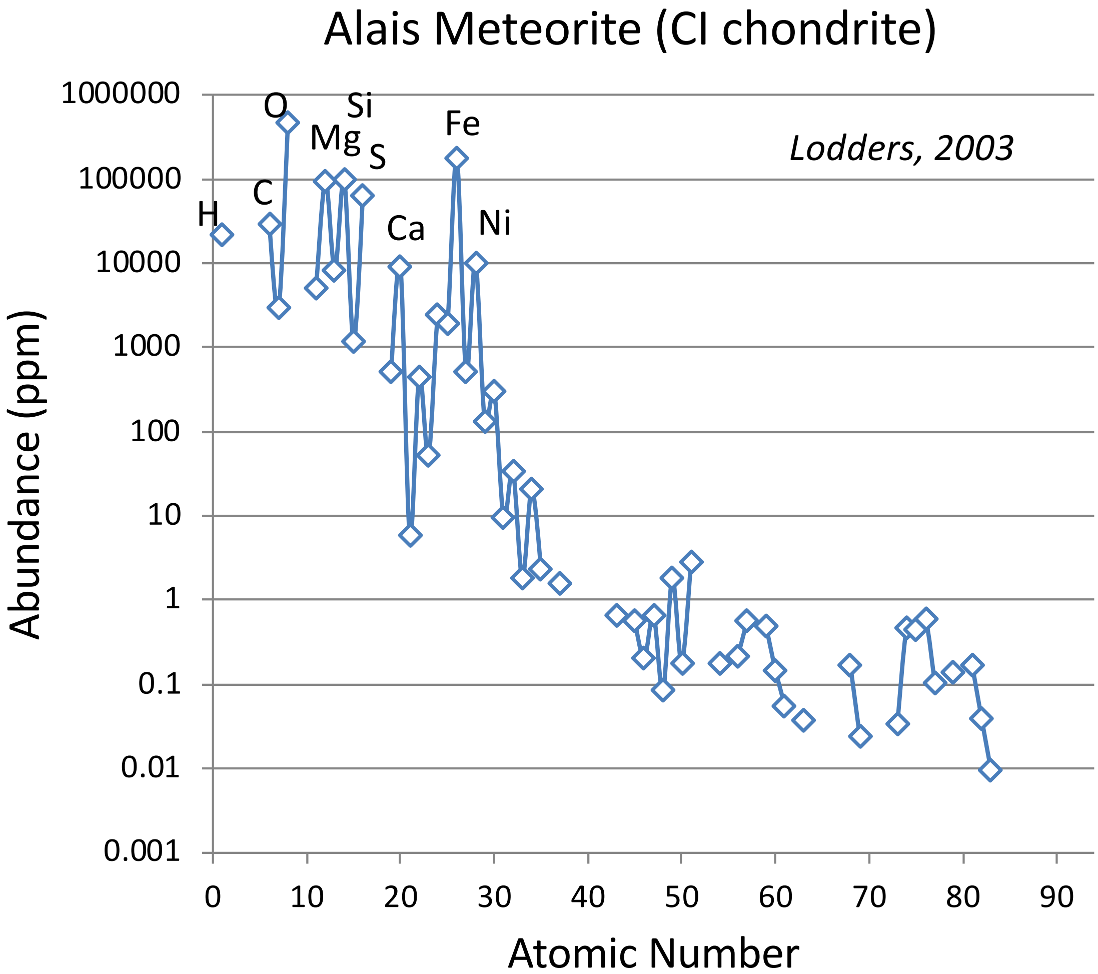
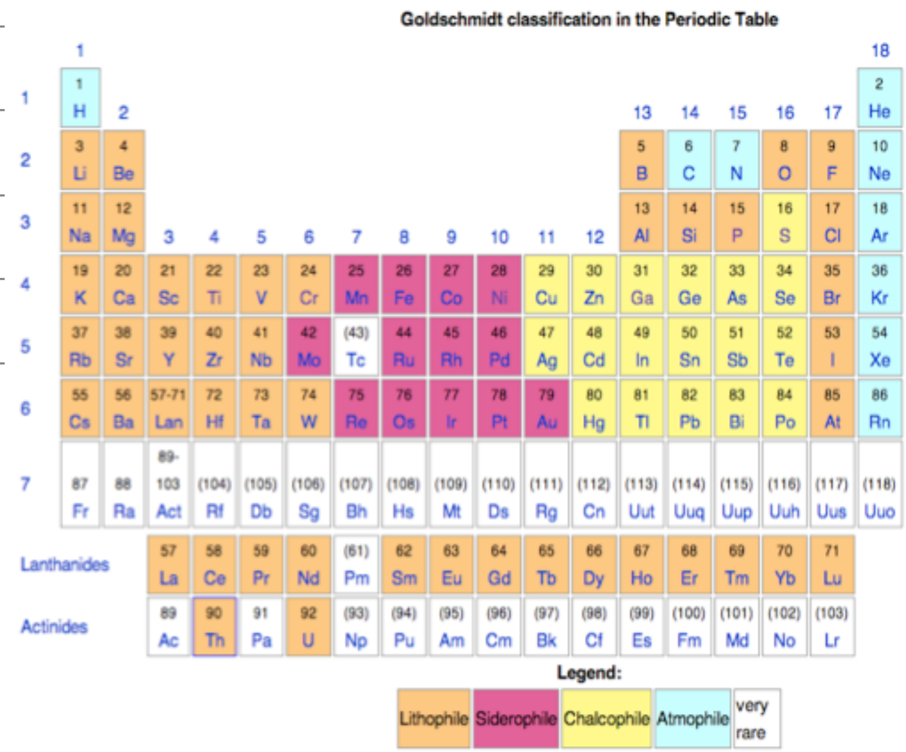

