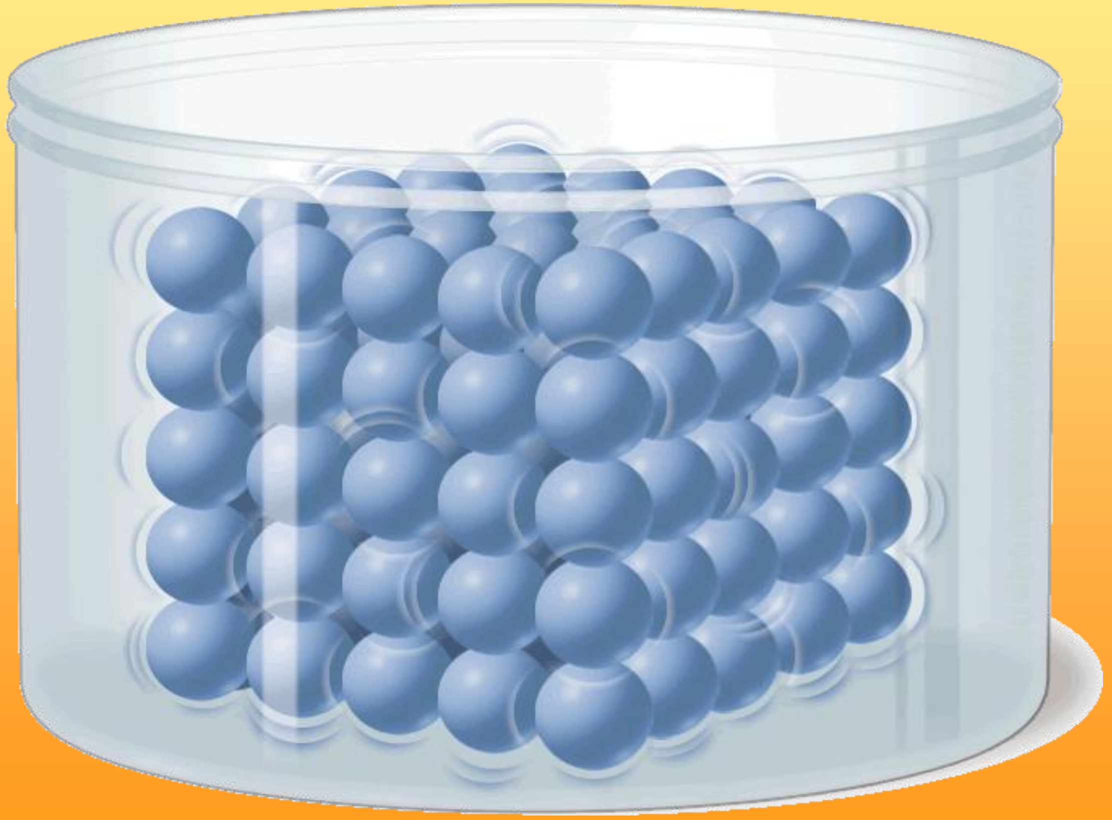
Solid State

Solids

- The fixed, closely packed arrangement of particles causes a solid to have a definite shape and volume
- A **solid** is a kind of matter that has a fixed shape and a fixed volume. Your pencil is a solid. The shape and volume of your pencil will not change if you move the pencil from place to place.

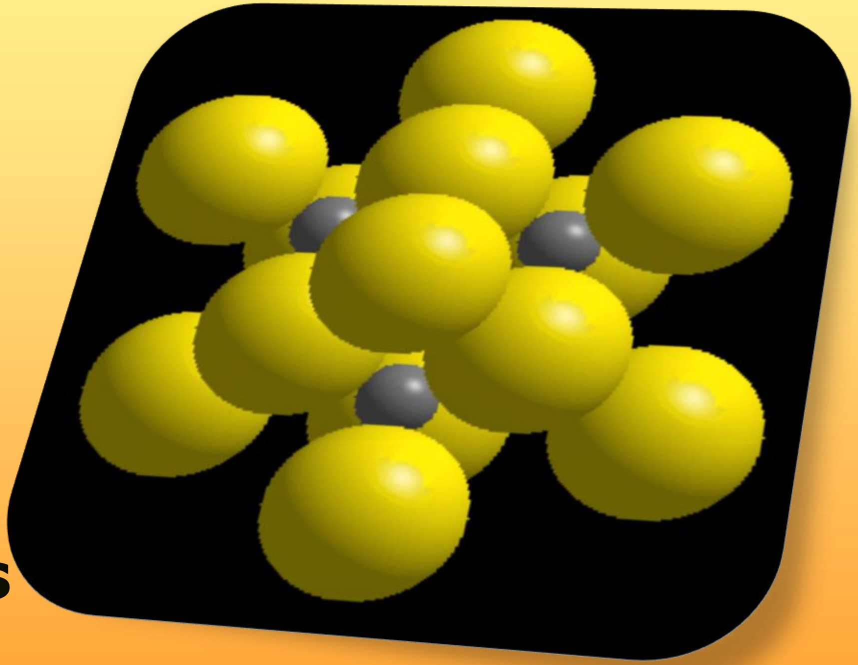
- The different elements and compounds that make up matter can be called *particles*. The particles of a solid are packed closely together.
- The *particles* of a solid cannot move from their spot within the solid. However, the particles can move slightly back and forth in place.

