Mineral Physics Lectures Overview:

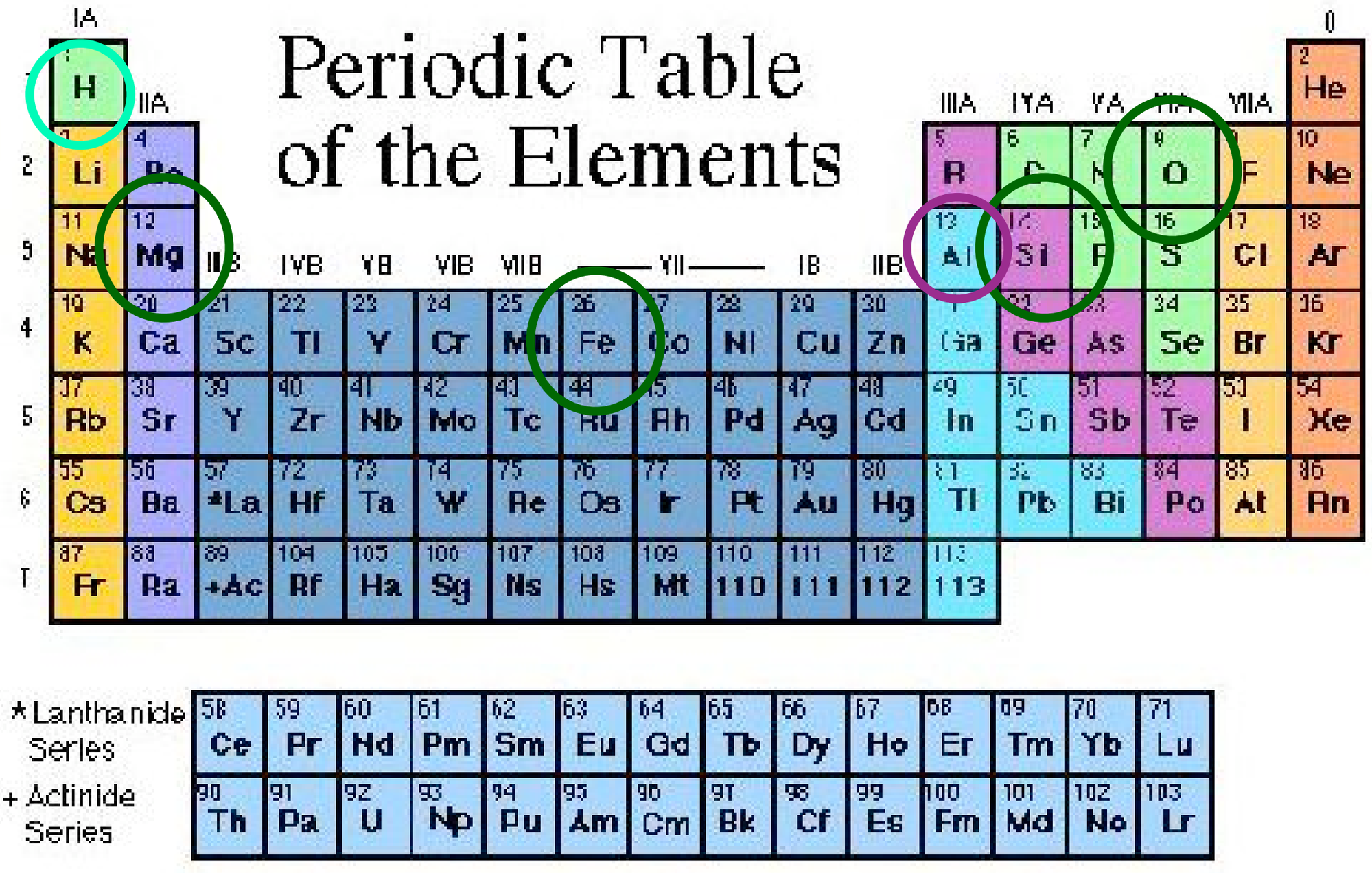
1. Overview of Earth Materials (L)
2. Deep Earth Mineralogy (A)
3. Thermodynamics (L)

4. Elasticity (A)
5. Lattice Dynamics (L)
6. Transport Properties (A)

7. Ab Initio Methods (L)
8. Experimental Challenges (A)
9. “building a planet” (L&A)

Earth Mineralogy:

1. ions and radii
2. X-ray diffraction review
3. Pauling's rules
4. Pressure trends
5. Earth mineralogy
6. Post-perovskite phase transformation?

