Announcements

- **Reading: p.155-160**
- **Important not to fall behind in reading or assignments!**
- **Turn in field trip notes at the end of next week**
- **Gimme your pictures**
- **Homework 3 due May 8**

Harker diagram for Crater Lake

Closure problem!

What does this mean?

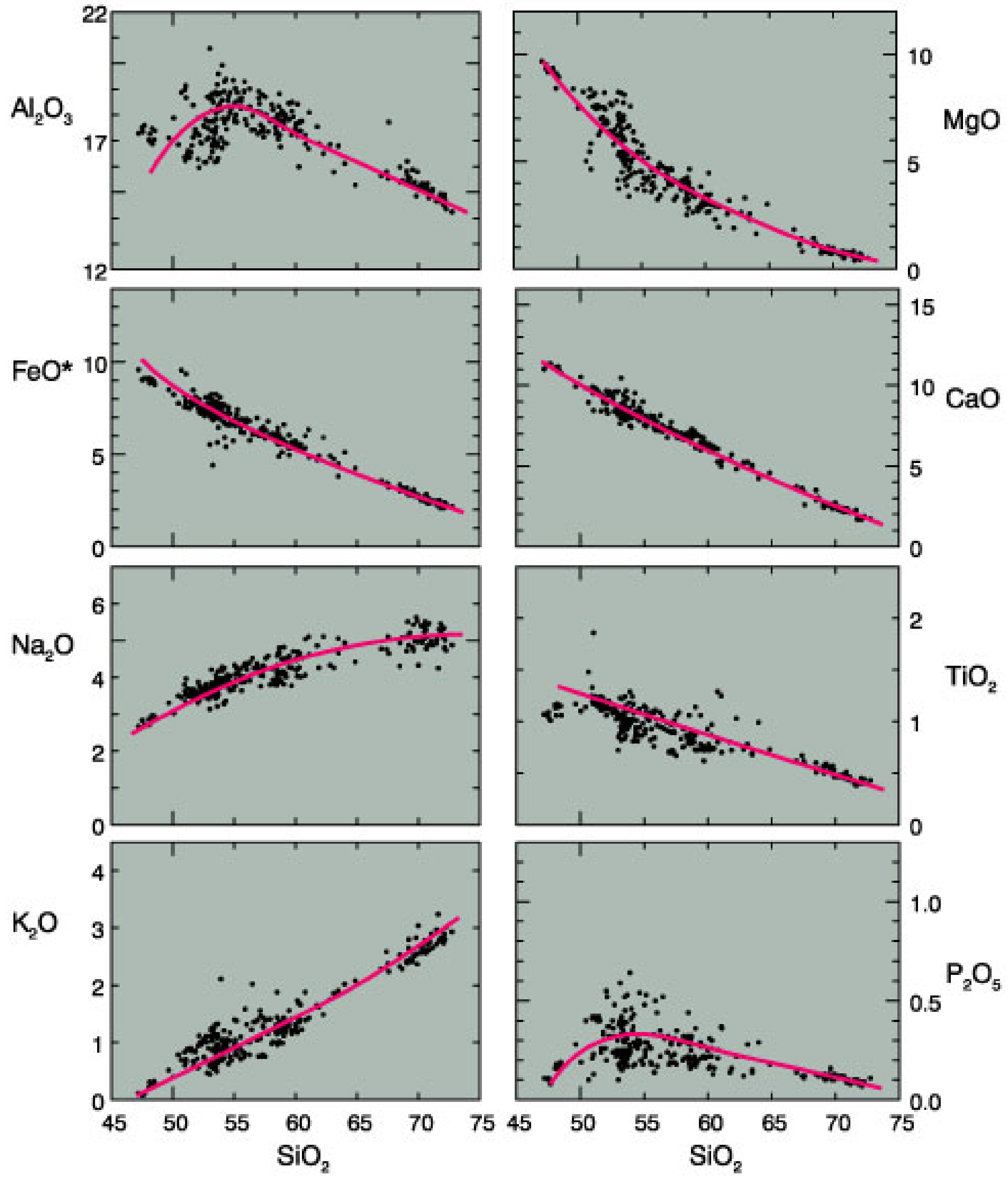


Figure 8-2. Harker variation diagram for 310 analyzed volcanic rocks from Crater Lake (Mt. Mazama), Oregon Cascades. Data compiled by Rick Conrey (personal communication).