Alais Meteorite (CI chondrite)
Lodders, 2003
Abundance (ppm)
Atomic Number
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0
10
20
30
40
50
60
70
80
90
H
C
O
Mg
Si
S
Ca
Fe
Ni

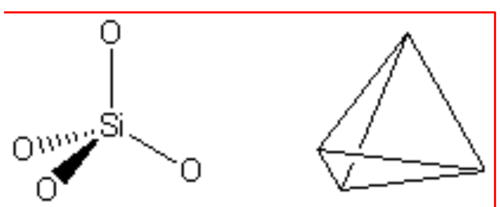

Goldschmidt classification in the Periodic Table
Lanthanides
Actinides
Legend:
Lithophile
Siderophile
Chalcophile
Atmophile
very rare

Solid Earth materials: minerals

What is a mineral?
-- a naturally occurring, solid material with a repeating crystal structure and restricted composition

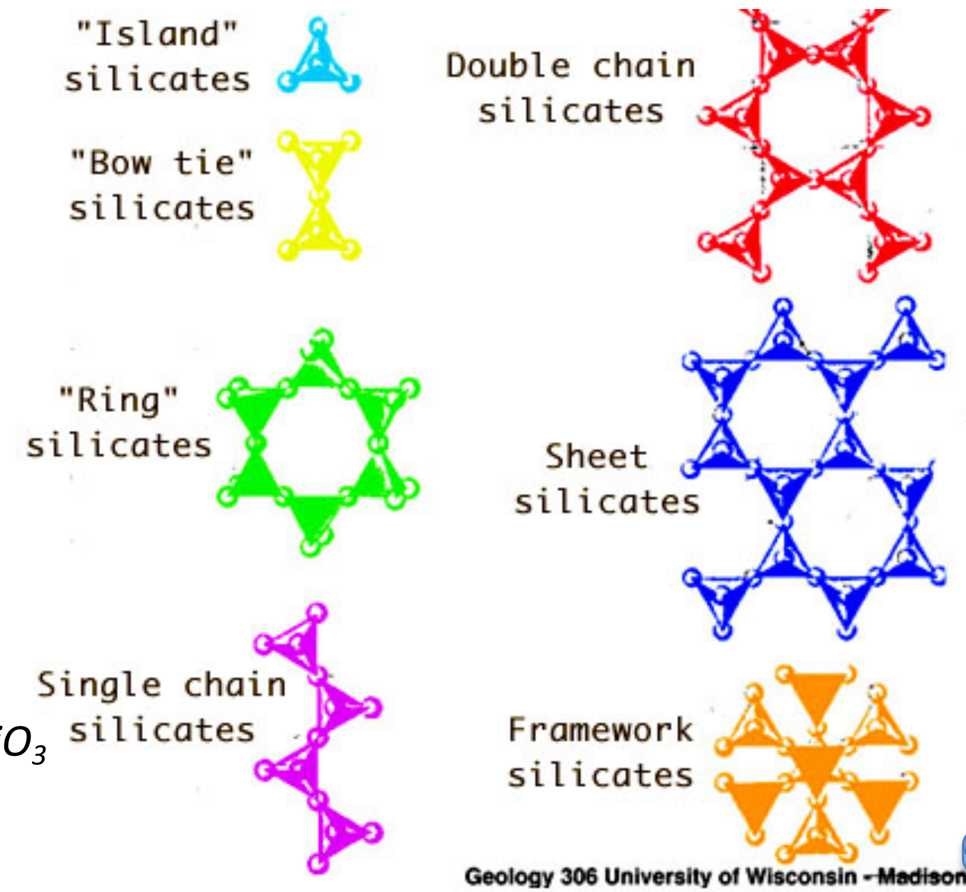
What minerals are there?
-- 1000’s, but most are very rare.
-- Most abundant at Earth’s surface are silicates, salts and oxides

