta E_{org} = \Delta E_{org}(Ag^{+}) + \Delta E_{org}(Cl^{-})$
$= +2.1$ kJ/mol $- 12$ kJ/mol
$= -10$ kJ/mol

$\Delta G_{dissolve} = \Delta E_{dissolve} + \Delta E_{org}$
$= +66$ kJ/mol $- 10$ kJ/mol
$= +56$ kJ/mol → insoluble!!!

Solubility "rules"

Soluble compounds

- Na^+, K^+, and NH_4^+
- NO_3^-, CH_3COO^-, ClO_4^-
- Cl^-, Br^-, I^-, except with Ag^+, Pb^{2+}, Hg_2^{2+}
- SO_4^{2-}, except with Ag^+, Pb^{2+}, Hg_2^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}

Insoluble compounds

- CO_3^{2-}, S^{2-}, and PO_4^{3-}, except with Na^+, K^+, and NH_4^+
- Ag^+, Pb^{2+}, Hg_2^{2+}
- OH^-, except with NH_4^+, Na^+, K^+, Ba^{2+}

Solubility data

- Rules: Dill/3e pp 211–212 and, e.g., http://snipurl.com/j7aej
- Chart: http://snipurl.com/j5l77
- Table: http://snipurl.com/j5l8m