Pearce Diagrams

- Molar units (elements or oxides)
- Ratio to a "perfectly" incompatible element (stays in melt)
- Way to test a hypothesis, or negate one
- Not a way to prove fractional crystallization

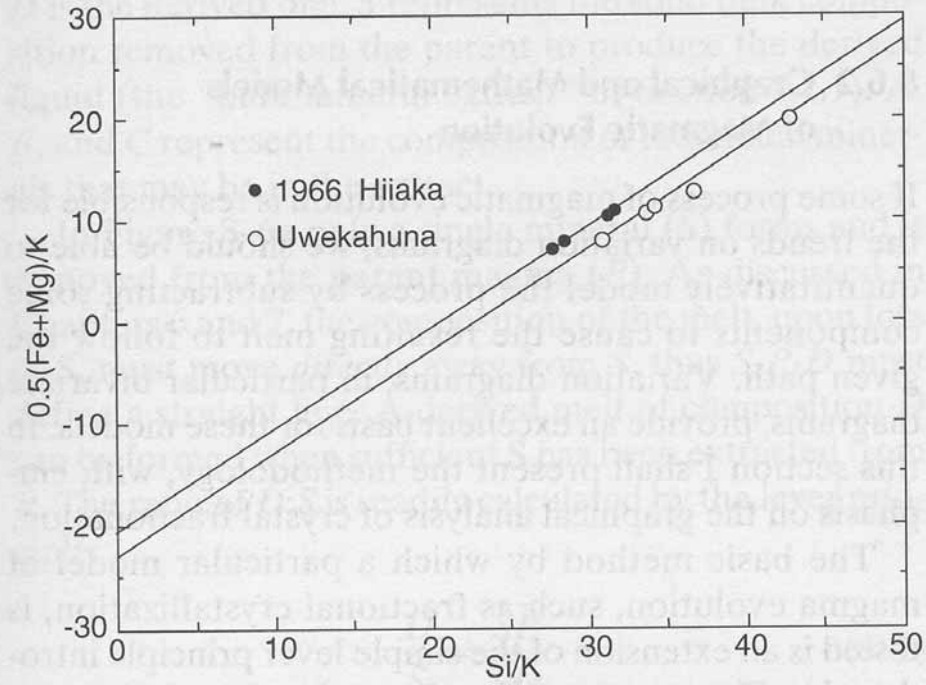


Figure 8–4 Pearce element diagram of 0.5(Fe + Mg)/K vs. Si/K for two Hawaiian picritic magma suites. From Nicholls and Russell (1990).