Olivine $(Mg,Fe)_2SiO_4$



(Also Al)

Pyroxene $(Ca,Mg,Fe)SiO_3$



Amphibole
$(Ca, Mg,Fe, Al)_7(Si,Al)_8O_{22}(OH)_2$

Mica
$KMg_3(Si,Al)_4O_{10}(OH)_2$ – biotite
$KAl_2(Si,Al)_4O_{10}(OH)_2$ – muscovite

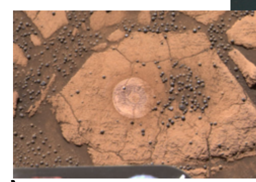
Clay
$Al_4Si_4O_{10}(OH)_8$ – kaolinite

Quartz SiO_2
Feldspar
$KAlSi_3O_8$ – K-feldspar
$NaAlSi_3O_8$ – Albite
$CaAl_2Si_2O_8$ – Anorthite

Salts – ionic bonding of cations and anions:

Simple halides		Halite	Na^+Cl^-
Complex salts			
	Carbonates	Calcite	$Ca^{2+}[CO_3]^{2-}$
		Aragonite	$Ca^{2+}[CO_3]^{2-}$
		Dolomite	$Ca^{2+}Mg^{2+}\,[CO_3]^{2-}{}_2$
	Sulfates	Anhydrite	$Ca^{2+}[SO_4]^{2-}$
		Gypsum	$Ca^{2+}[SO_4]^{2-}.2H_2O$

Oxides – most common tend to have X^{3+} and X^{4+} cations (why?):



Iron oxides	Hematite	$Fe^{3+}{}_2O_3$
Iron oxy-hydroxides	Goethite	$Fe^{3+}O(OH)$
Aluminum oxy-hydroxides	Diaspore	$Al^{3+}O(OH)$
	Gibbsite	$Al^{3+}(OH)_3$
Manganese oxides	Birnessite	$X^{+,2+}Mn^{3+,4+}O_2.nH_2O$