A solid looks likes as at particle form



Properties of Solids

- Molecules, atoms or ions locked into a CRYSTAL LATTICE
- Particles are CLOSE together
- STRONG INTERMOLECULAR forces
- Highly ordered, rigid, incompressible



Example: ZnS (zinc sulfide)

Properties of Solids

- **Melting point** – The crystal lattice of a solid breaks converting to a liquid
- **Enthalpy of fusion** – Energy needed to convert one mole from Solid → Liquid
  - It increases with increasing Molecular weight due to strength of Intermolecular forces
  - It increases in ionic compounds due to increase in lattice energy (depends on size and charge)
- **Sublimation** – Conversion of a solid to a gas

Types of Solids

TYPE	EXAMPLE	FORCE
Ionic	NaCl, CaF_2, ZnS	Ion-ion
Metallic	Na, Fe	Metallic
Molecular	Ice, I_2	Dipole Ind. dipole
Network	Diamond Graphite	Extended covalent

Types of Solids

Type	Built from	Examples
Amorphous	Covalently bonded network with limited ordering	Glass, plastics, polymers
Ionic	+ and – ions	NaCl, CsCl, $(NH_4)_2SO_4$
Metallic	Atoms or metallic ions in sea of e^-	
Molecular	Molecules with internal covalent bonds, and intramolcular attractions: dipole-dipole, H-bond, London dispersion	H_2, ice, I_2, CH_3OH
Network	Atoms held in network covalent bonds	Graphite, diamond, quartz

- **Ionic crystals**

The ionic crystals consist of positively and negatively charged ions arranged in a regular fashion throughout the crystal.