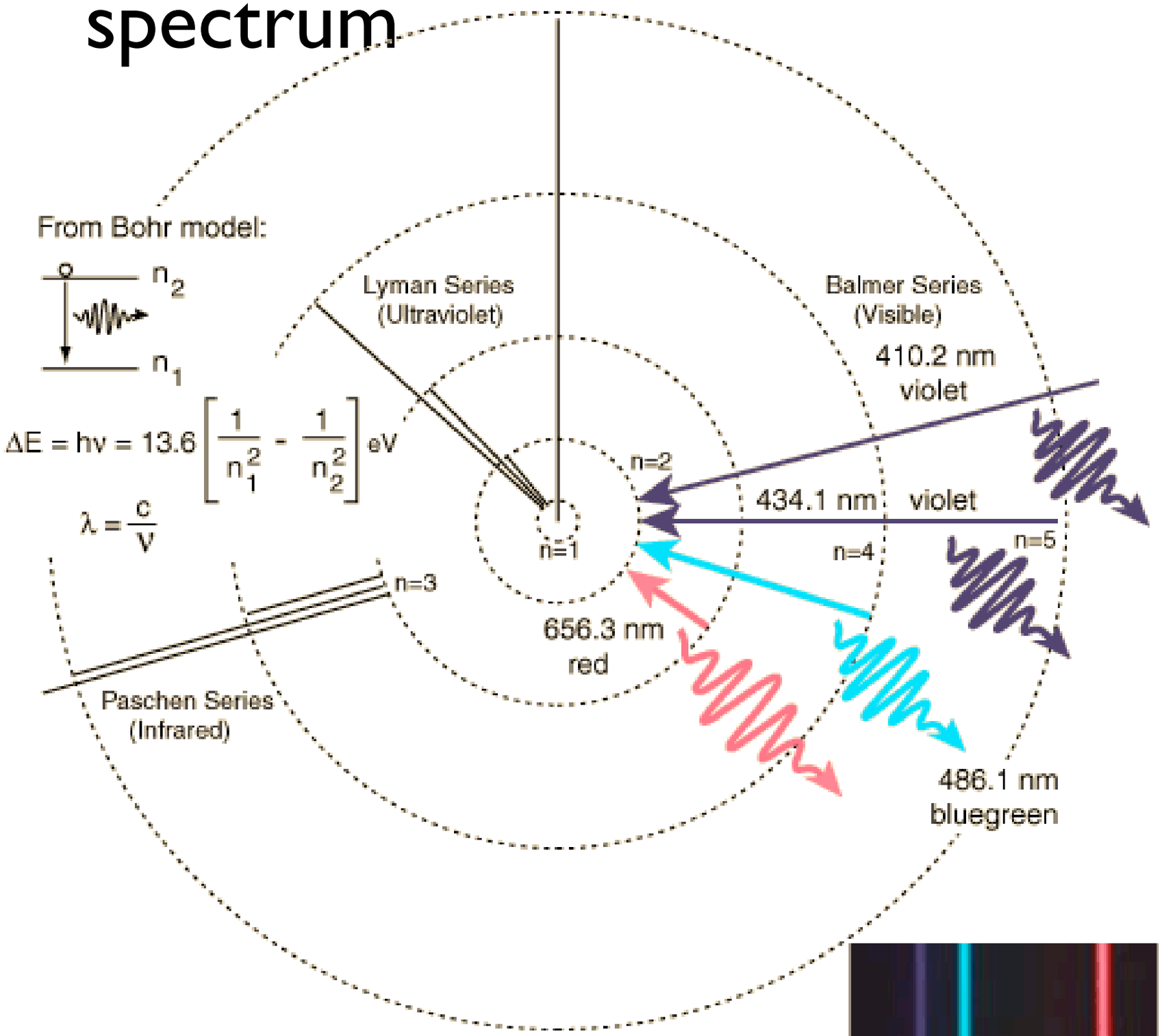


today: Fe in core/ O, Si, Mg in mantle

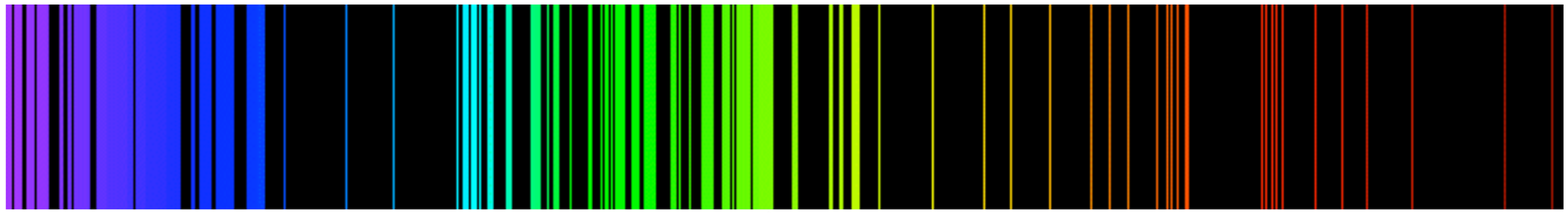
Al--elasticity lecture

H--rheology (transport) lecture

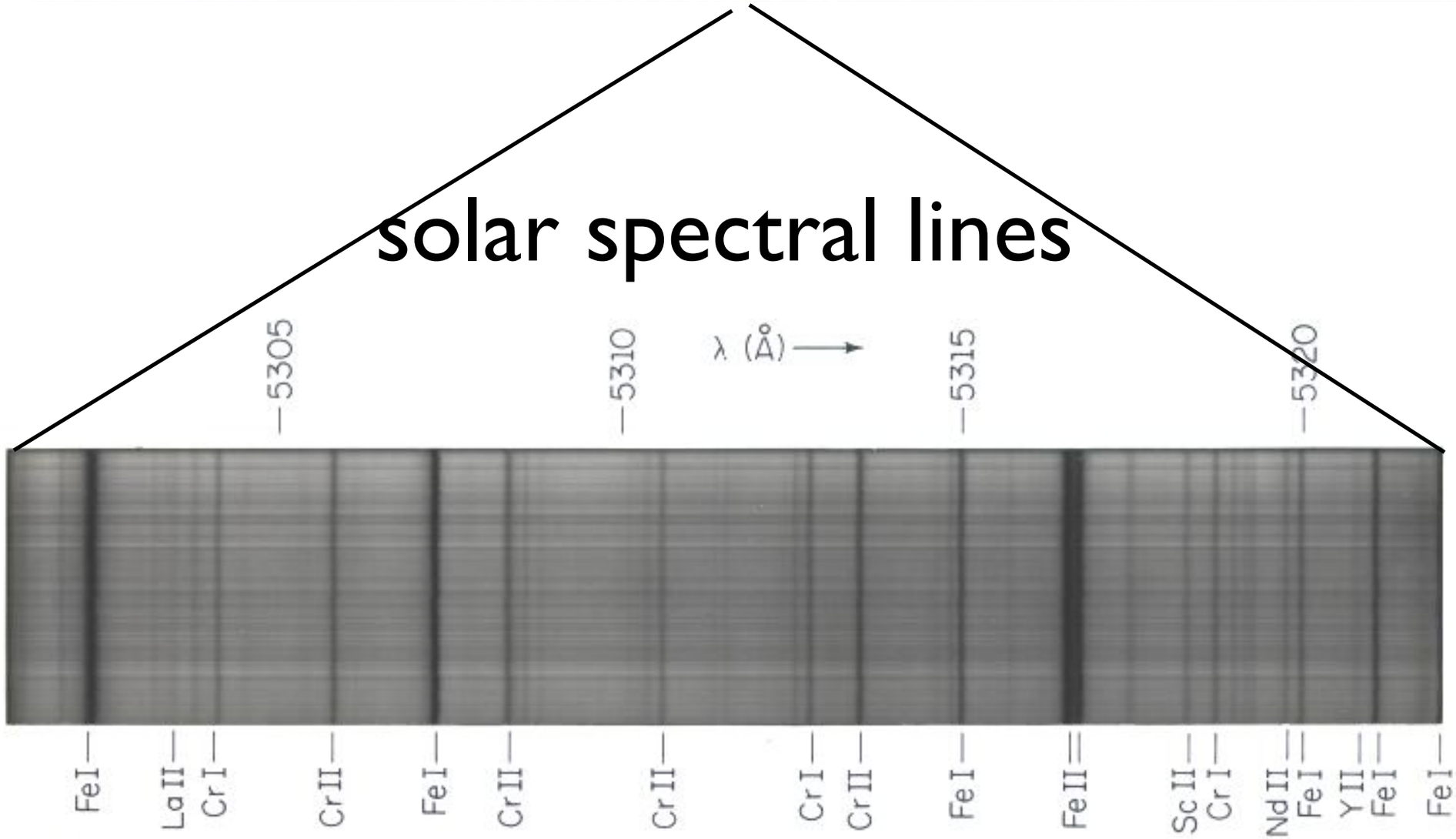
hydrogen spectrum



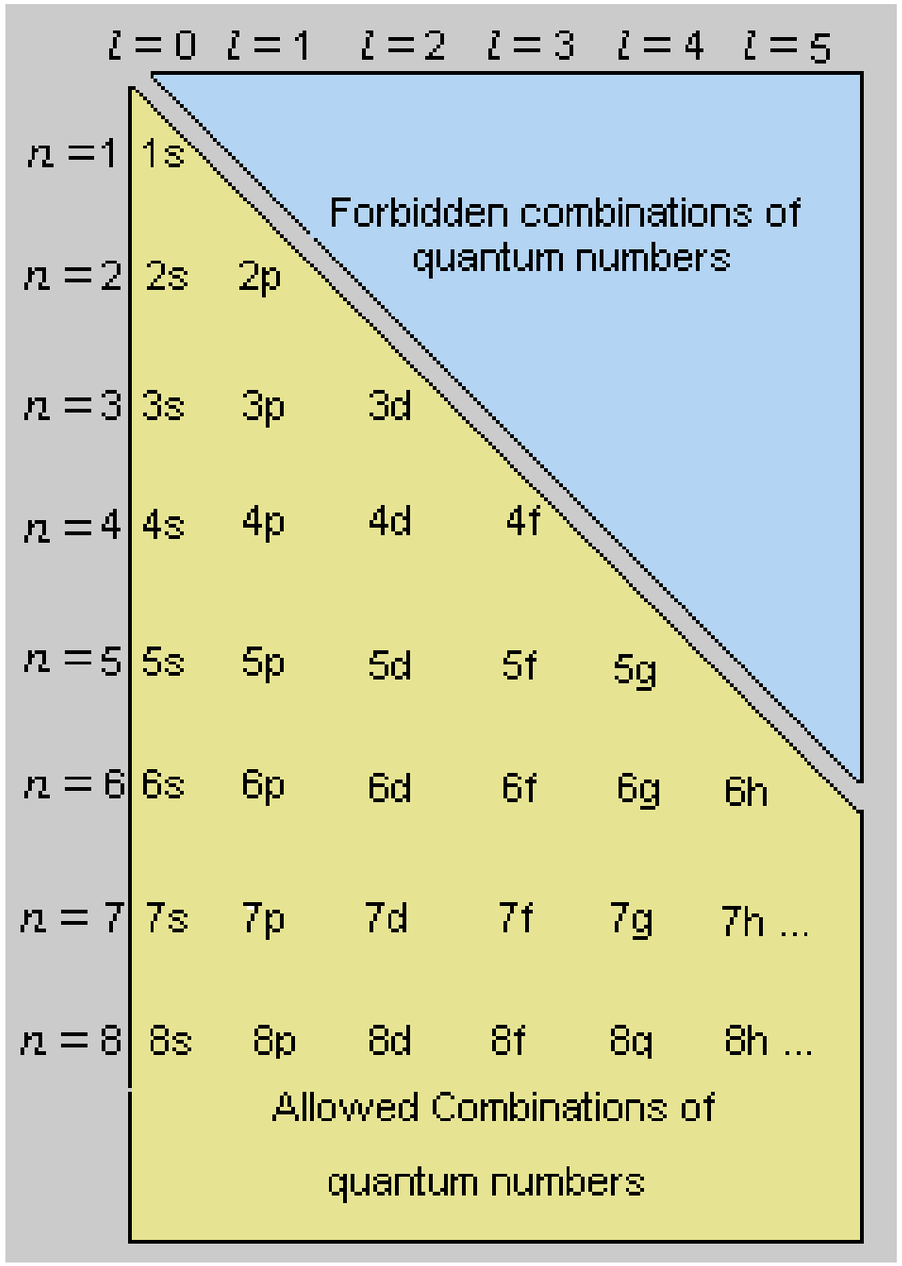
emission spectra of Fe

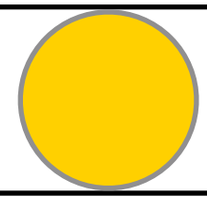
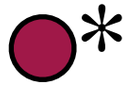


solar spectral lines

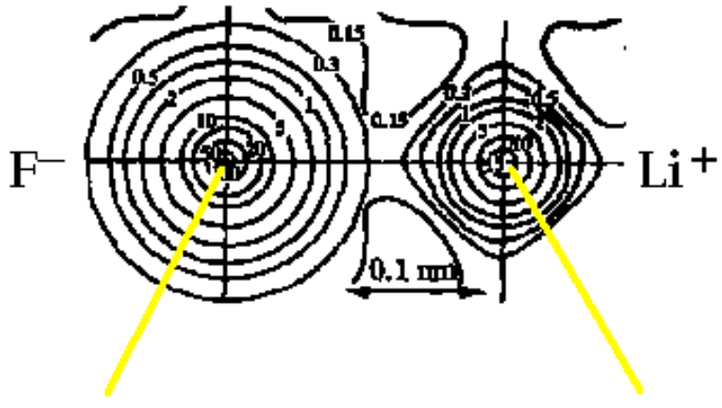


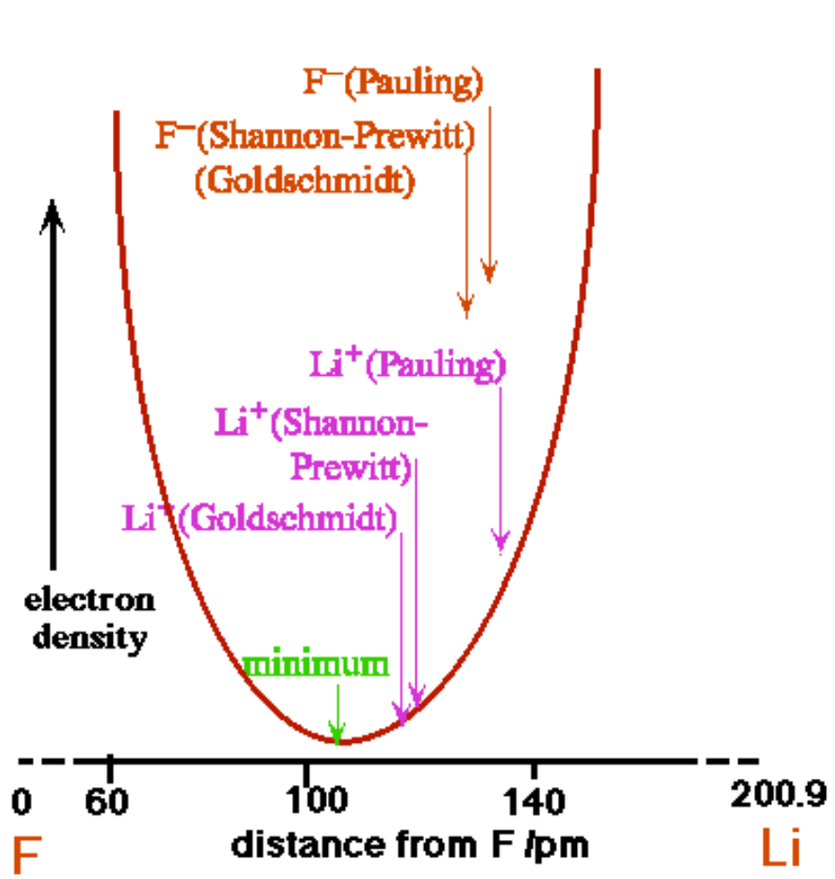
electronic structure: hund's rules



element	electron configuration	ionic radius
O	$1s^2 2s^2 2p^4$	
Si	$1s^2 2s^2 2p^6 3s^2 3p^2$	
Mg	$1s^2 2s^2 2p^6 3s^2$	
Fe*	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$	

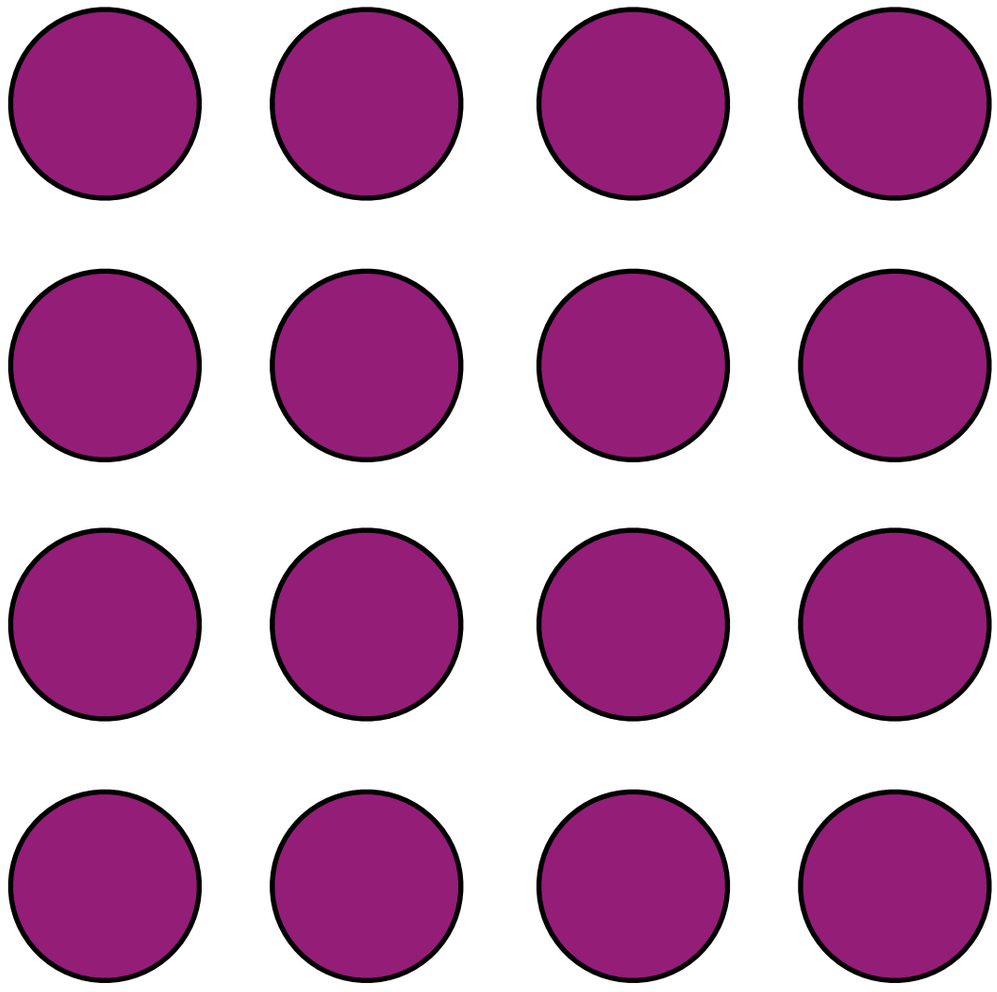
how are ionic radii determined?