Phosphates – rare but important source of nutrient

Calcium phosphates	Apatite	$Ca_5[PO_4]^{3-}{}_3(F,OH,Cl)$

Bowen's reaction series

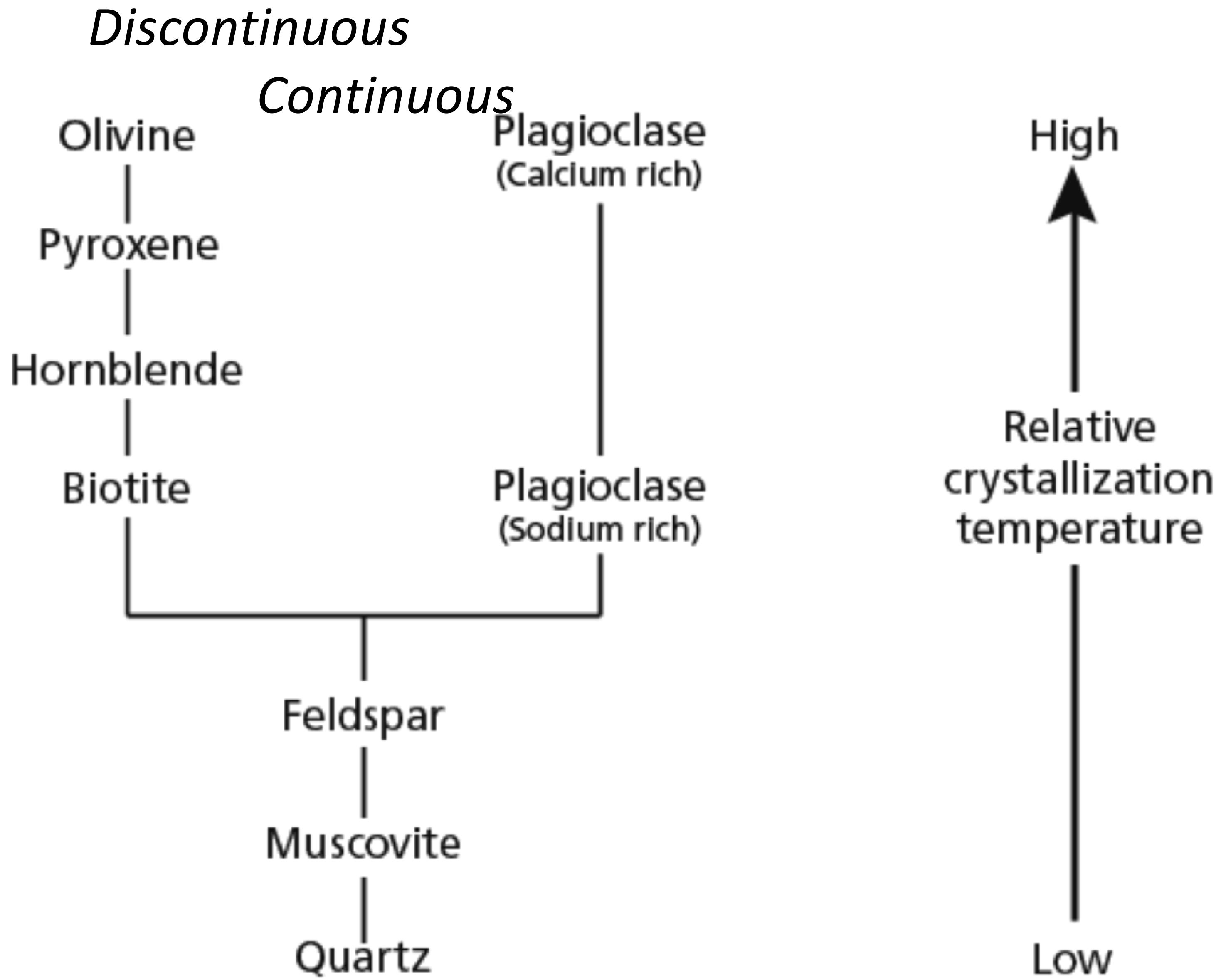
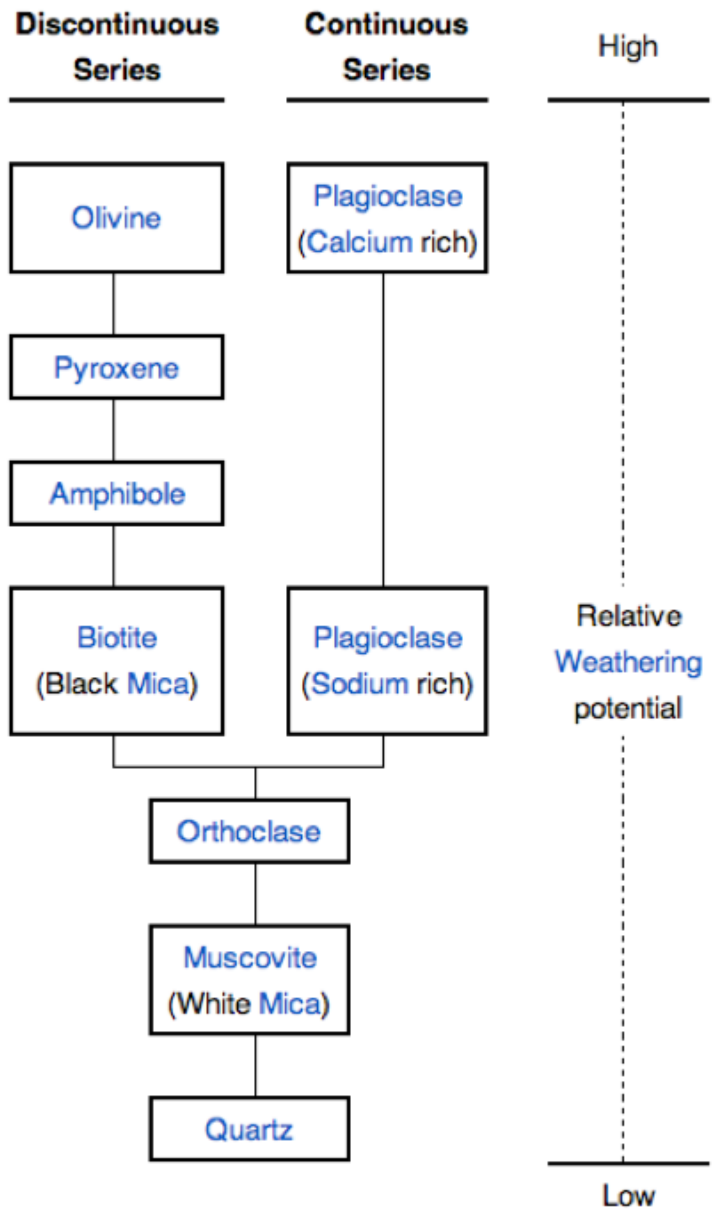


Diagram from Wikimedia Commons

Goldich's weathering series



Notice a pattern?