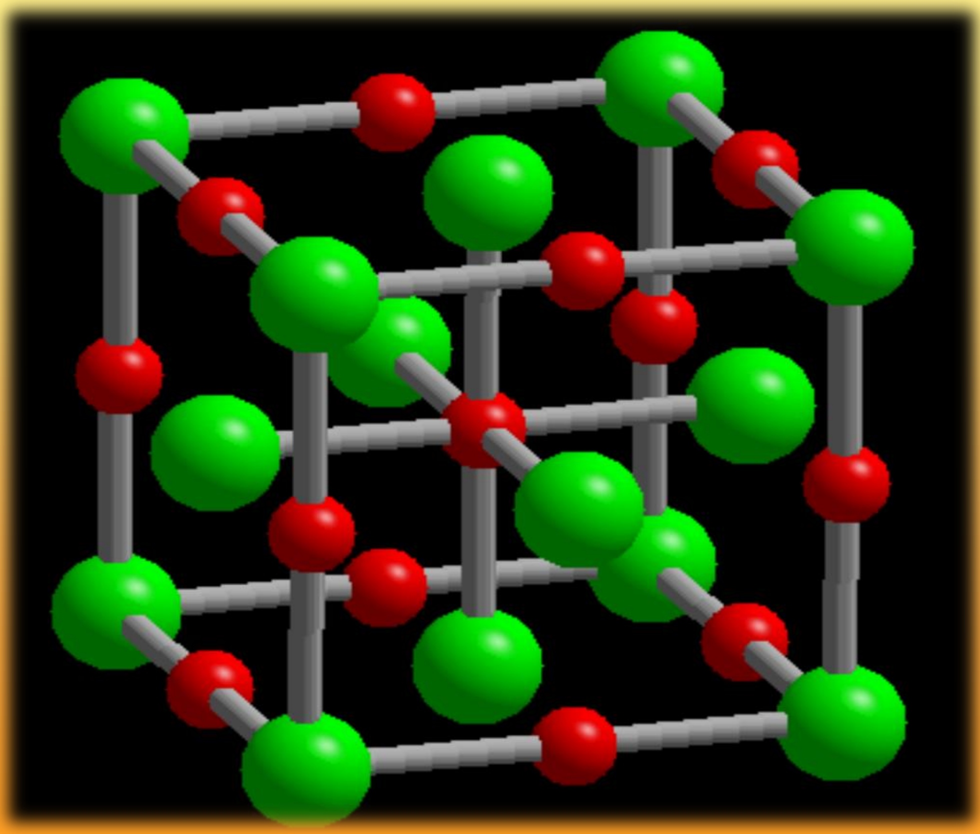
- **Covalent or Network crystals**

In covalent crystals, the constituent particles are atoms of the same or different kind, which are bonded to one another by a network of covalent bonds.

- **Metallic crystals**

In metallic crystals the constituent particles are positive metal ions (kernels) i.e., nuclei where inner electrons are dispersed in a sea of mobile valence electrons.

Metallic and Ionic Solids



Simple Ionic Compounds

Lattices of many simple ionic solids are built by taking a SC or FCC lattice of ions of one type and placing ions of opposite charge in the holes in the lattice.

Example: **CsCl has a SC lattice of Cs^+ ions with Cl^- in the center.**

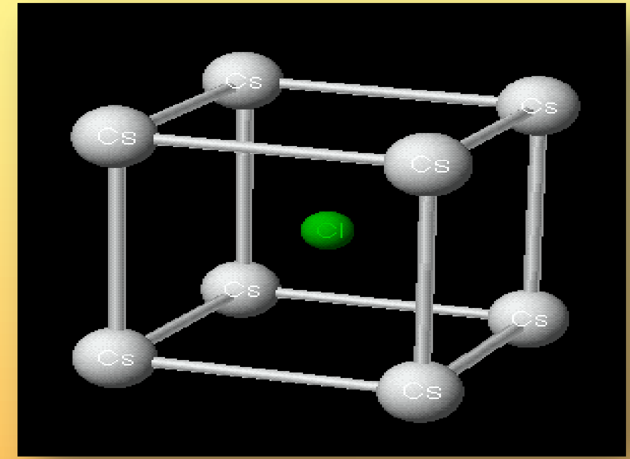
Simple Ionic Compounds

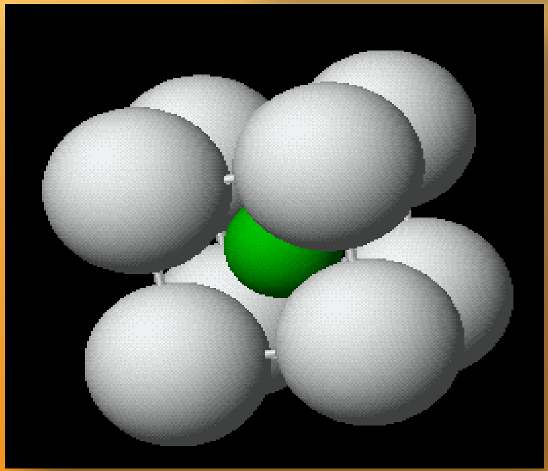
CsCl has a SC lattice of Cs^+ ions with Cl^- in the center.

1 unit cell has 1 Cl^- ion plus

(8 corners)(1/8 Cs^+ per corner)