The Basalt Tetrahedron and the Ne-Ol-Q base

Alkaline and subalkaline fields are again distinct

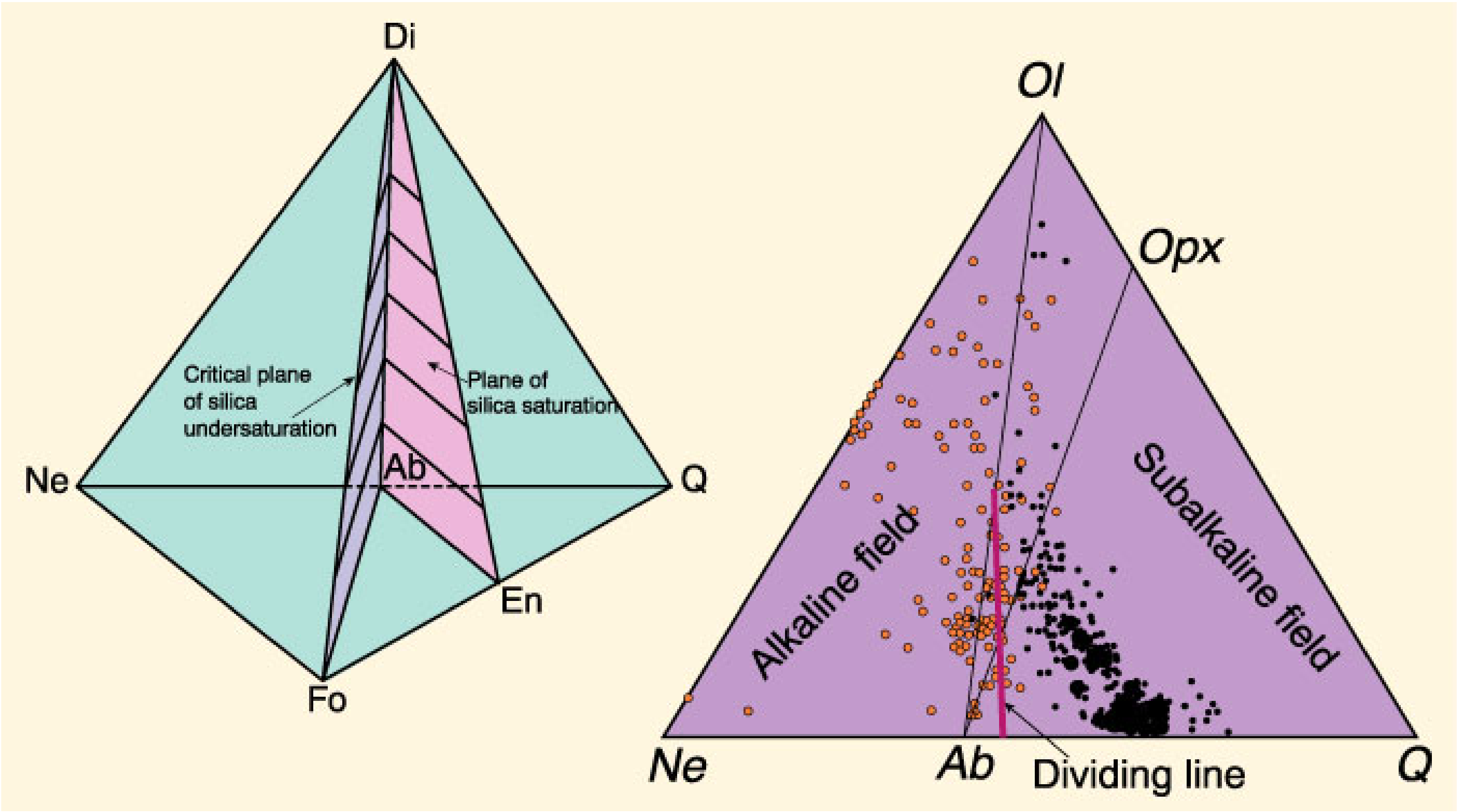
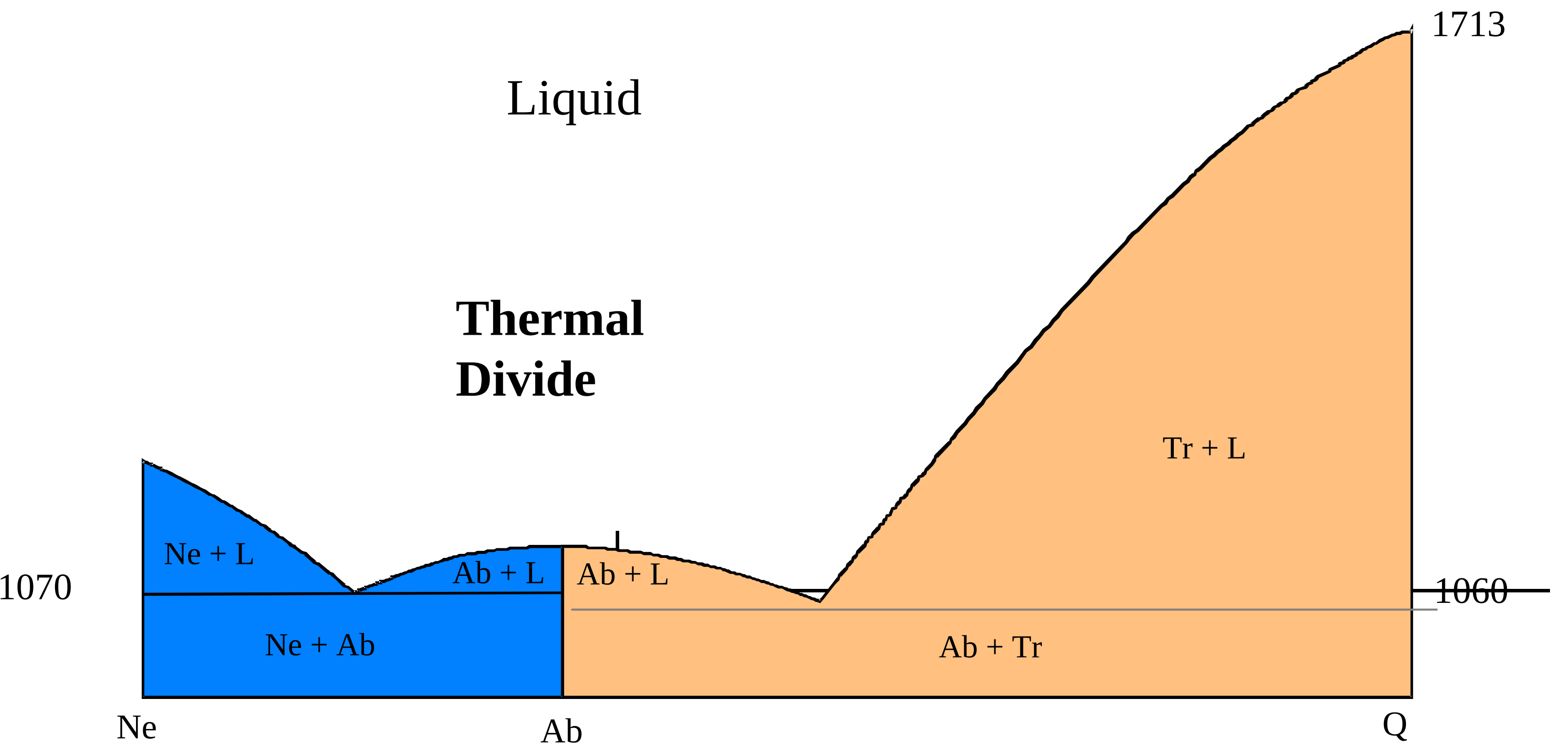
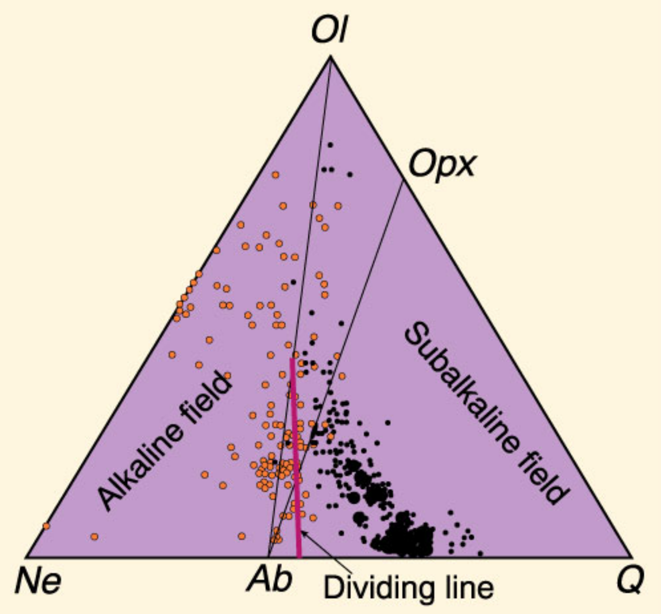