Diagram from Wikipedia

Solvation and solubility

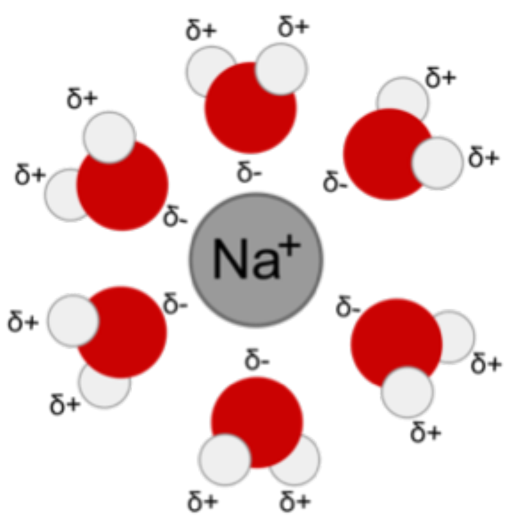


image from Taxman, Wikimedia

+1, +2, –1 charged ions, & polar molecules participate in polar, H-bonded network of liquid water

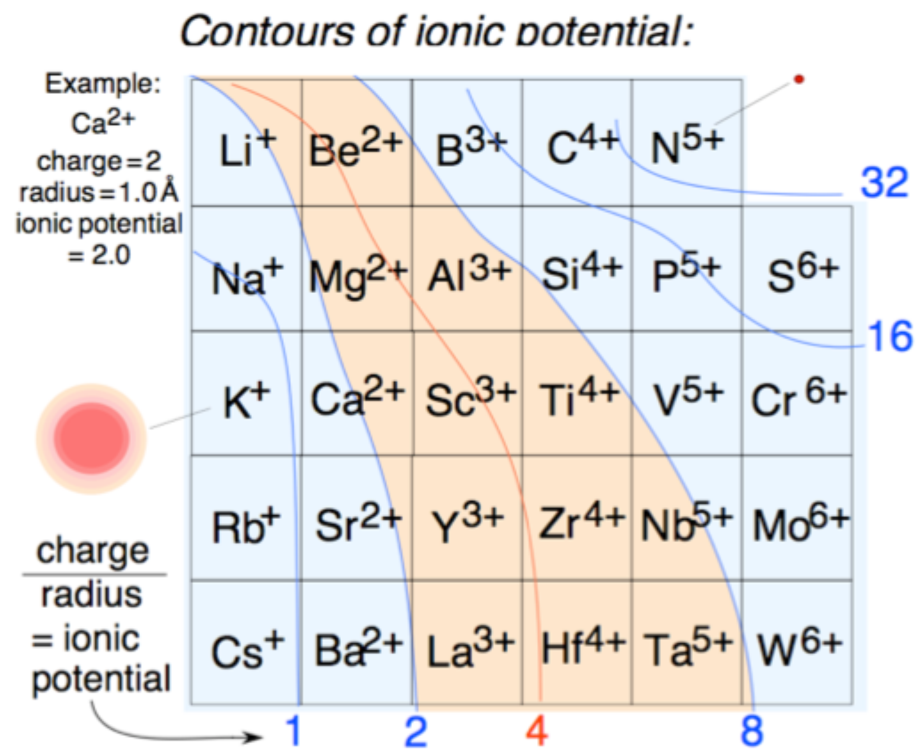


image from Railsback, U. Ga.

What happens to elements with stronger ionic potential?

Solubility “rules” from Introductory Chemistry

Solubility Rules

The following are the solubility rules for common ionic solids. If two rules appear to contradict each other, the preceding rule takes precedence.

1.Salts containing Group I elements (Li^+, Na^+, K^+, Cs^+, Rb^+) are soluble . There are few exceptions to this rule. Salts containing the ammonium ion (NH_4^+) are also soluble.

2.Salts containing nitrate ion (NO_3^-) are generally soluble.

3.Salts containing Cl^-, Br^-, or I^- are generally soluble. Important exceptions to this rule are halide salts of Ag^+, Pb^{2+}, and $(Hg_2)^{2+}$. Thus, AgCl, $PbBr_2$, and Hg_2Cl_2 are insoluble.

4.Most silver salts are insoluble. $AgNO_3$ and $Ag(C_2H_3O_2)$ are common soluble salts of silver; virtually all others are insoluble.