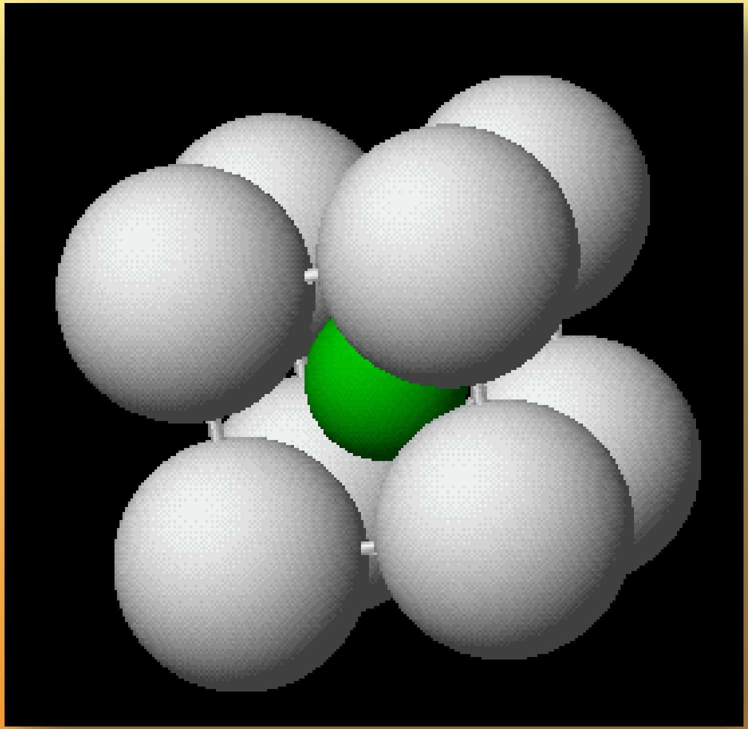
= 1 net Cs^+ ion.





Simple Ionic Compounds

Salts with formula MX can have SC structure — but not salts with formula MX_2 or M_2X



Simple Ionic Compounds

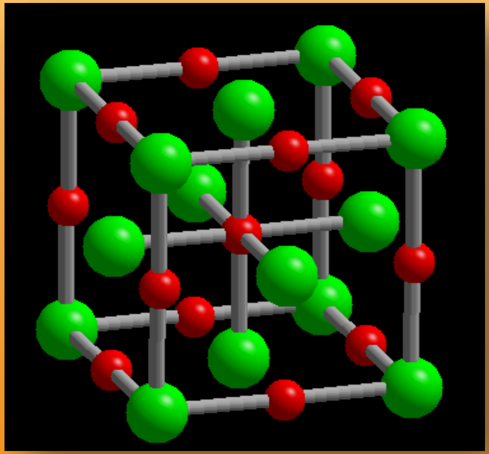
Many common salts have FCC arrangements of anions with cations in OCTAHEDRAL HOLES —

e.g., salts such as CA = NaCl

- FCC lattice of anions ----> 4 A^-/unit cell
- C^+ in octahedral holes ---> 1 C^+ at center

+ [12 edges • 1/4 C^+ per edge]