Figure 8-12. **Left: the basalt tetrahedron (after Yoder and Tilley, 1962). J. Pet., 3, 342-532. Right: the base of the basalt tetrahedron using cation normative minerals, with the compositions of subalkaline rocks (black) and alkaline rocks (gray) from Figure 8-11, projected from Cpx. After Irvine and Baragar (1971). Can. J. Earth Sci., 8, 523-548.**

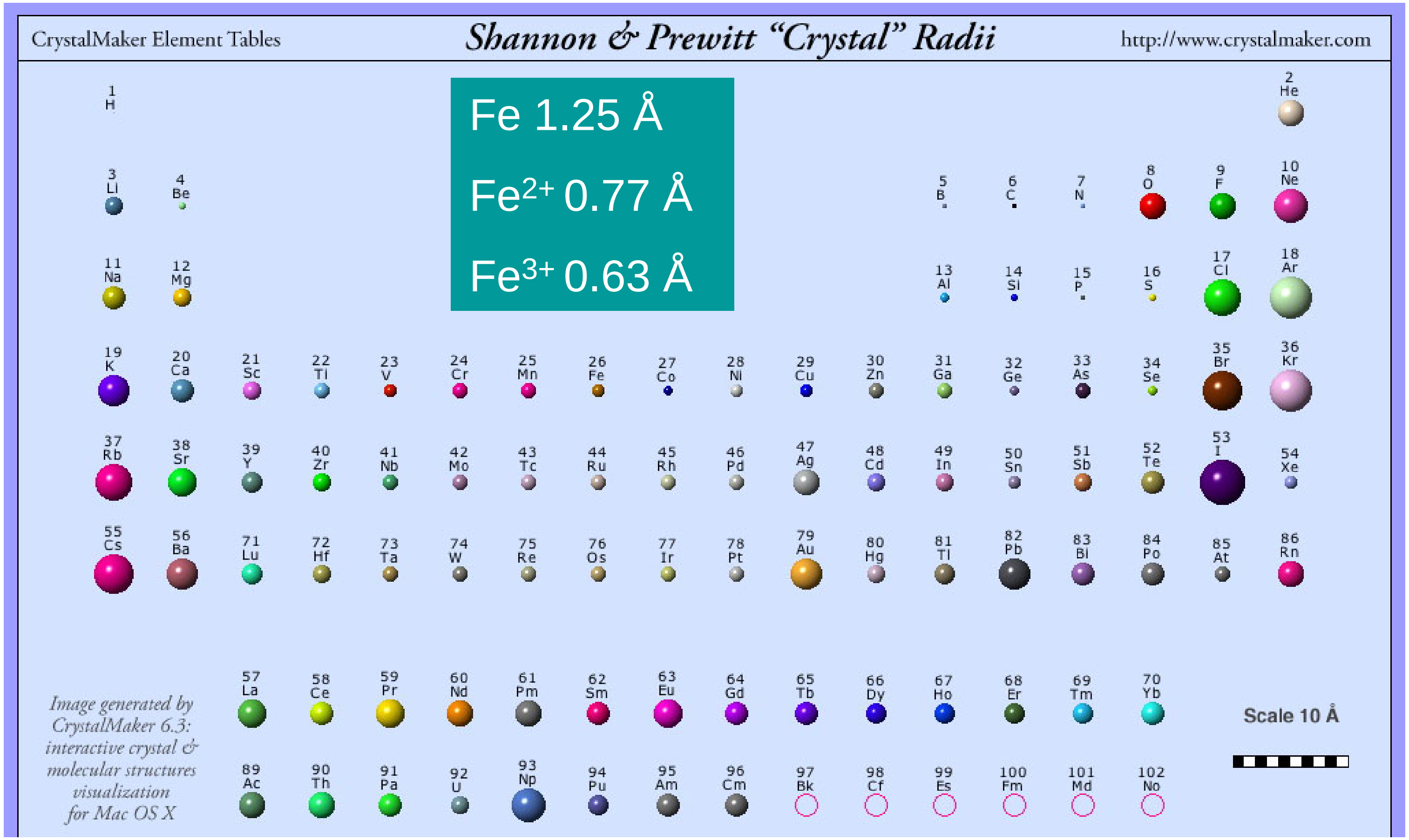


Thermal divide separates the silica-saturated (subalkaline) from the silica-undersaturated (alkaline) fields at low pressure

Cannot cross this divide by FX, so can't derive one series from the other (at least via low-P FX)

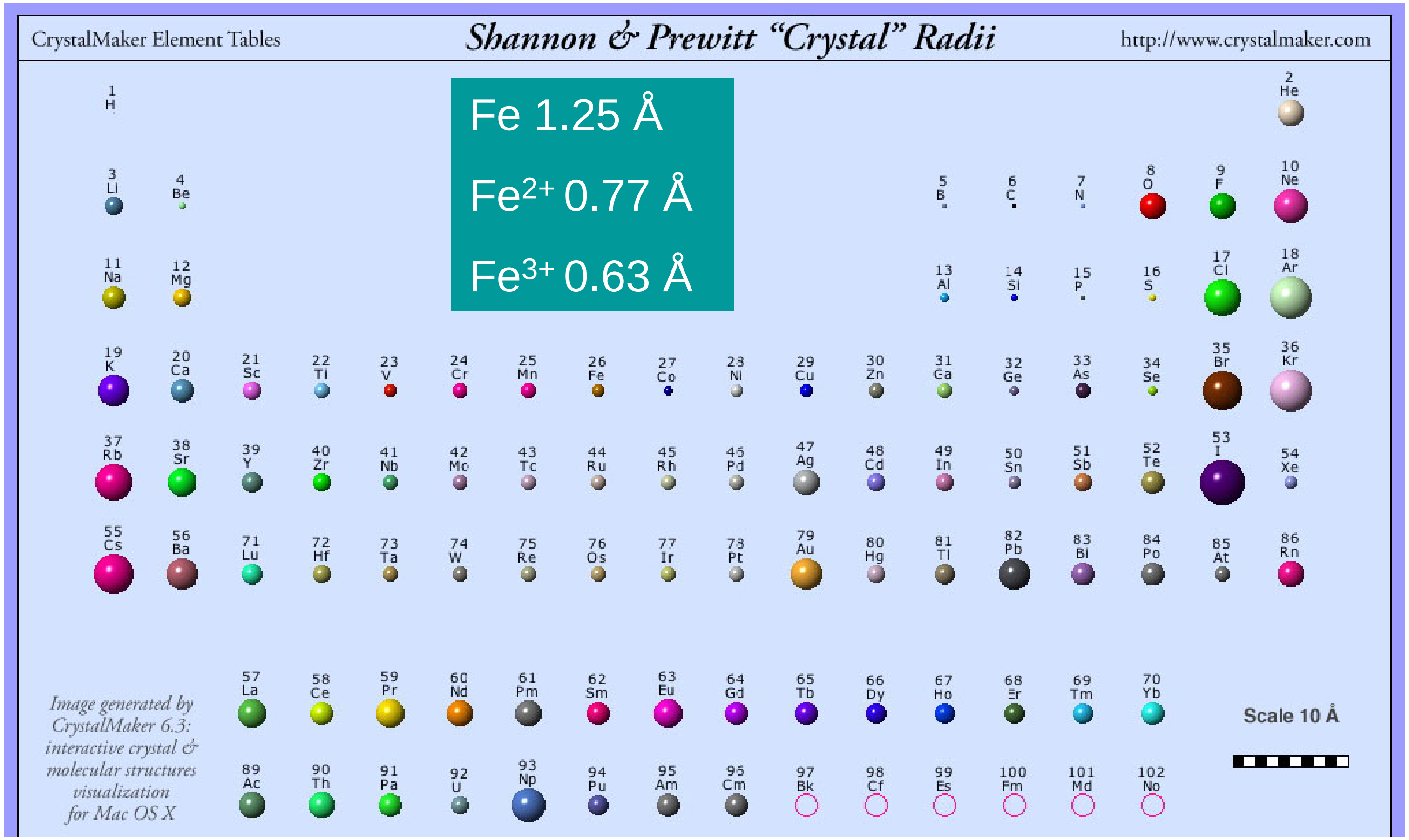


Ionic radii



- Cations are smaller than neutral atoms, anions are larger. For a given element, size decreases with increasing charge.