5.Most sulfate salts are soluble. Important exceptions to this rule include $CaSO_4$, $BaSO_4$, $PbSO_4$, Ag_2SO_4 and $SrSO_4$.

6.Most hydroxide salts are only slightly soluble. Hydroxide salts of Group I elements are soluble. Hydroxide salts of Group II elements(Ca, Sr, and Ba) are slightly soluble. Hydroxide salts of transition metals and Al^{3+} are insoluble. Thus, $Fe(OH)_3$, $Al(OH)_3$, $Co(OH)_2$ are not soluble.

7.Most oxide salts are insoluble. Important exceptions include Group 1 element oxides (Na^+, K^+, etc.)

8.Most sulfides of transition metals are highly insoluble, including CdS, FeS, ZnS, and Ag_2S. Arsenic, antimony, bismuth, and lead sulfides are also insoluble.

9.Carbonates are frequently insoluble. Group II carbonates ($CaCO_3$, $SrCO_3$, and $BaCO_3$) are insoluble, as are $FeCO_3$ and $PbCO_3$.

10.Chromates are frequently insoluble. Examples include $PbCrO_4$ and $BaCrO_4$.

11.Phosphates such as $Ca_3(PO_4)_2$and Ag_3PO_4 are frequently insoluble.

12.Fluorides such as BaF_2, MgF_2, and PbF_2 are frequently insoluble.

Also see Monroe and Abrams (1984) A perspective on solubility rules. *J. Chem. Ed.* V.61 p. 885.

They tend to disrupt the water – splitting it or agglomerating into separate clusters

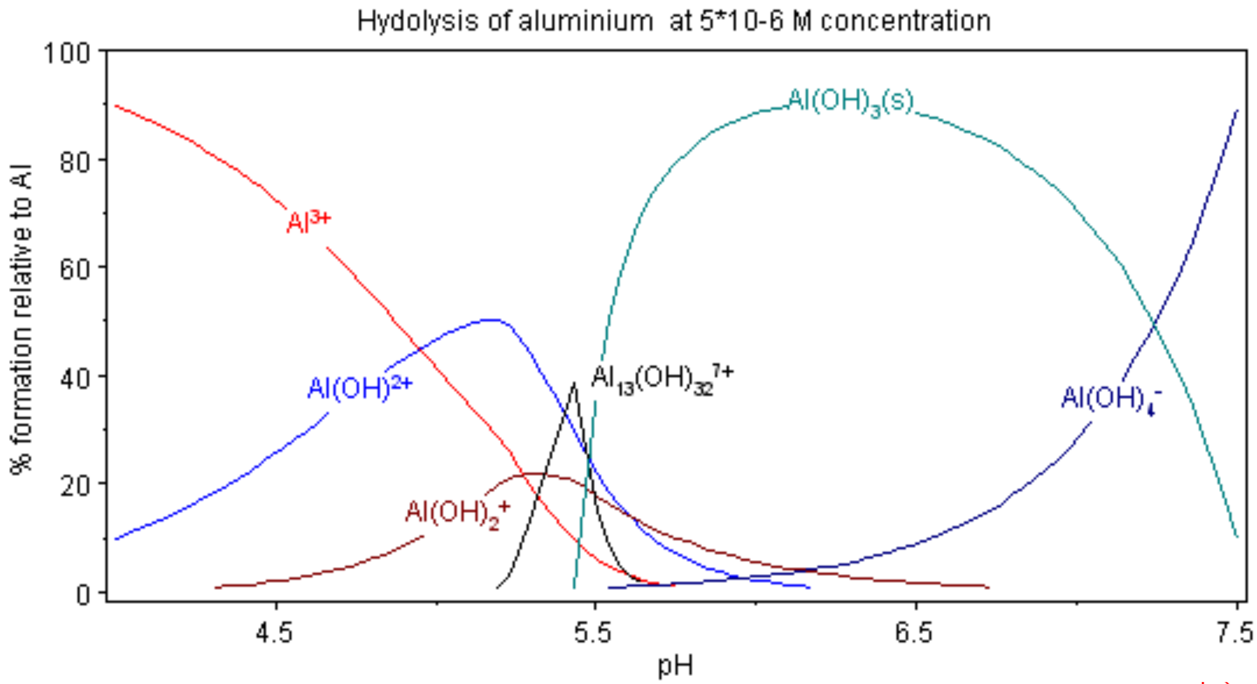
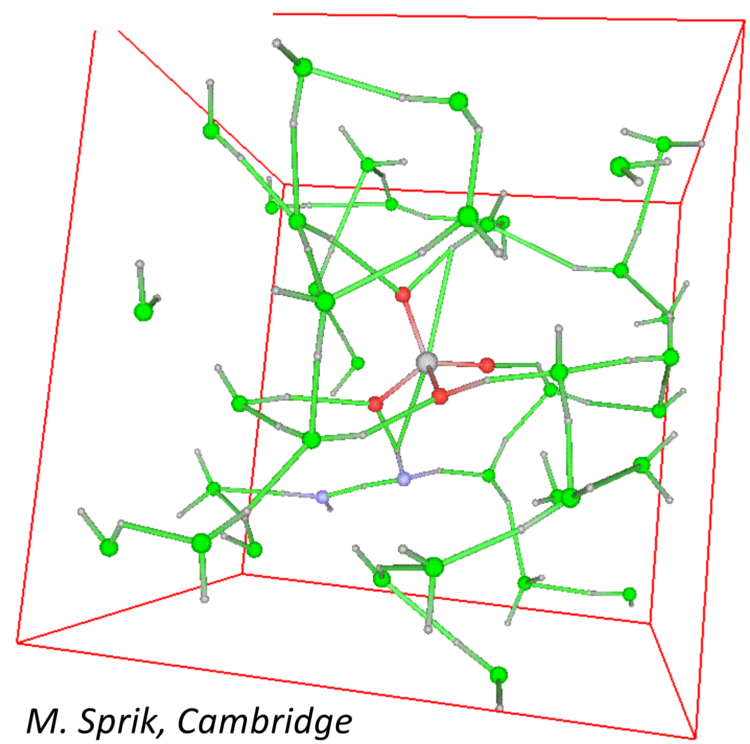