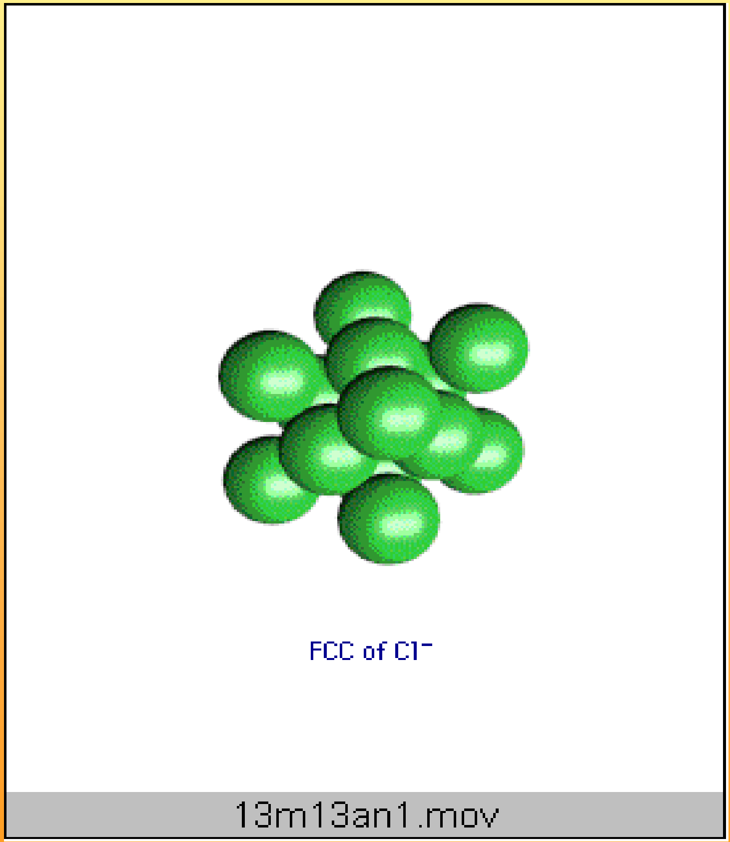
= 4 C^+ per unit cell



Construction of NaCl

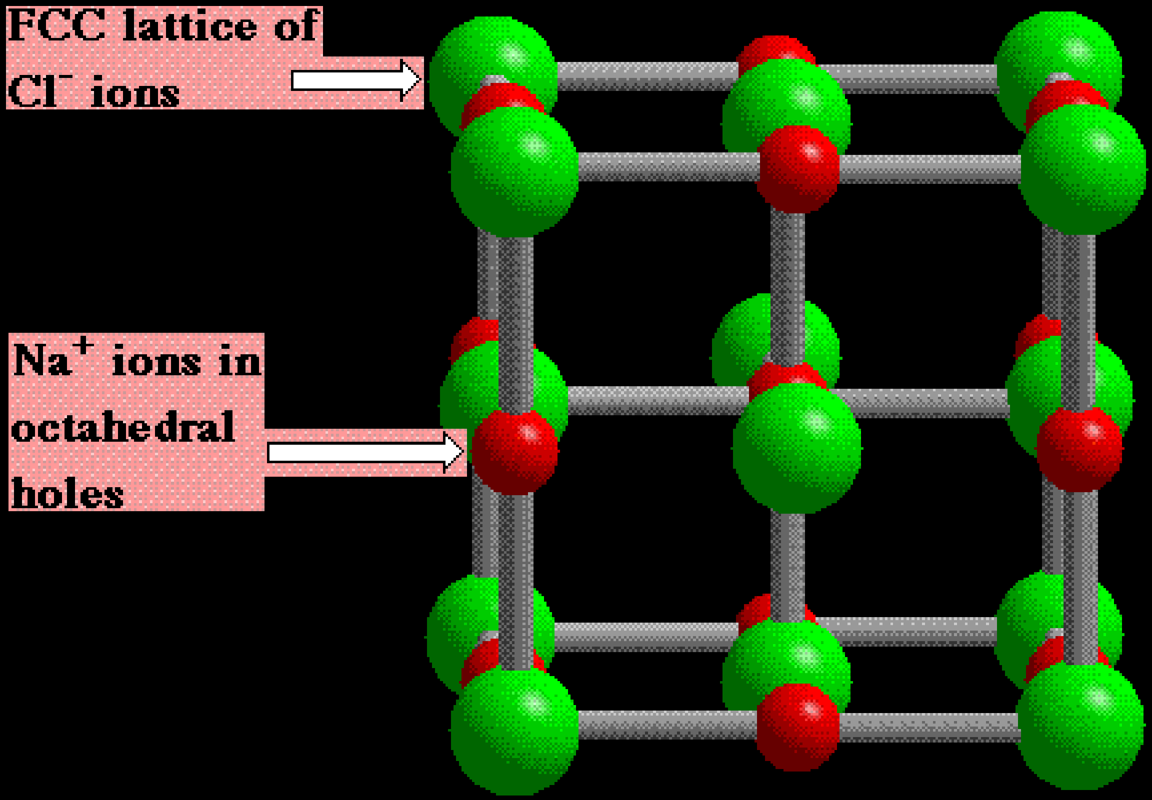
We begin with a cube of Cl^- ions. Add more Cl^- ions in the cube faces, and then add Na^+ ion in the octahedral holes.

The Sodium Chloride Lattice

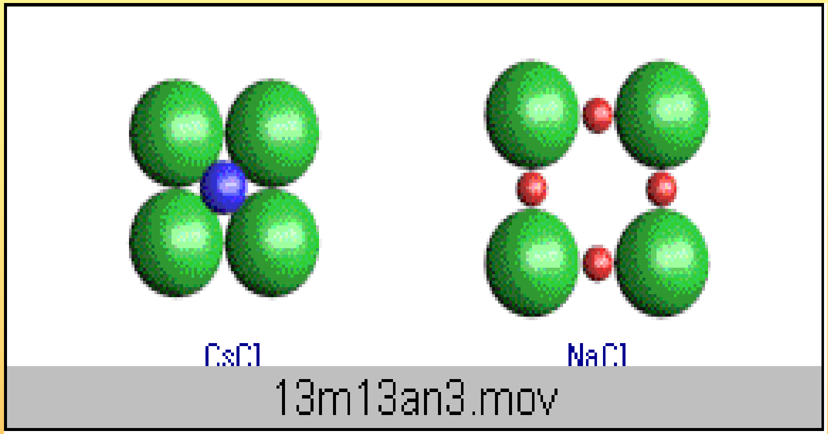


Na^+ ions are in OCTAHEDRAL holes in a face-centered cubic lattice of Cl^- ions.