Ionic radii



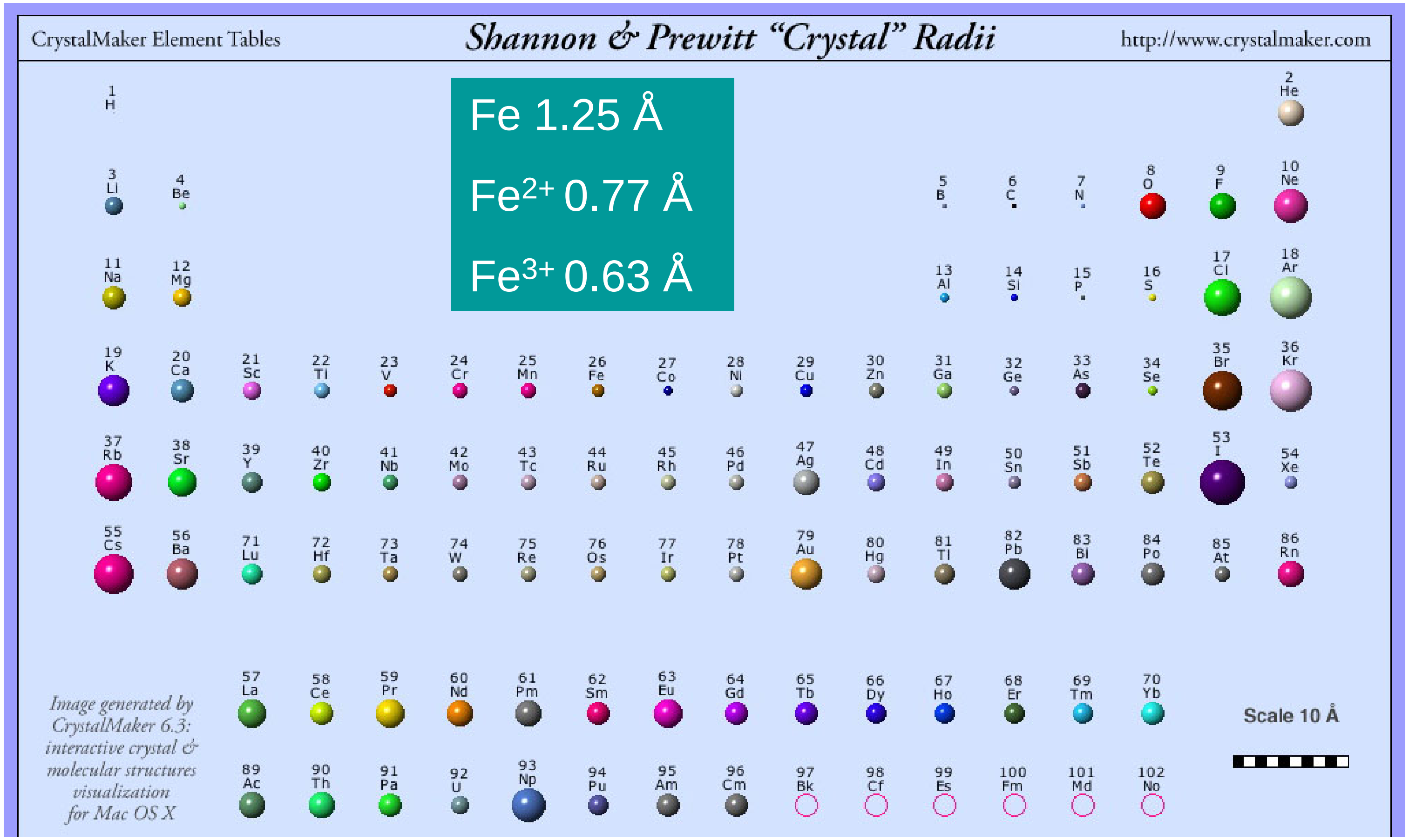
Fe 1.25 Å

Fe^{2+} 0.77 Å

Fe^{3+} 0.63 Å

- Ionic radius increases down a chemical group. Many exceptions: REE's, many d-block transition elements

Ionic radii



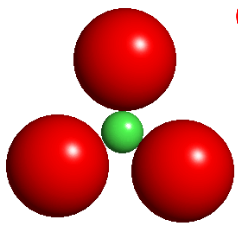
- For ions with same electronic structure within a period (i.e., Na^{+}, Mg^{2+}) size decreases with increasing charge (increasing attractive charge of nucleus)

Pauling's Rules

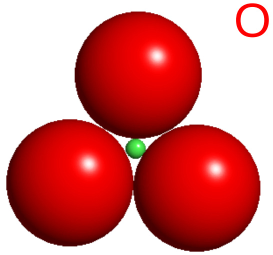
- Basic mineral structures can be understood by looking at the relative sizes and the charges of different elements in their common oxidation states!
- Nobel Prize in Chemistry 1954:
  - "for his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances"
- Nobel Peace Prize 1962

Pauling's Rules

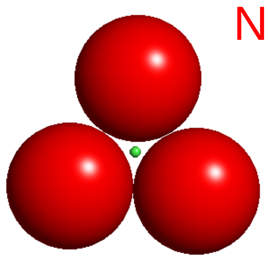
OK



OK



NO!