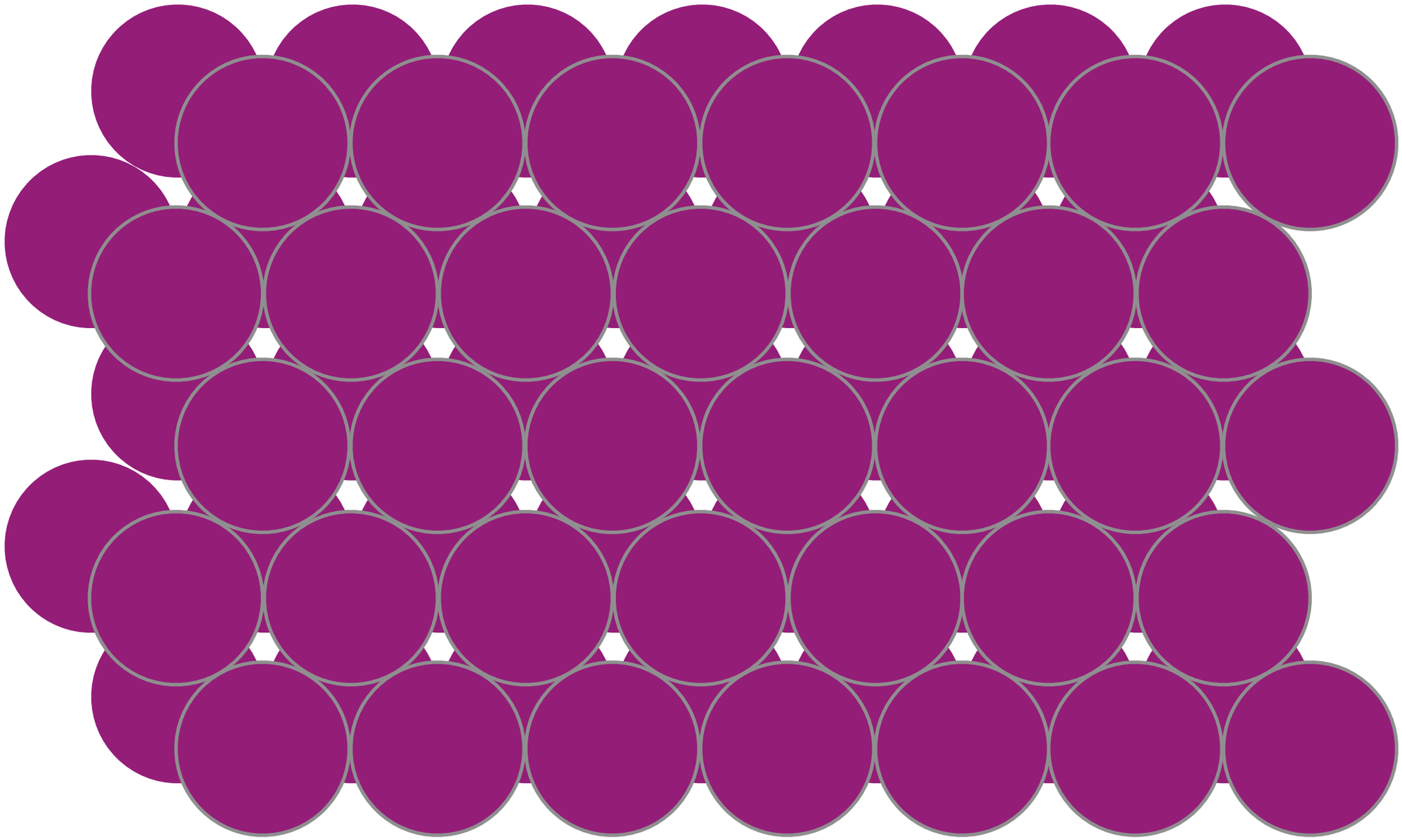




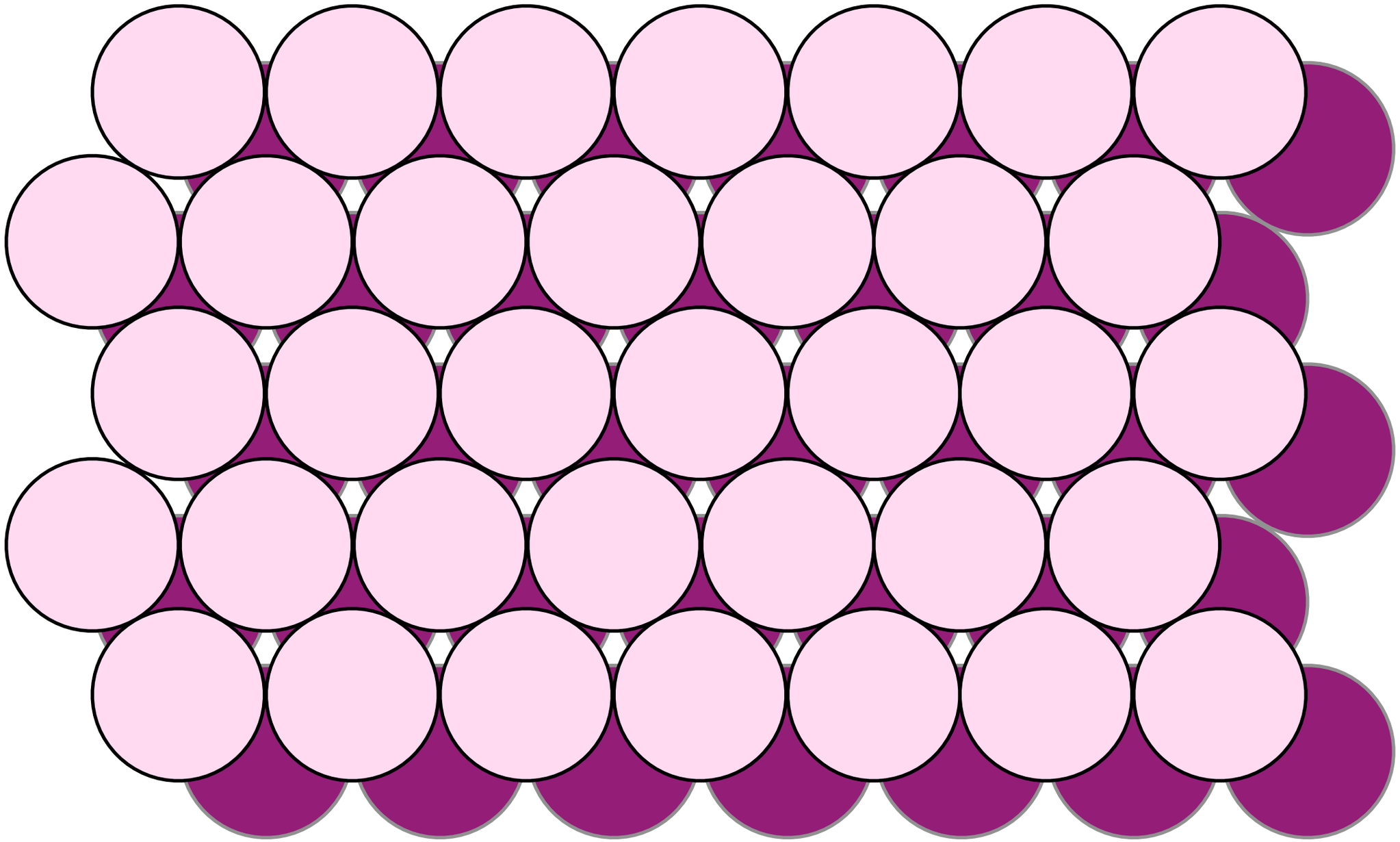
Goldschmidt & Pauling rules for creating structures:

1. geometric considerations
2. charge neutrality
3. Other effects

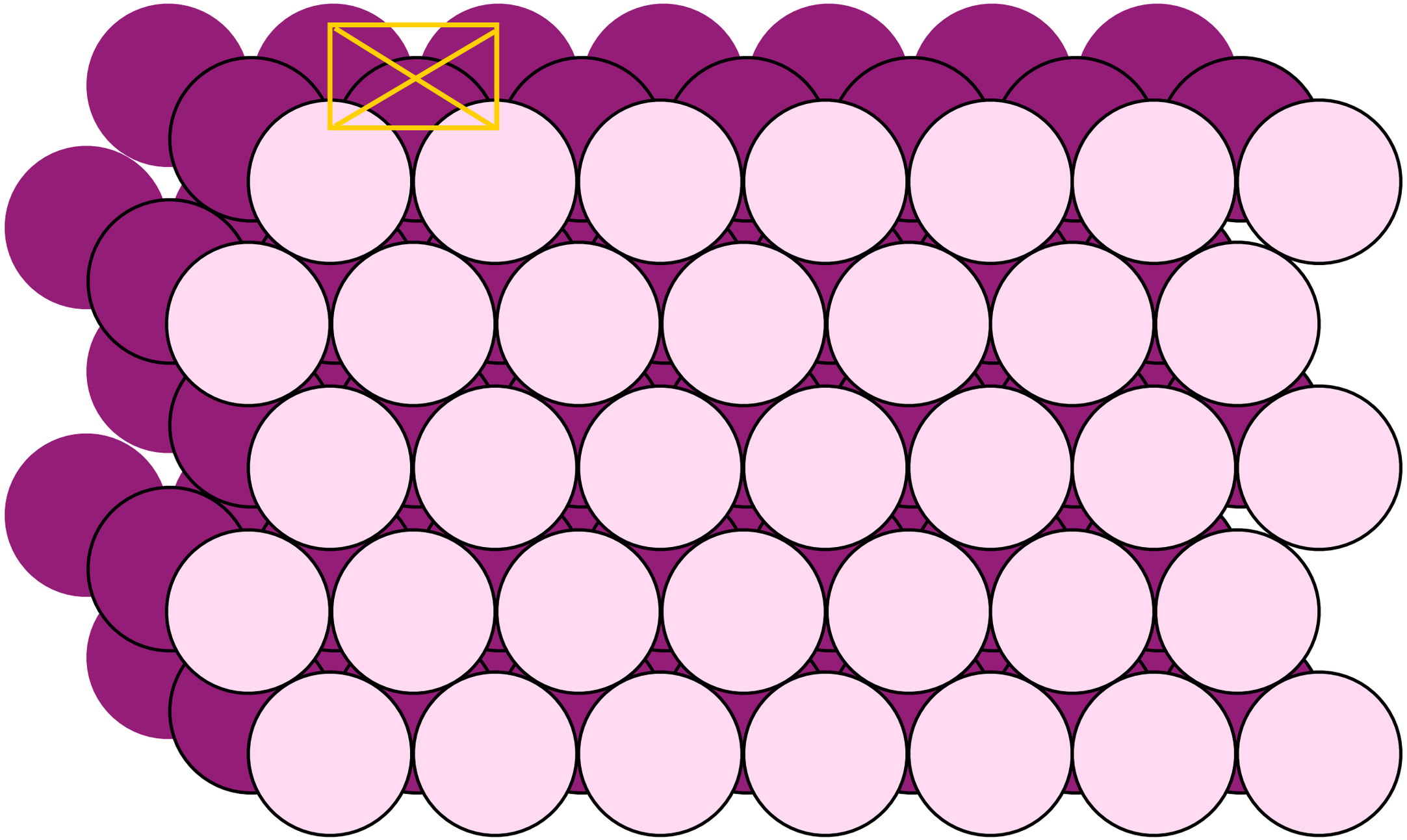




A B



A B A B... hexagonal close packed



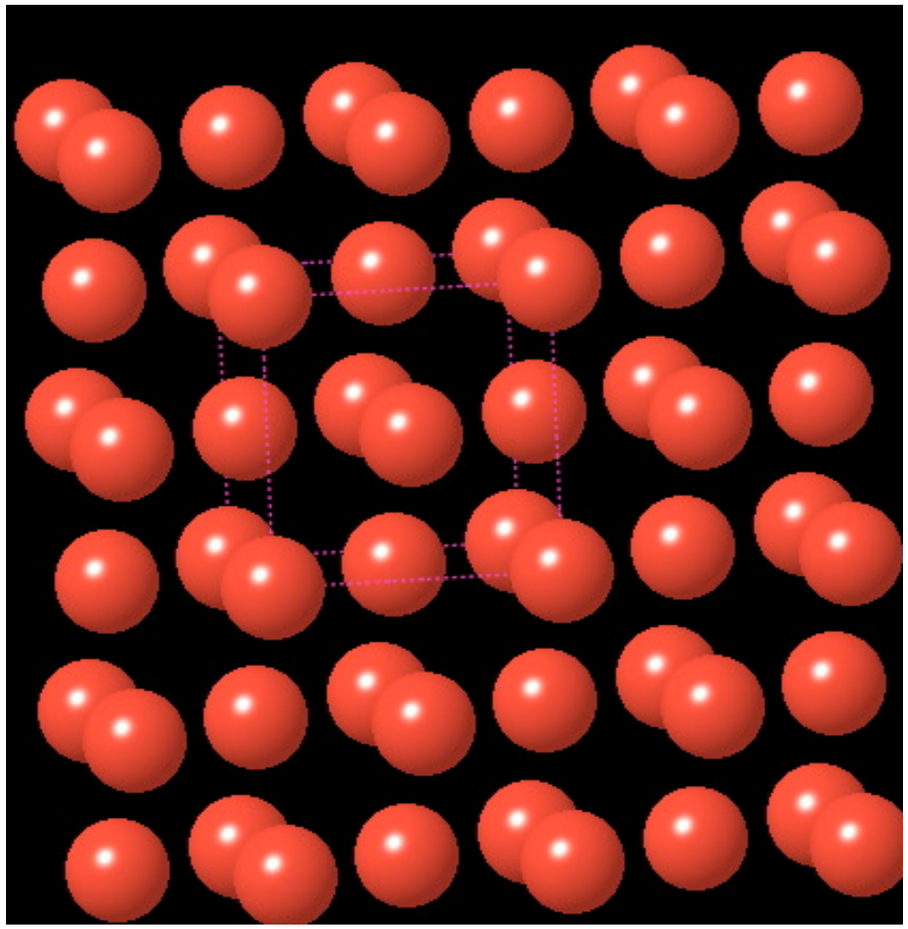
A B C A B C...

cubic close packed

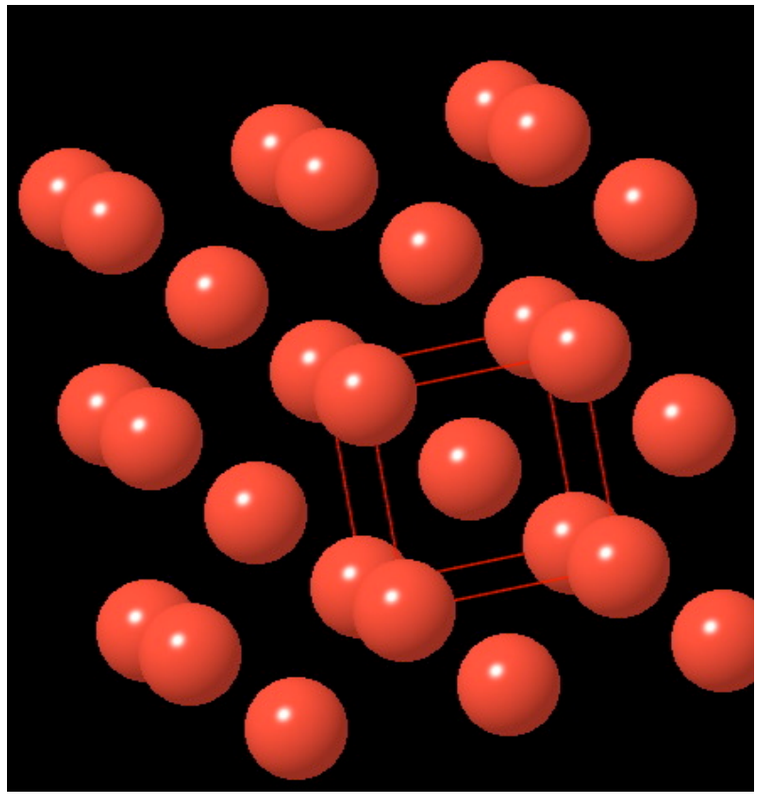
or

face centered cubic

Fe in the core?