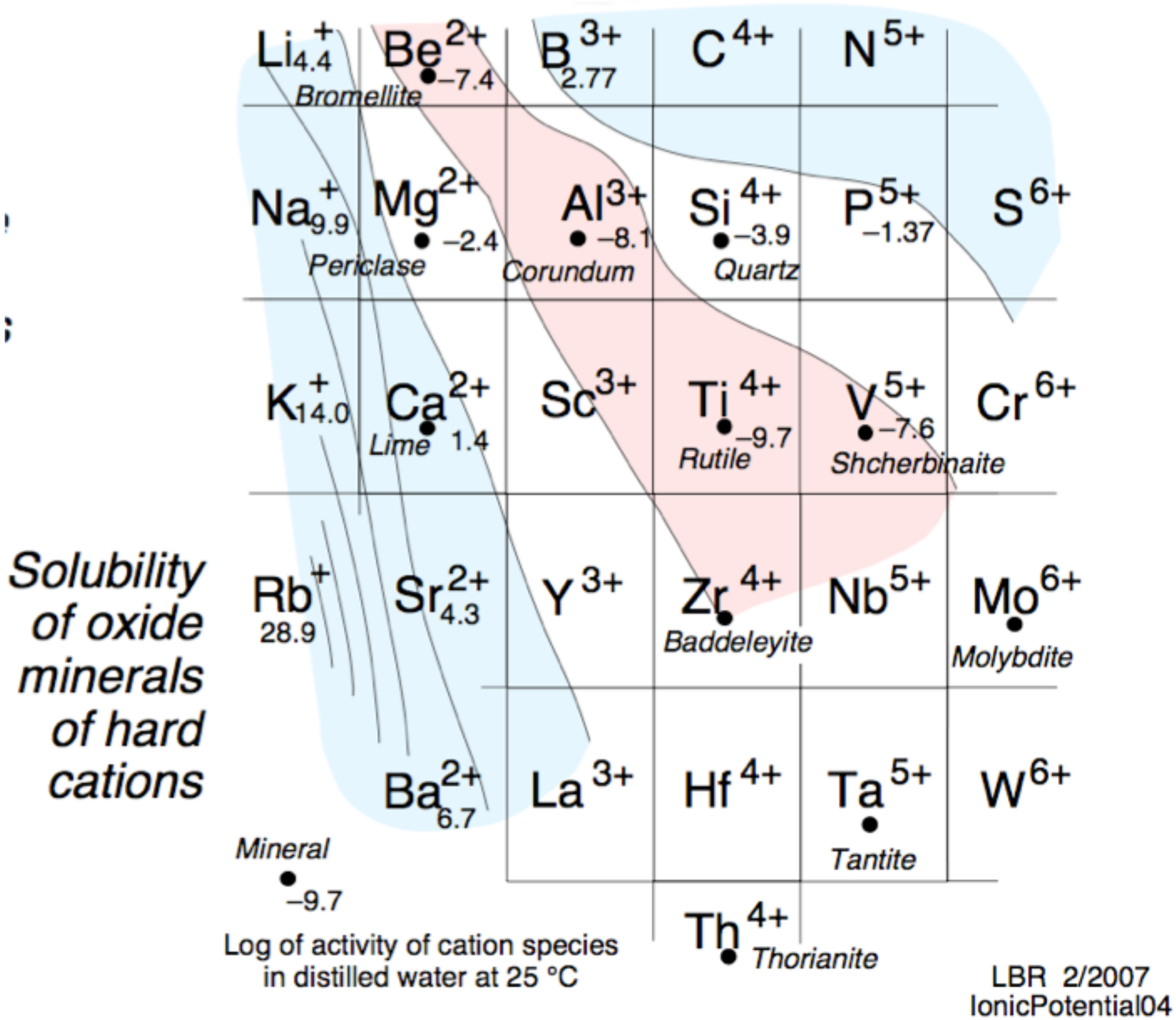
image APalmer, Wikidoc.org

Very high ionic potentials can lead to formation of oxy-ions, where the ion "steals" oxygen atoms from water to make its own sheath, e.g., $S^{6+} \rightarrow SO_4^{2-}$