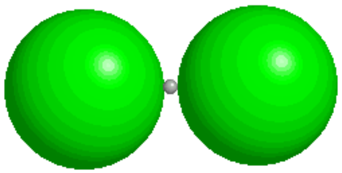


1. The Coordination Principle

- Cation-anion distance is determined by the sum of the cation and anion radii
- Number of anions coordinating with cation is determined by relative size of cation and anions.
  - Cations want to fit snugly in anions- equal bonding environments for all.
  - Assumptions!

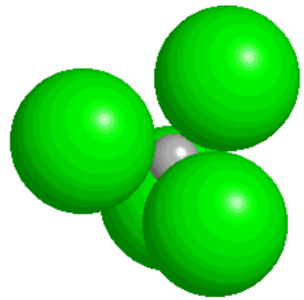
Pauling's Rules

RR = Rc/Ra



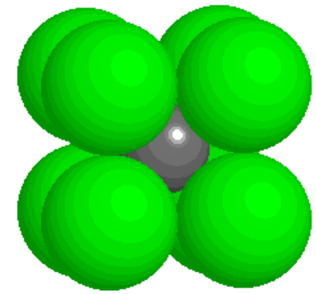
CN = 2

RR < 0.155



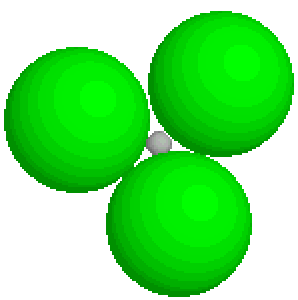
CN = 4

RR = 0.225-0.414



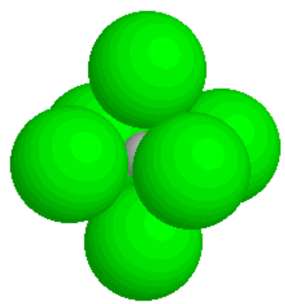
CN = 8

RR = 0.732-1



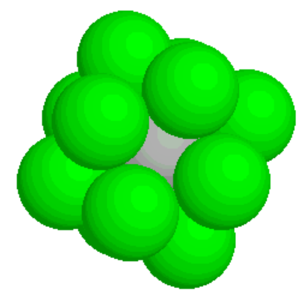
CN = 3

RR = 0.155-0.225



CN = 6

RR = 0.414-0.732



CN = 12

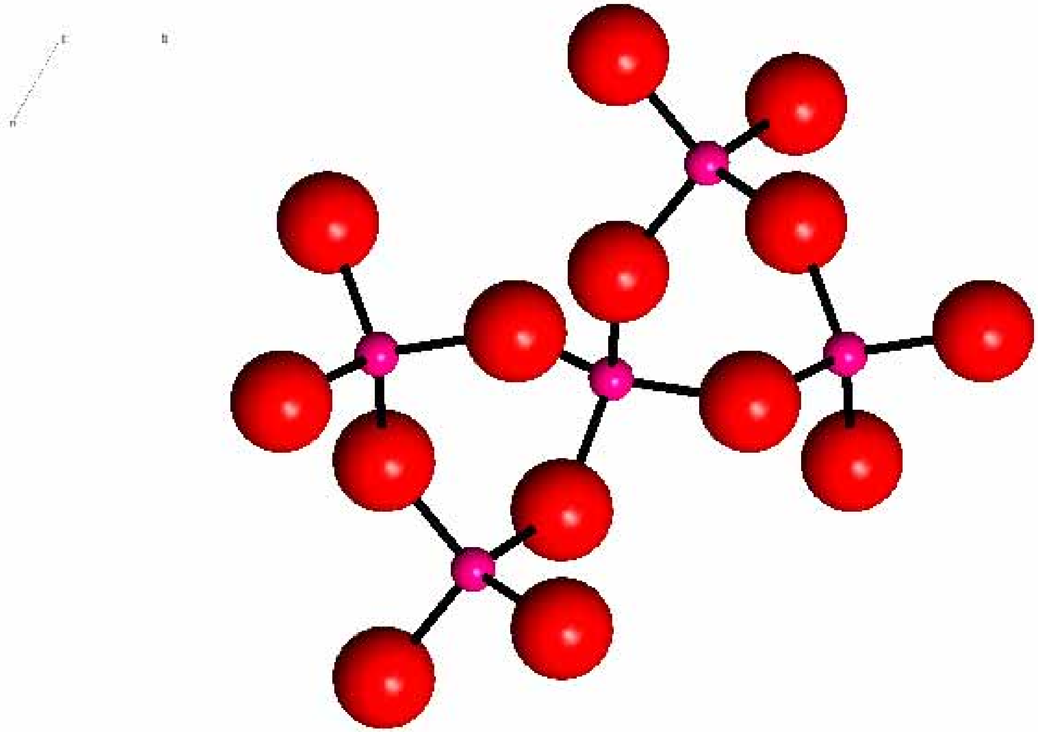
RR ~ 1

UA Downs

Pauling's Rules

2. The Electrostatic Valency Principle

Total strength of valency bonds that reach an anion from all neighboring cations = charge of anion.



Pauling's Rules

3. Sharing of Polyhedral Elements I

The stability of ionic structures is decreased when coordination polyhedra share edges and faces.

Melting temperature of

Forsterite = 1890 °C

Enstatite = 1550 ° C

4. Sharing of Polyhedral Elements II