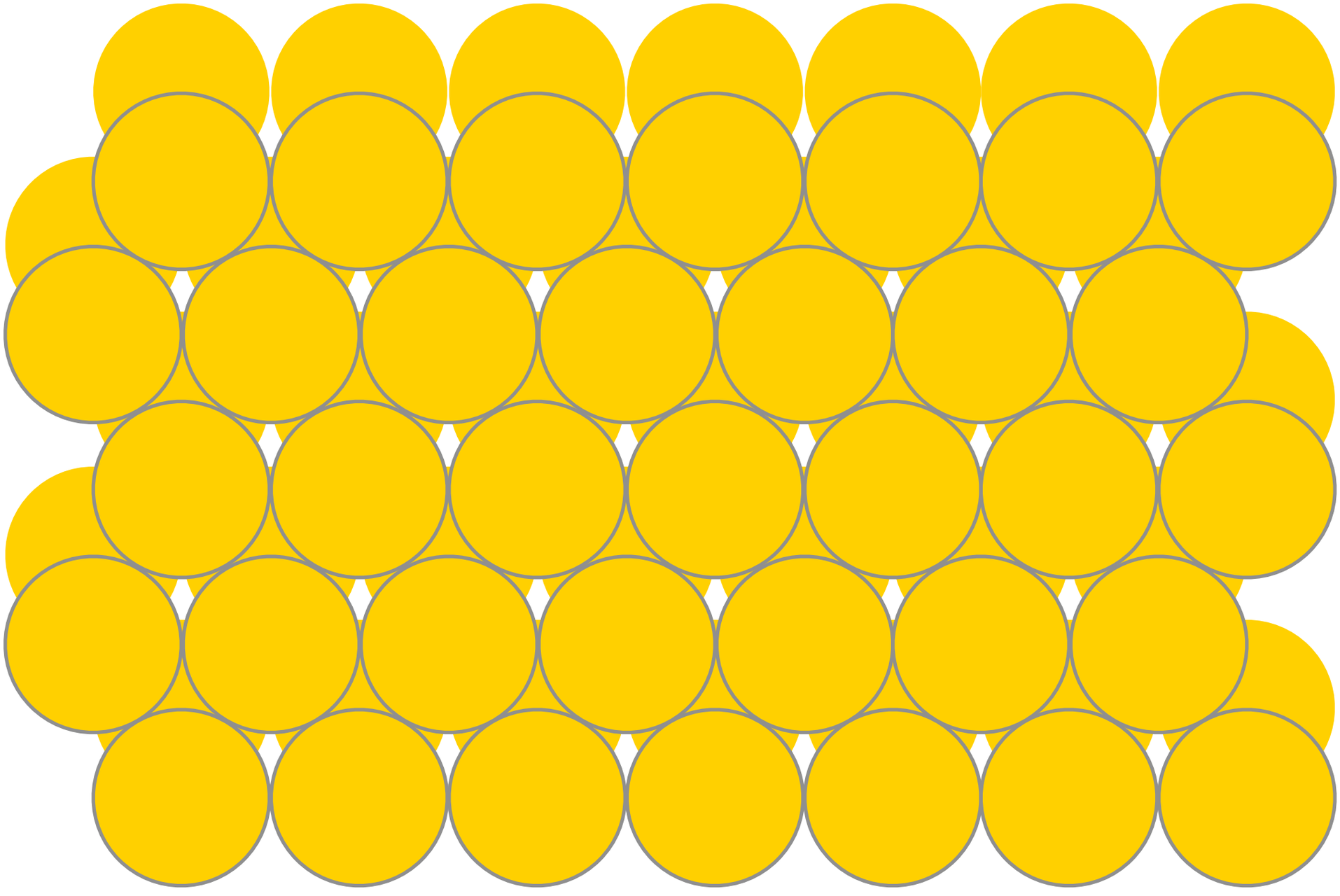


fcc

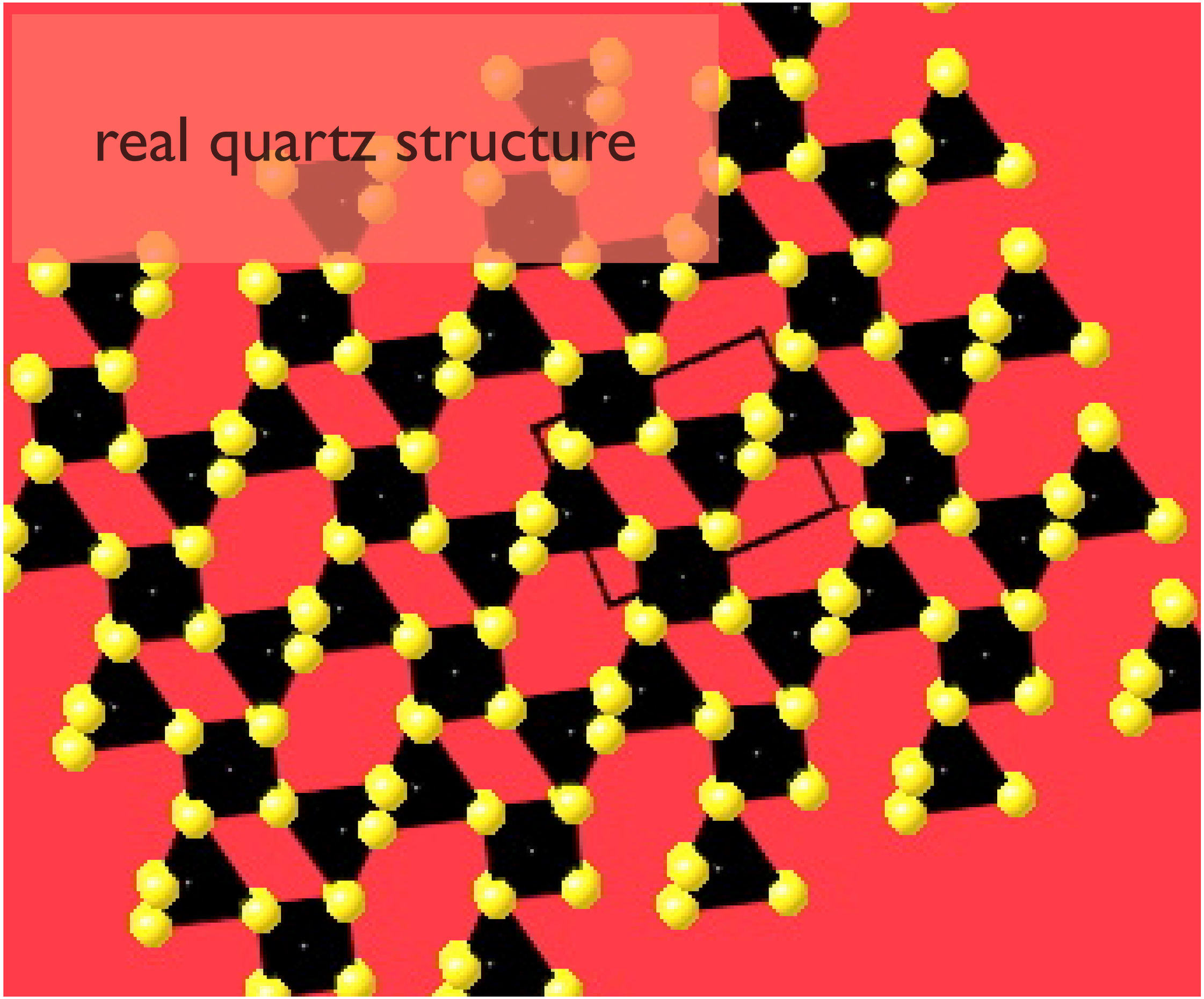


bcc

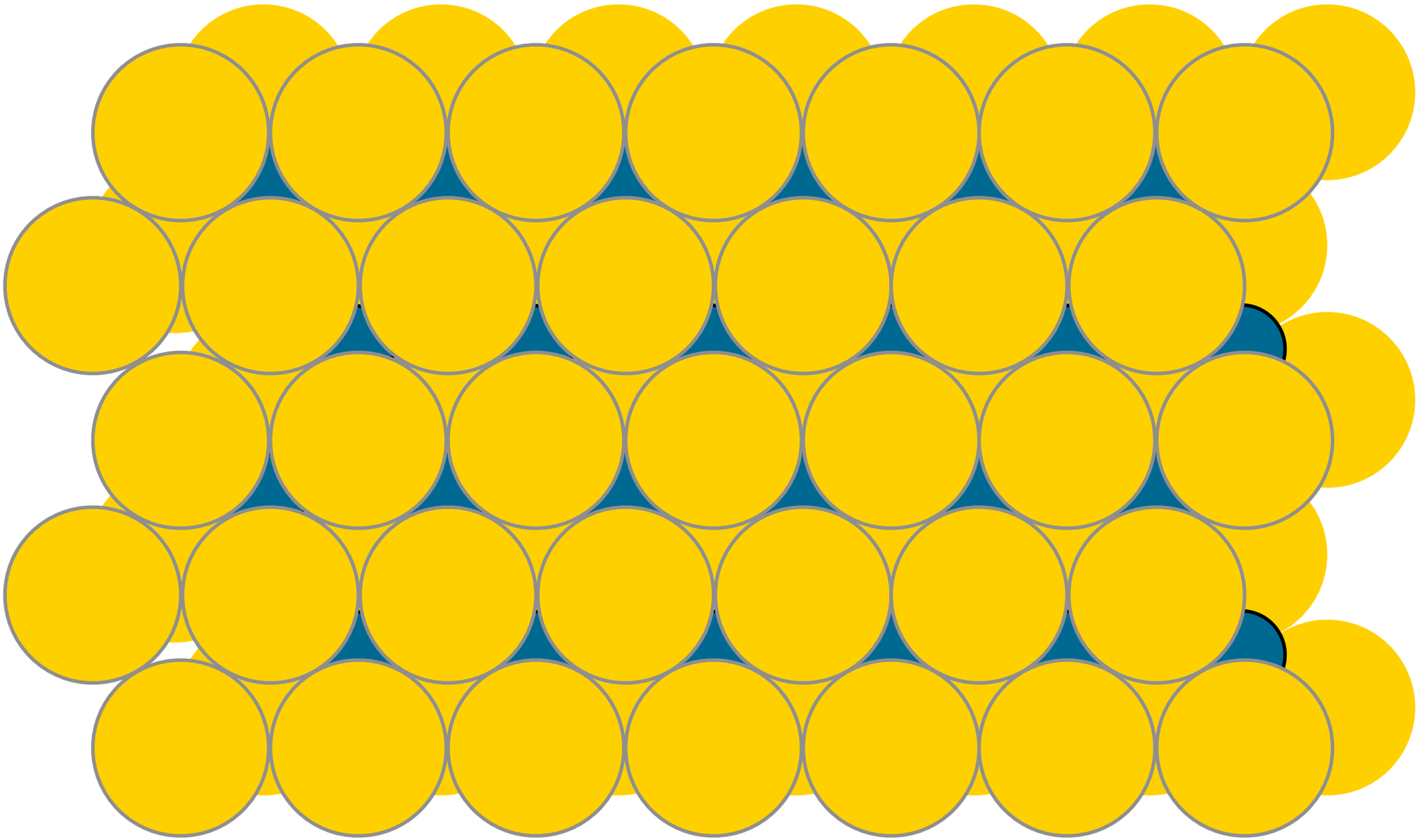
two different sized spheres:
O and Si



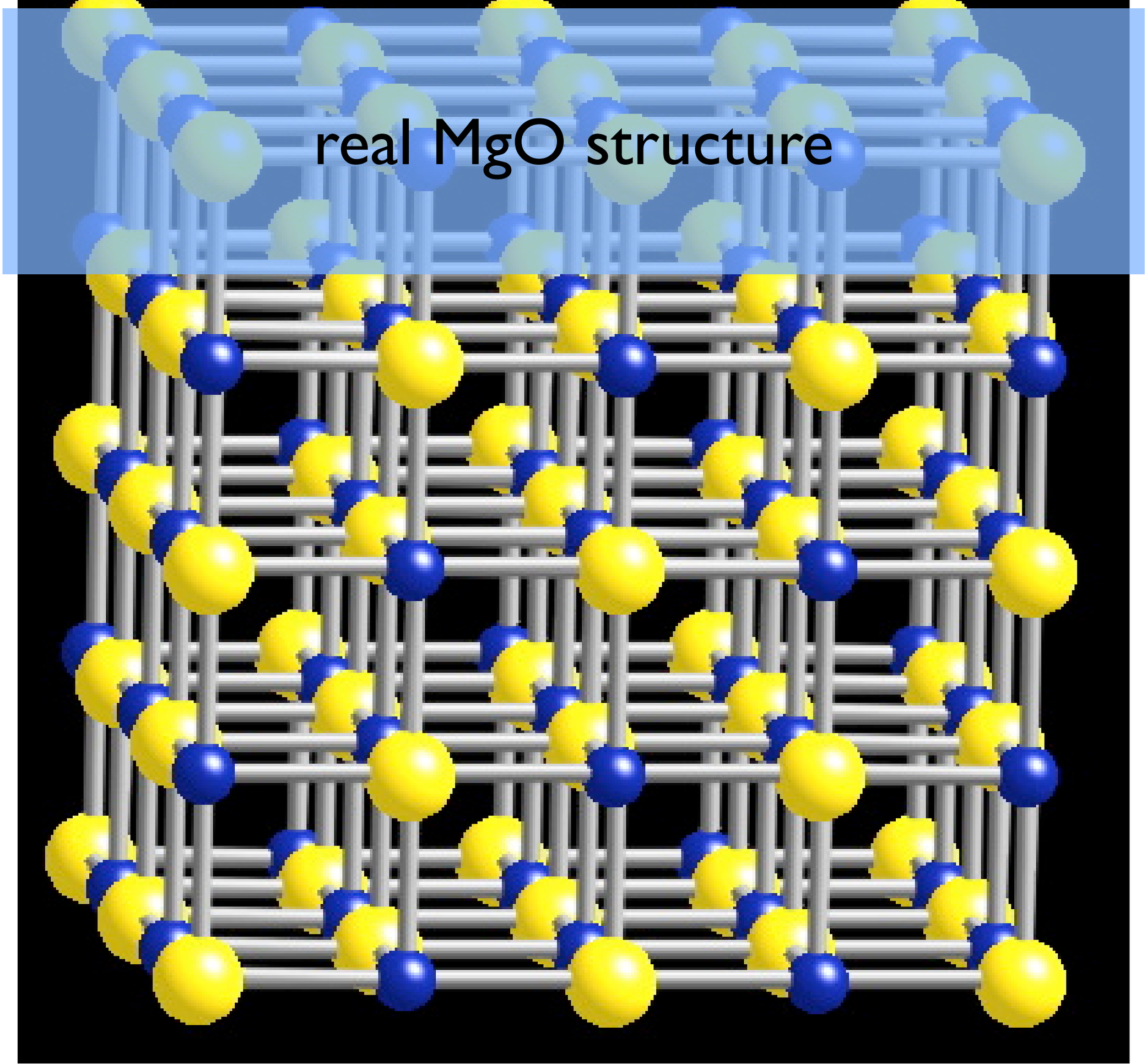
real quartz structure



two different sized spheres:
O and Mg

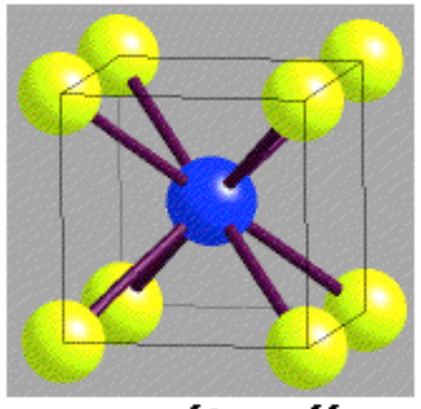


real MgO structure



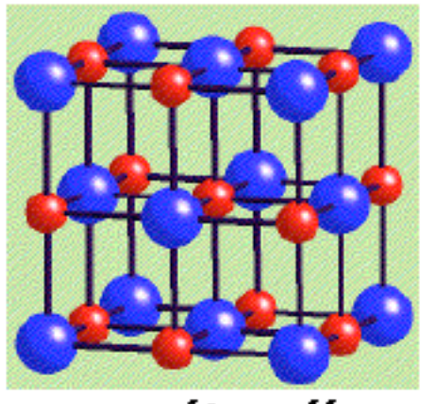
Limiting Radius Ratios

CsCl 8:8



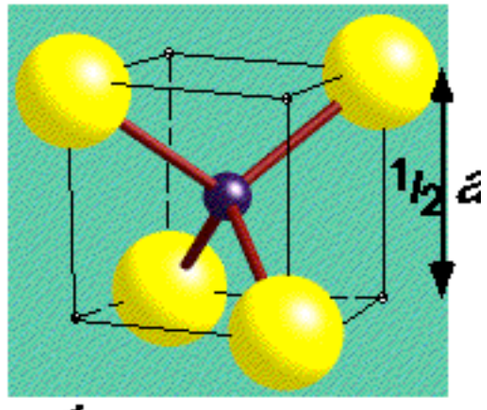
unit cell

NaCl 6:6



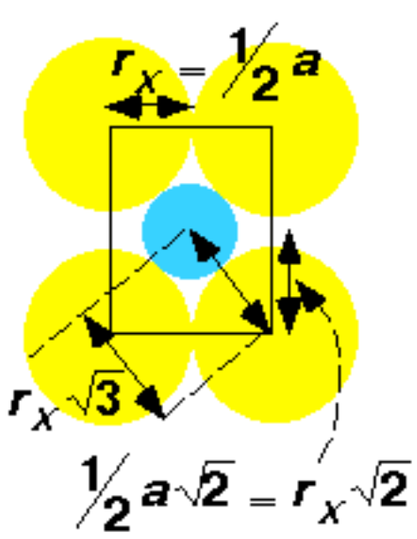
unit cell

ZnS 4:4



1/8th unit cell

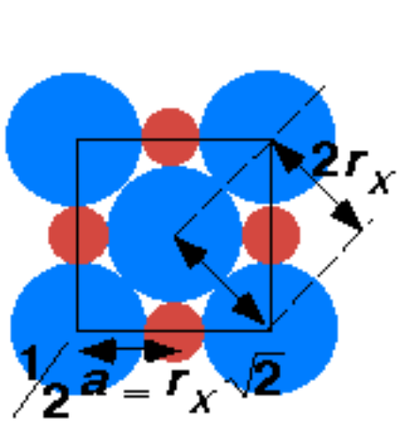
cell side a face diagonal $a\sqrt{2}$ body diagonal $a\sqrt{3}$



$r_M + r_X = r_X\sqrt{3}$

$r_M / r_X = \sqrt{3} - 1$

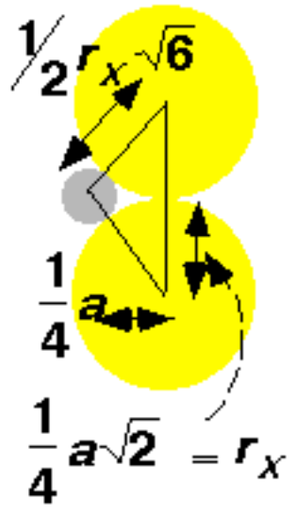
$= 0.732$



$r_M + r_X = r_X\sqrt{2}$

$r_M / r_X = \sqrt{2} - 1$

$= 0.414$



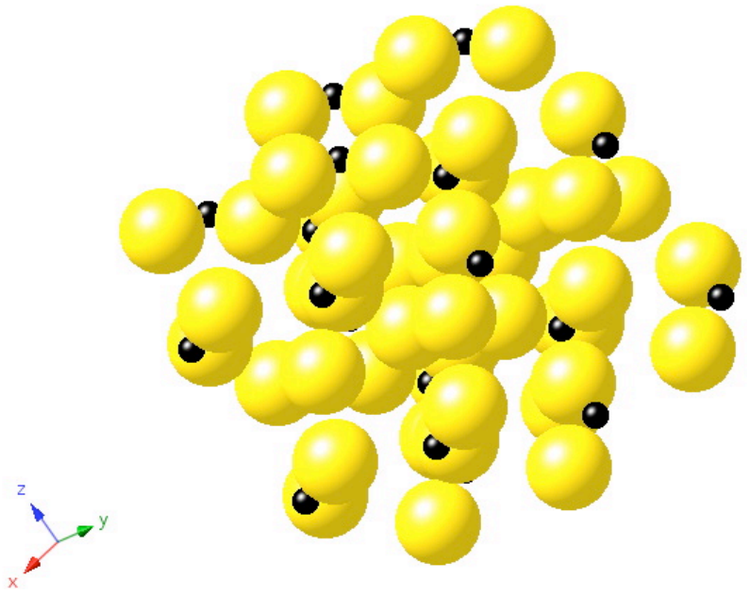
$r_M + r_X = \frac{1}{2}r_X\sqrt{6}$

$r_M / r_X = \frac{1}{2}\sqrt{6} - 1$

$= 0.225$

rules for creating structures:

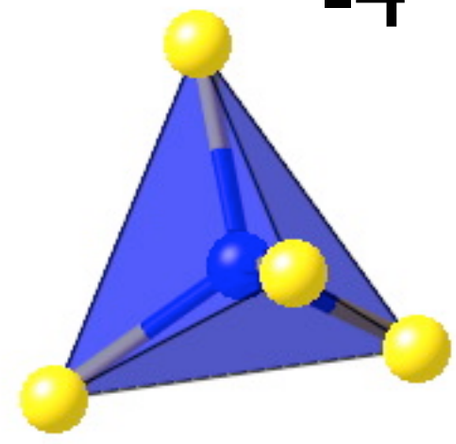
1. geometric considerations
2. charge neutrality
3. Other effects



fully networked
silicate tetrahedra
(quartz)

everything
in between
=crustal
mineralogy

-4



isolated
silicate tetrahedra
(olivine)

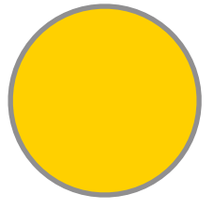
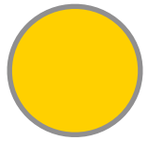
rules for creating structures:

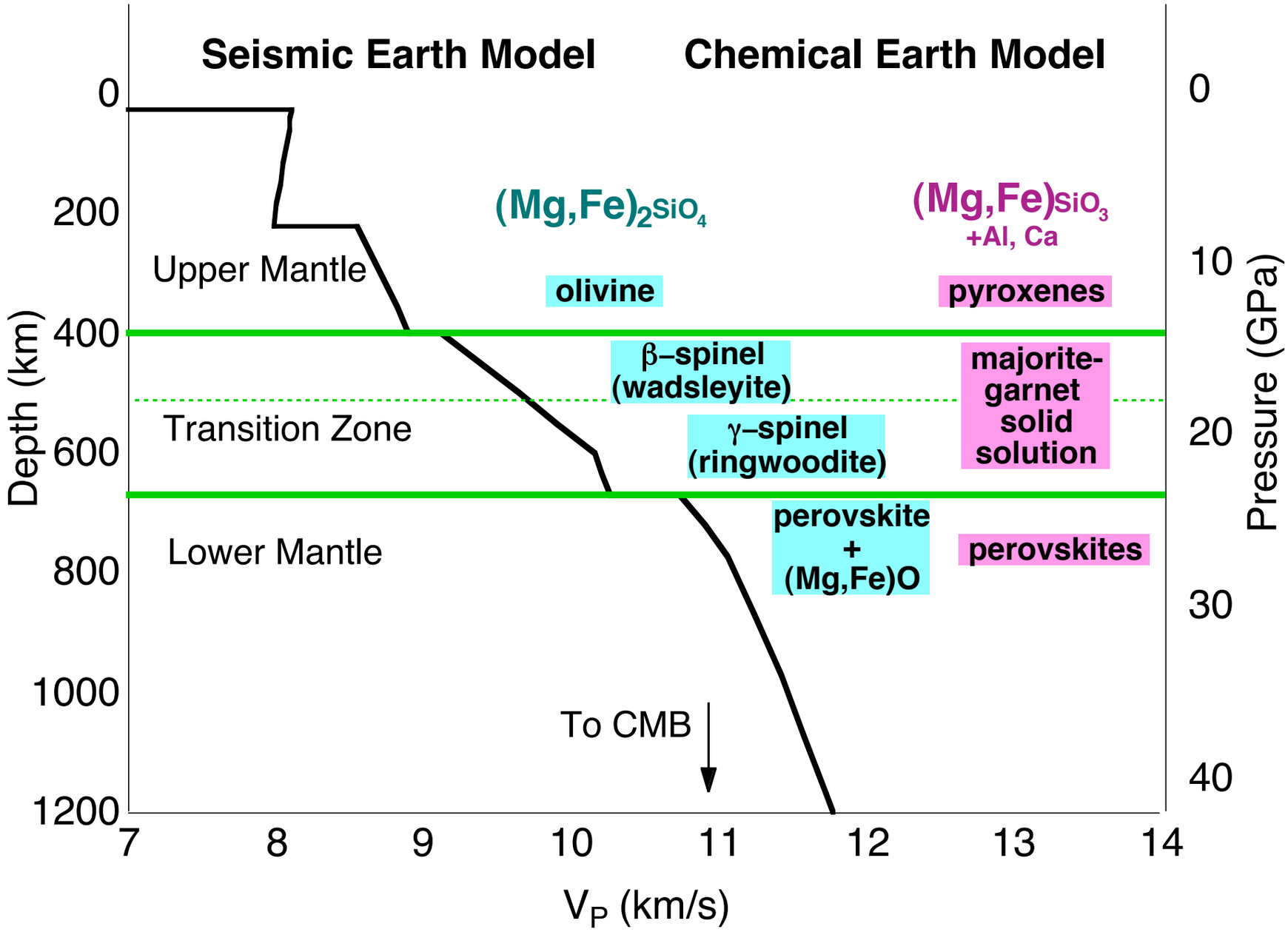
1. geometric considerations
2. charge neutrality
3. Other effects

i. Energetics:
(polyhedra face sharing>edge sharing>vertex)

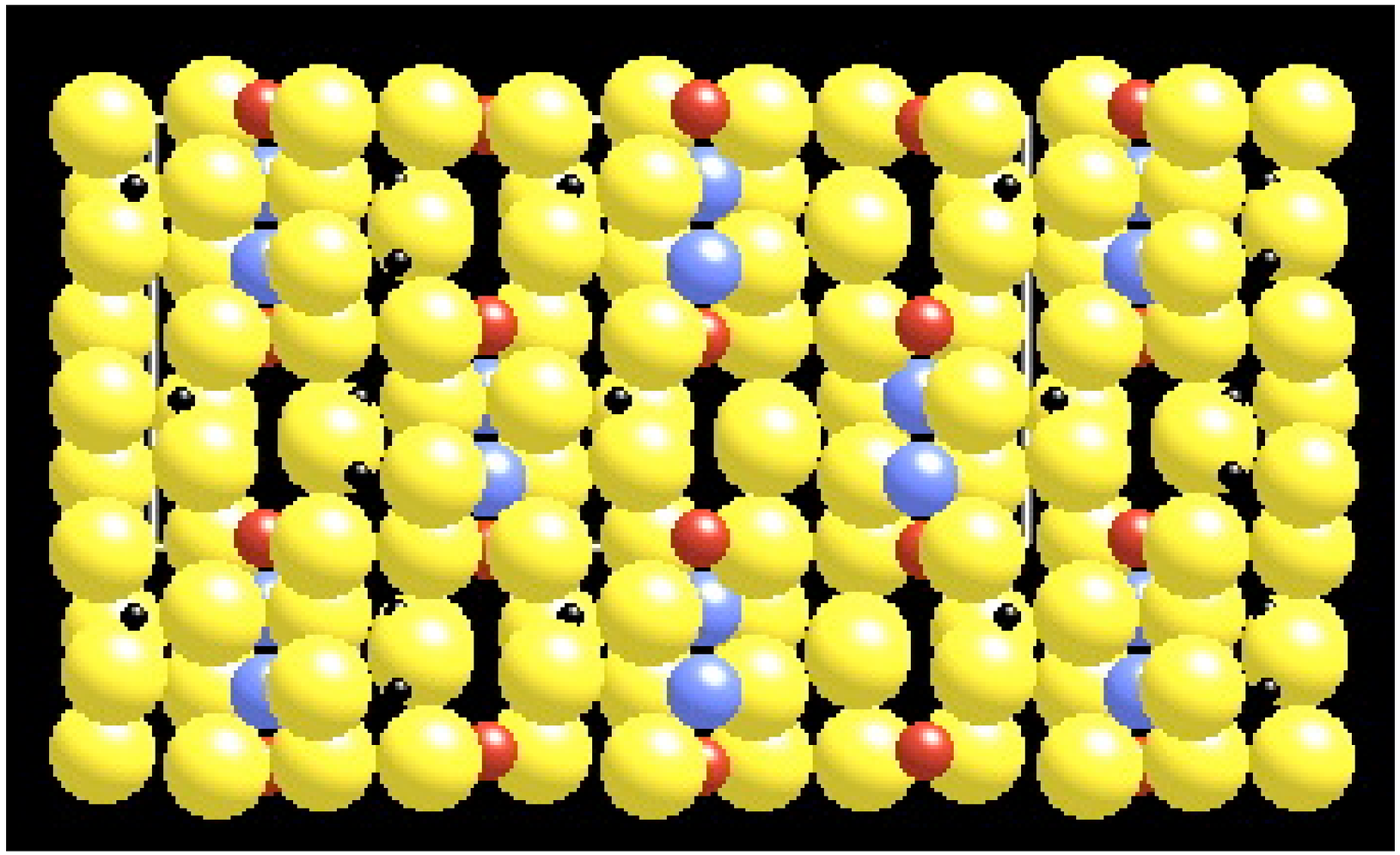
ii. Principal of Parsimony:
fewer rather than more structures

pressure rules:

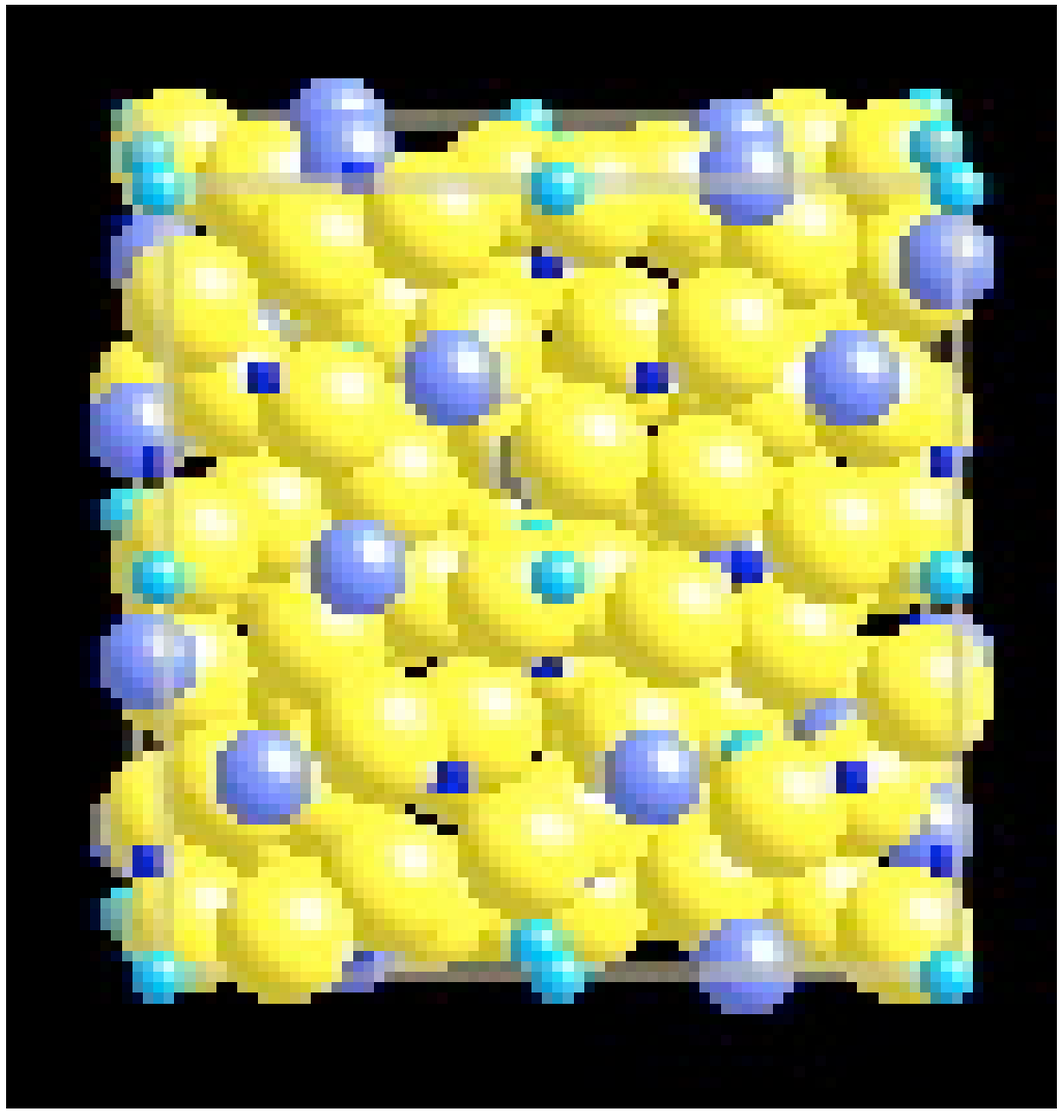
pressure	0	15 GPa	25 GPa
O			
Si			
depth	crust	410 km	660 km
coordination	tetrahedral (4)	octahedral (6)	cubic (8)