SODIUM CHLORIDE

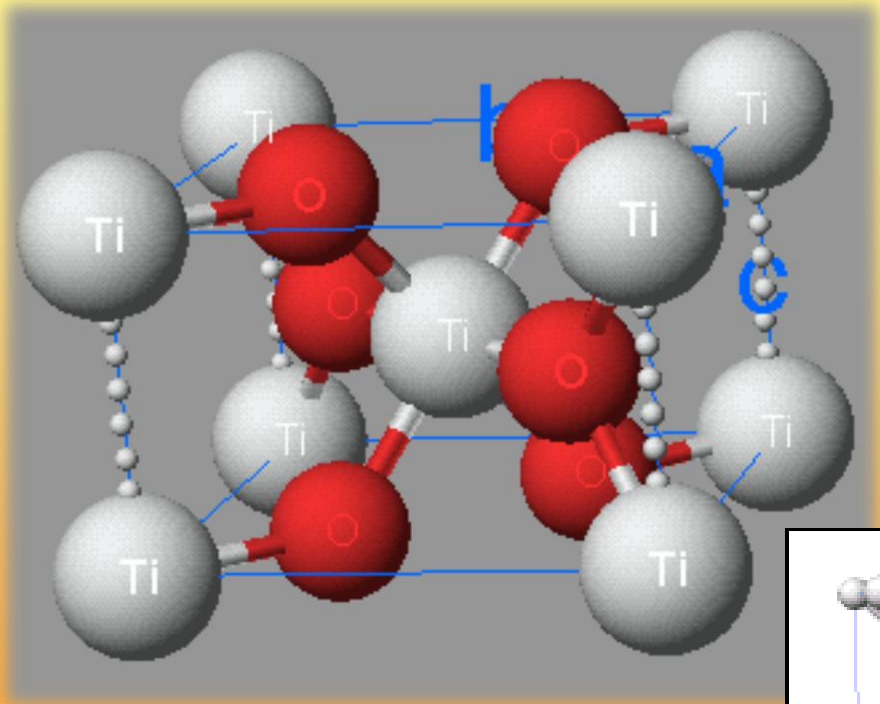


Comparing NaCl and CsCl



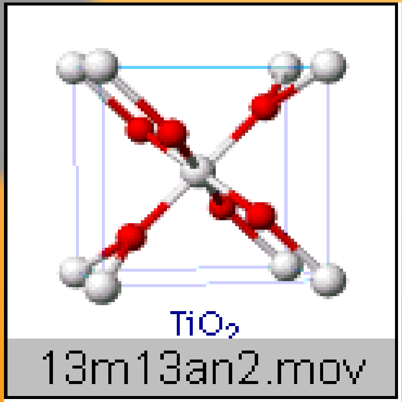
- Even though their formulas have one cation and one anion, the lattices of CsCl and NaCl are different.
- The different lattices arise from the fact that a Cs^{+} ion is much larger than a Na^{+} ion.