In a crystal containing different cations, large valence, small CN cations tend not to share polyhedral elements with each other.

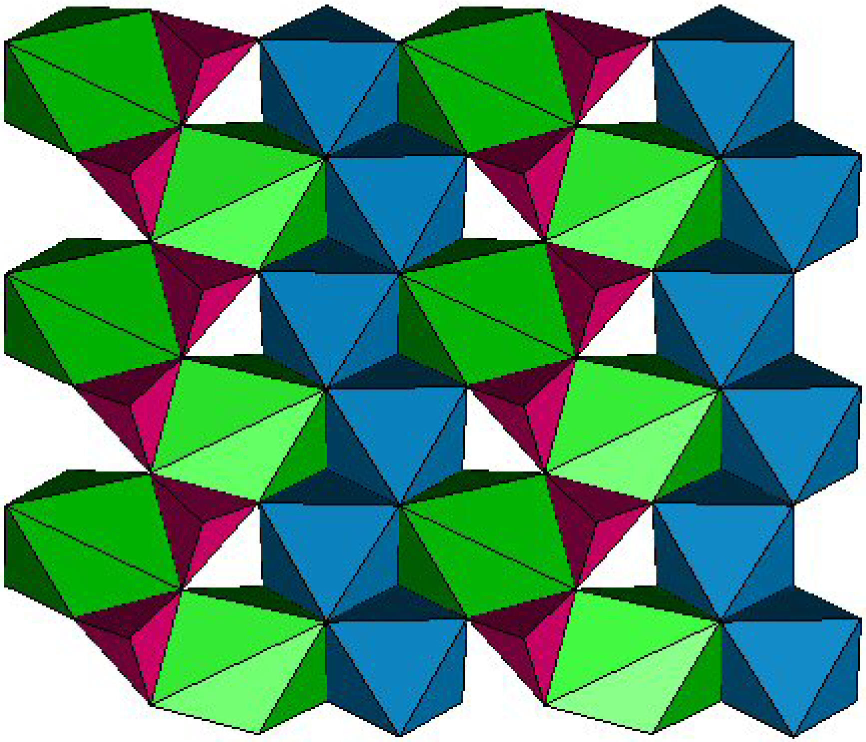
More than half of ionic charge is occupied with small, highly-charged cation: CO_3^{2-}, PO_4^{3-}

Pauling's Rules

5. Principle of Parsimony

Nature tends towards simplicity!

Mineral structures tend to be simple, with only one or a few different cation sites – but each may be accommodate many different cations.



M1 = Mg, Fe^{2+}, Fe^{3+}, Al

M2 = Mg, Fe^{2+}, Ca, Na, Li

Goldschmidt’s Rules: general guidelines

Cation A^{X+}:

Radius = R_A
Charge = X

Cation B^{Y+}:

Radius = R_B
Charge = Y

- Partition coefficient: K_D or D $_{(mineral\text{-}melt)}$

$K_D^A = [A]_{mineral}/[A]_{melt}$

$K_D^B = [B]_{mineral}/[B]_{melt}$

$R_A \sim R_B$

$K^A \sim K^B$

+2 +2

If radii are the same but charges are different (X > Y)

$R_A \sim R_B$

$K^A > K^B$

+3 +2

If charges are the same (X = Y) but radii are different

$R_A > R_B$

$K^A < K^B$

+2 +2

Example: olivine

- Na : 0.02
- Mg : 6.1
- Ni : 14

- Expect to see a Na olivine? Ni?

- Partition coefficient: K_D or D (mineral-melt)

$K_D^A = [A]_{mineral}/[A]_{melt}$

$K_D^B = [B]_{mineral}/[B]_{melt}$