Seismic Earth Model
Chemical Earth Model
0
200
400
600
800
1000
1200
Depth (km)
Upper Mantle
Transition Zone
Lower Mantle
(Mg,Fe)2SiO4
(Mg,Fe)SiO3
+Al, Ca
olivine
pyroxenes
β–spinel
(wadsleyite)
majorite-
garnet
solid
solution
γ–spinel
(ringwoodite)
perovskite
+
(Mg,Fe)O
perovskites
To CMB
7
8
9
10
11
12
13
14
VP (km/s)
0
10
20
30
40
Pressure (GPa)

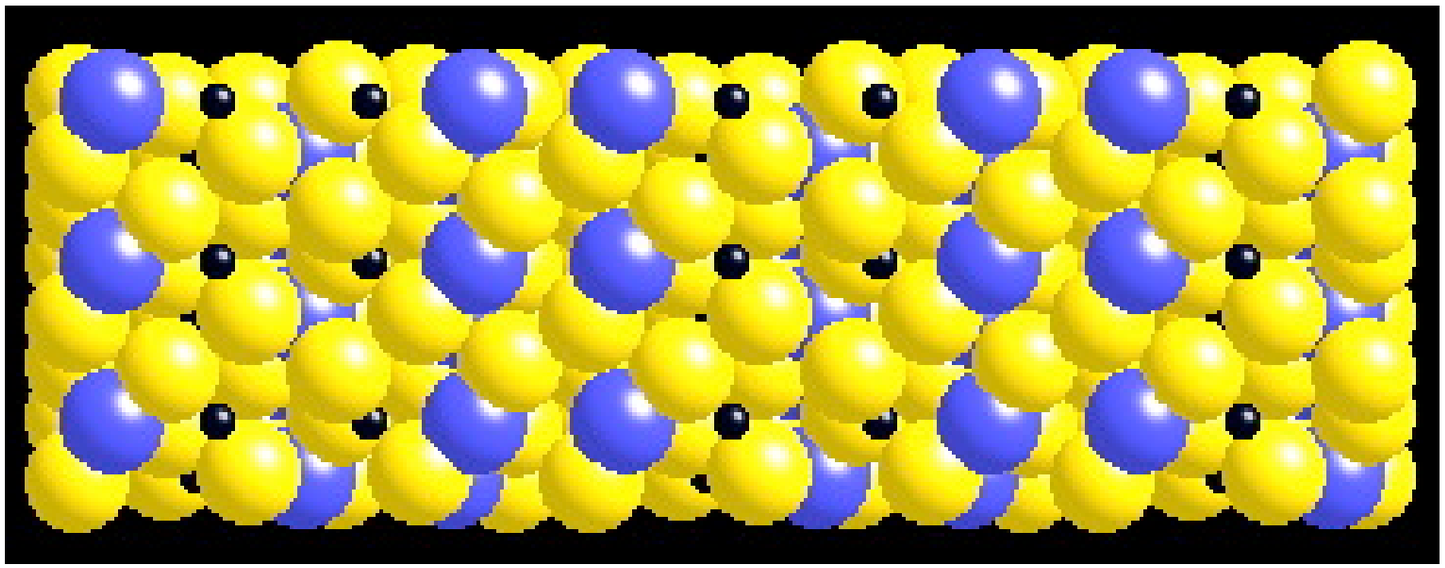
Si:3O mantle mineralogy