Common Ionic Solids

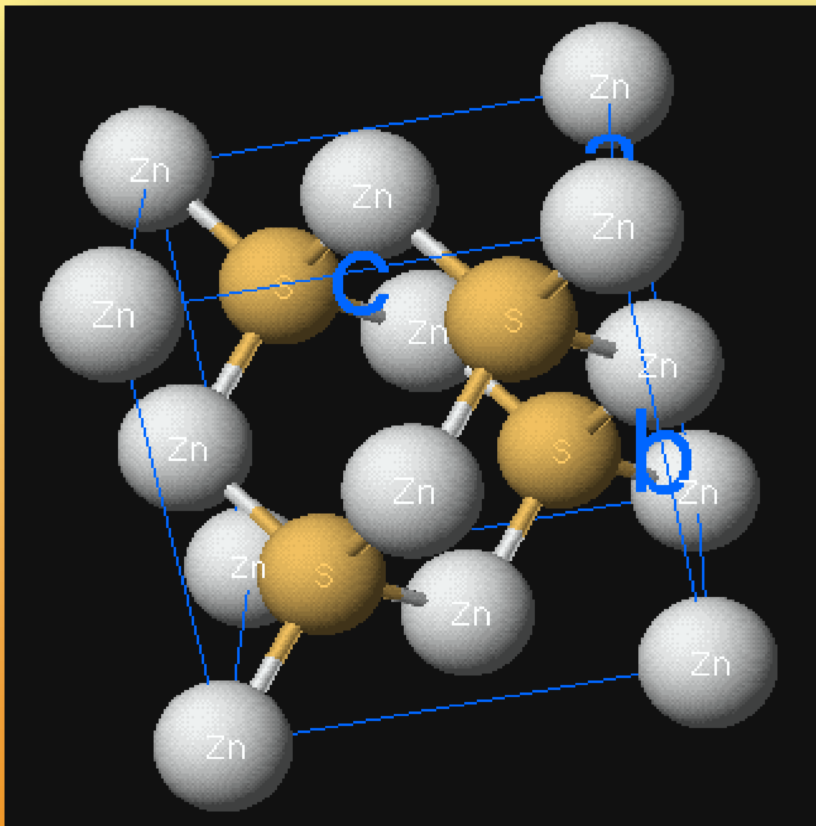


Titanium dioxide, TiO_2

There are 2 net Ti^{4+} ions and 4 net O^{2-} ions per unit cell.

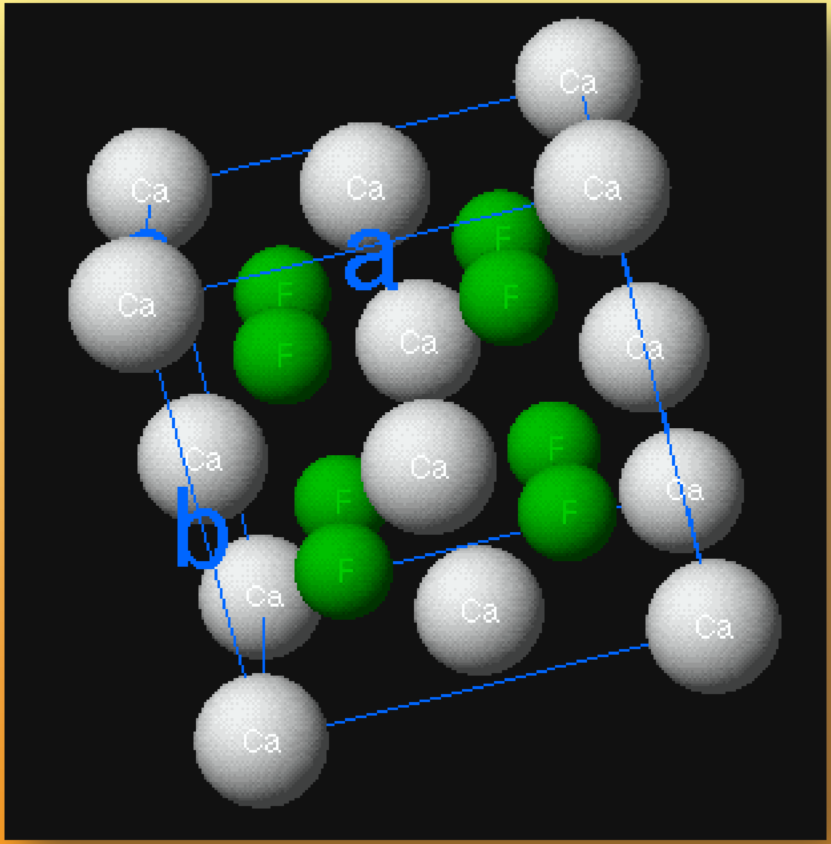


Common Ionic Solids



- Zinc sulfide, ZnS
- The S^{2-} ions are inTETRAHEDRAL holes in the Zn^{2+} FCC lattice.
- This gives 4 net Zn^{2+} ions and 4 net S^{2-} ions.

Common Ionic Solids



- Fluorite or CaF_2
- FCC lattice of Ca^{2+} ions
- This gives 4 net Ca^{2+} ions.
- F^- ions in all 8 tetrahedral holes.
- This gives 8 net F^- ions.

Summary Ionic Solids

- **Compounds with formula MX are commonly either sc or fcc**
- **Many salts have NaCl structure (fcc) especially alkali metals**
- **Exceptions are CsCl, CsBr, CsI, alkaline oxides and sulfides, and oxides of 4^{th} row transition metals (MO)**
- **Formulas can always be found from unit cell structure**

Thanks…