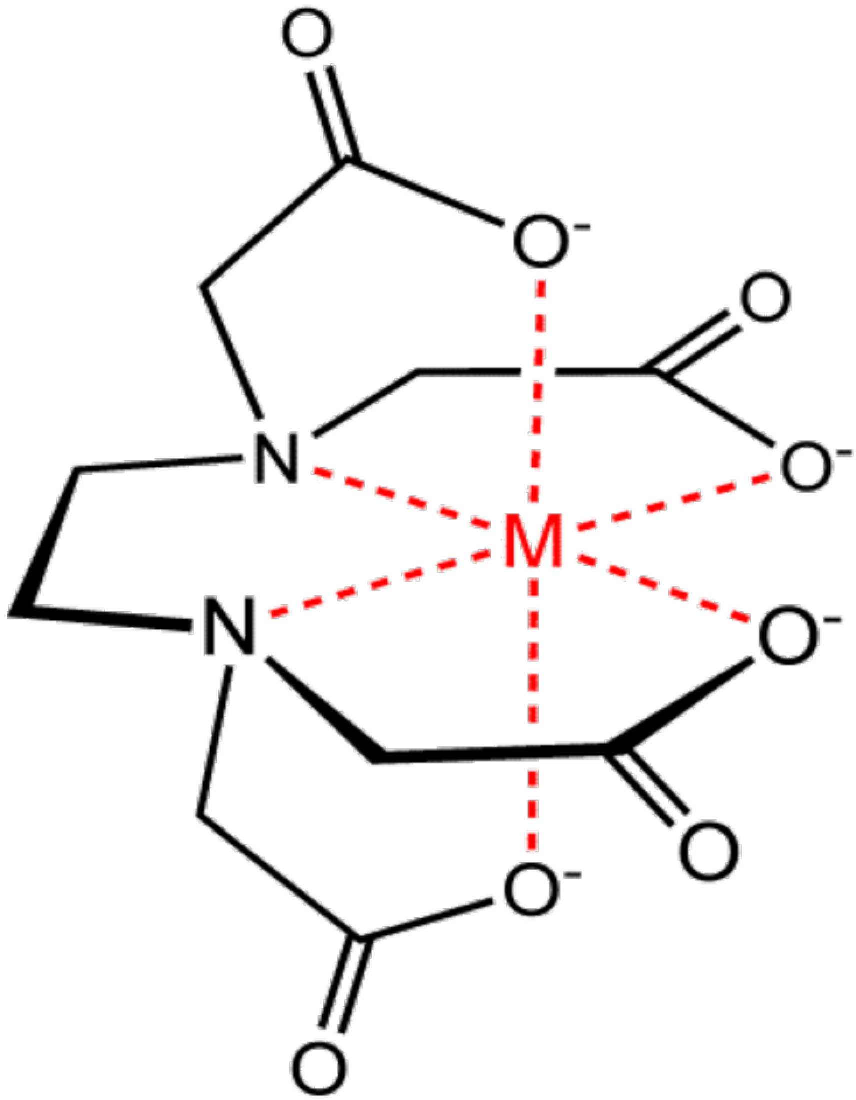
These oxyions tend to be larger, and have lower charge, and so can be highly soluble (sulfate) or sparingly soluble (phosphate, silicic acid)



M. Sprik, Cambridge



Railsback, U. Ga.



EDTA chelate of a metal cation “M”