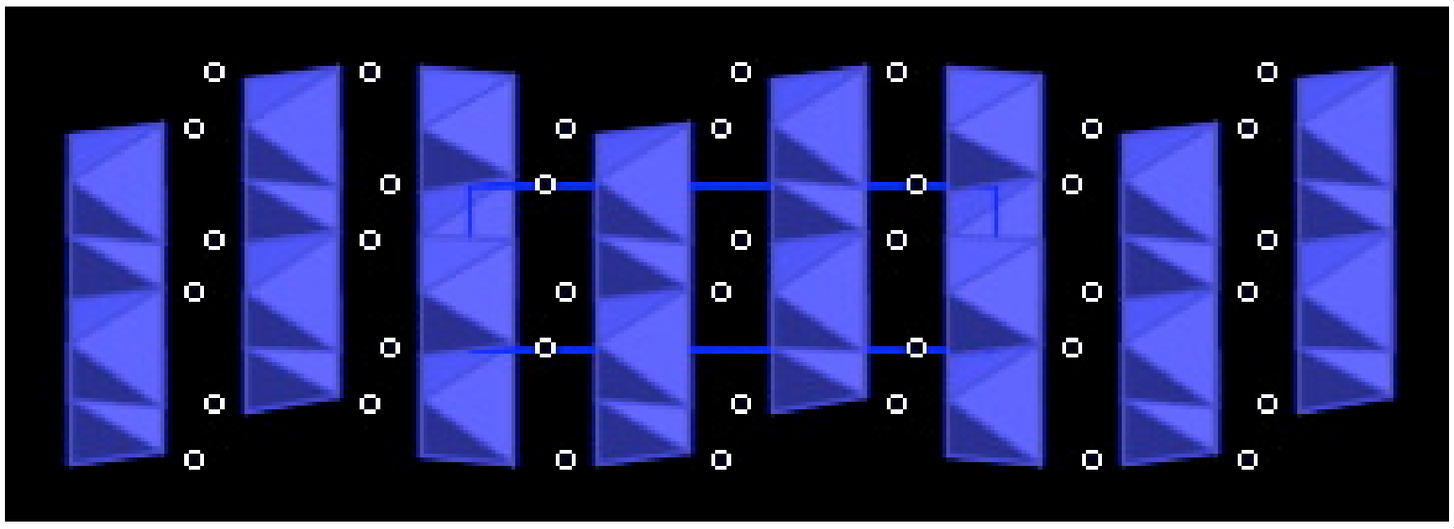


orthopyroxene



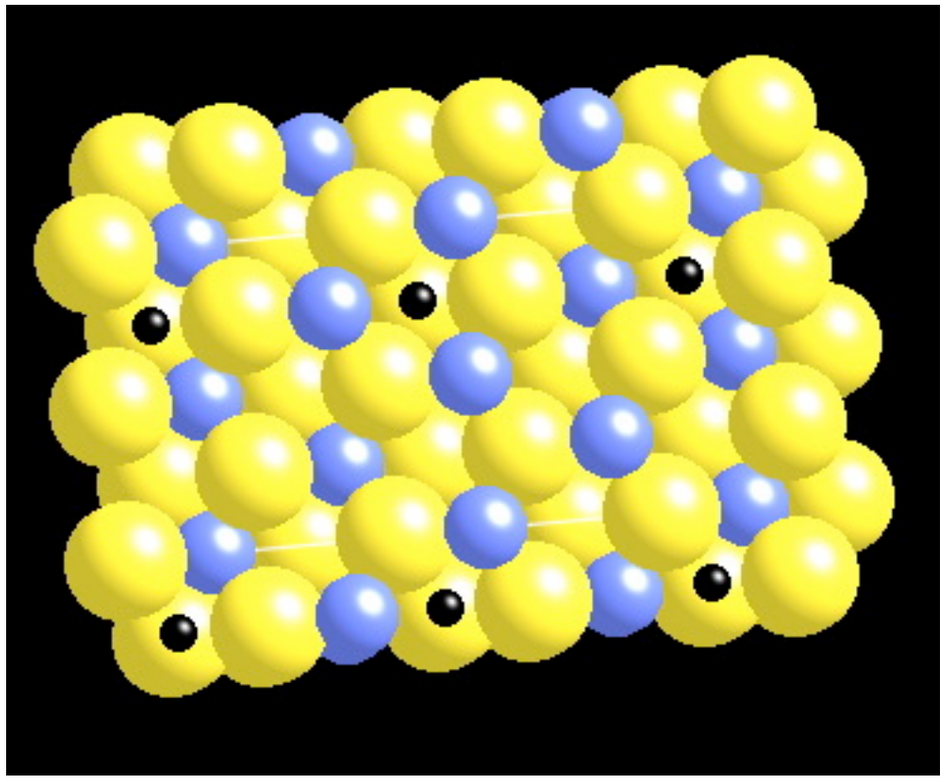
majorite garnet

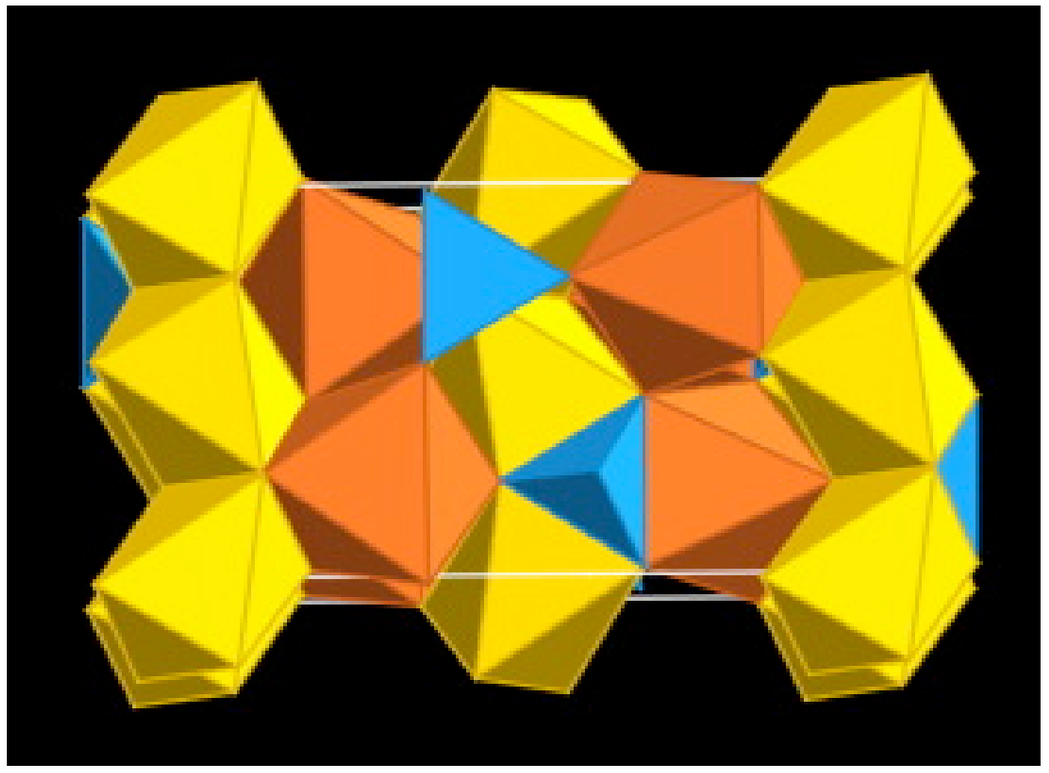




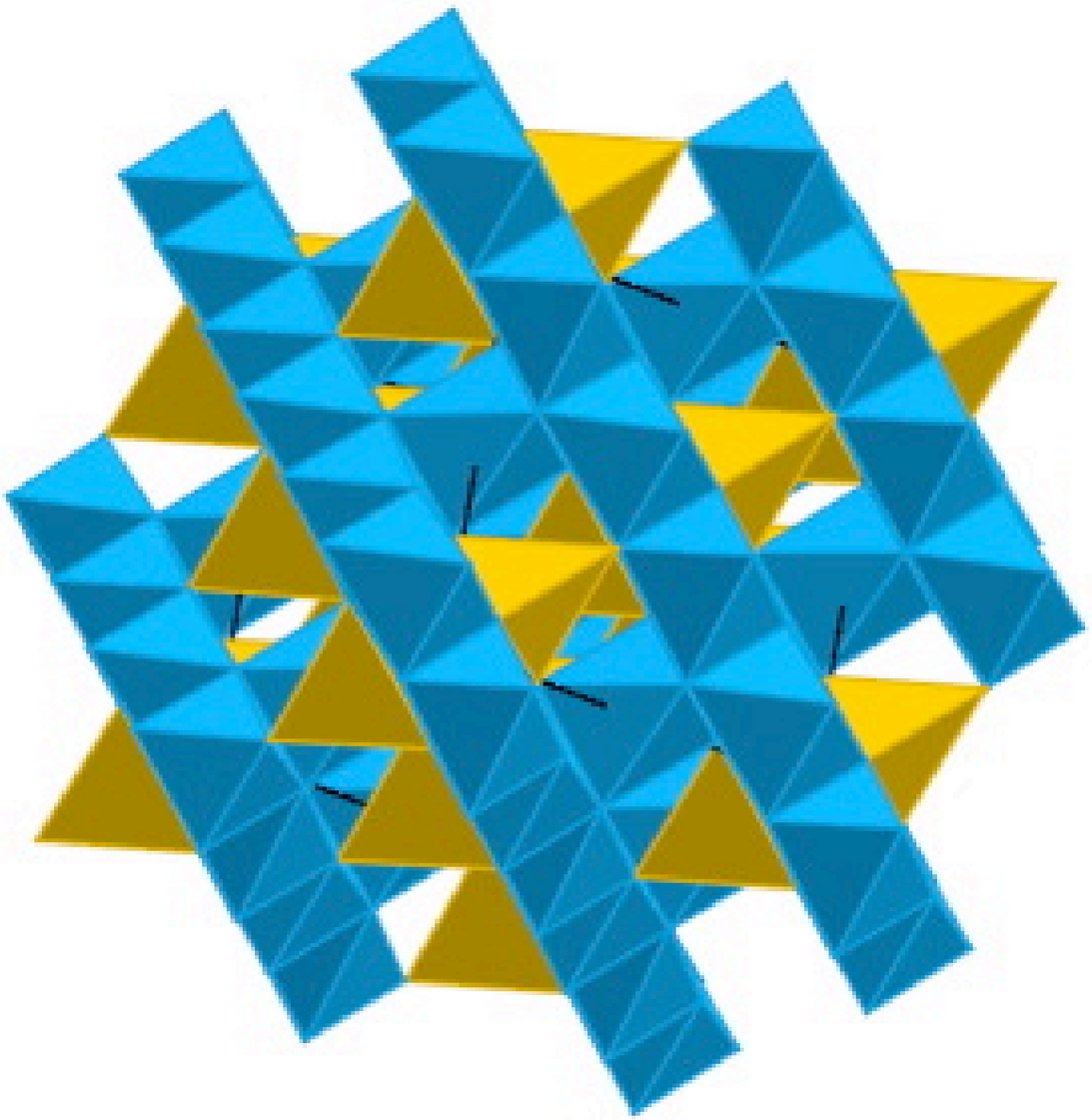
akimotoite

Si:2O mantle mineralogy

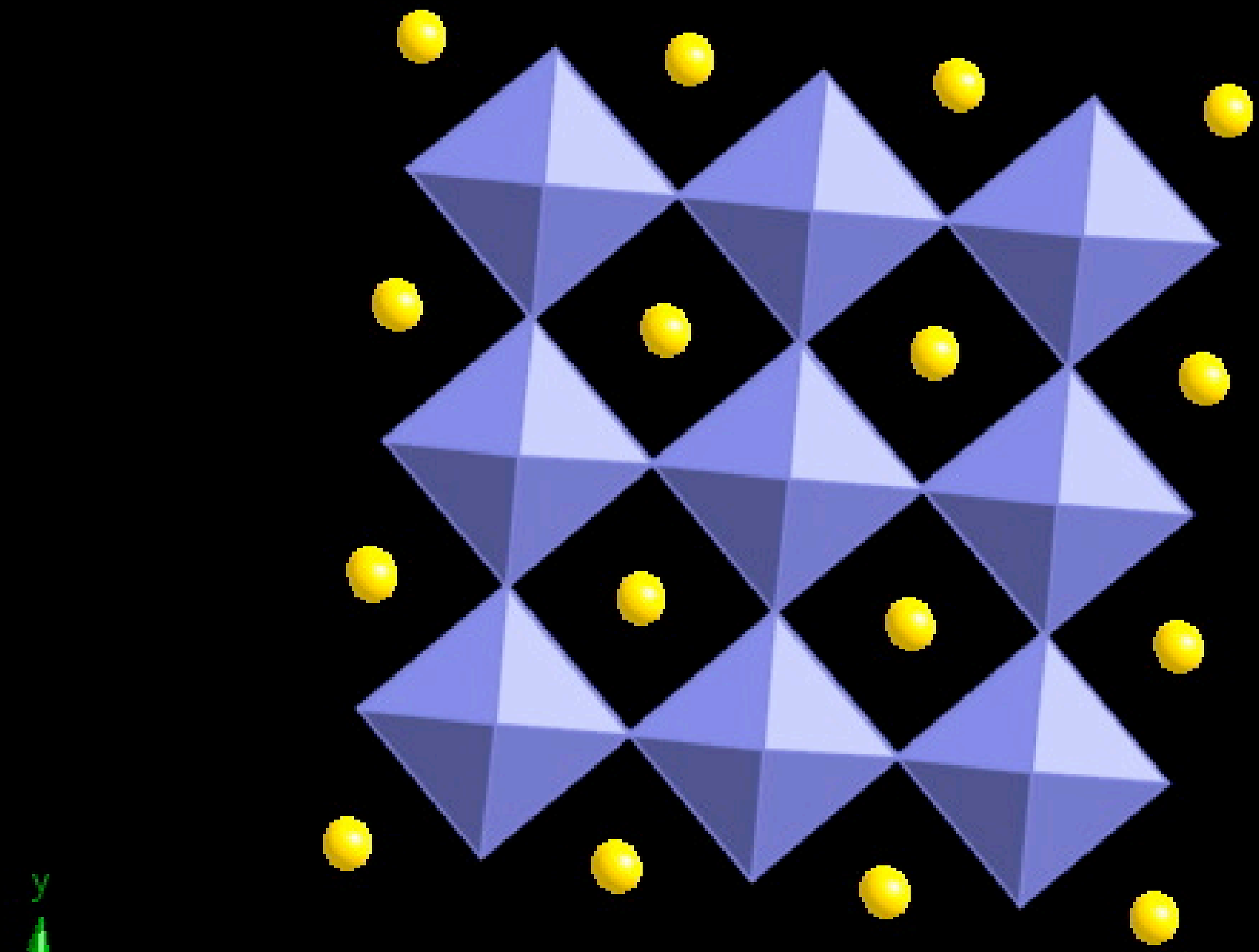




olivine

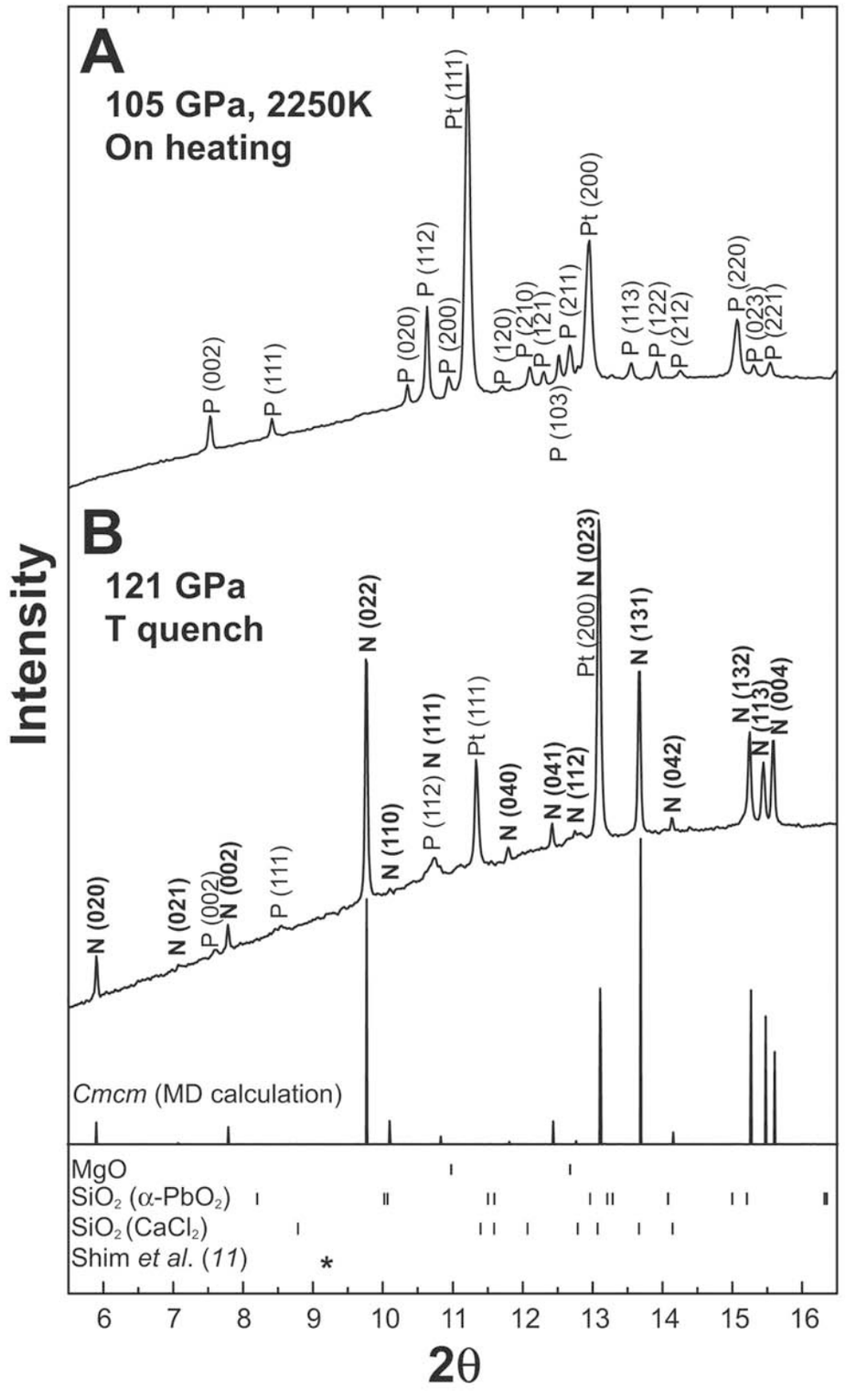


ringwoodite



perovskite

Murakami et al, 2004



post-perovskite phase transformation?