PAPER-A: CONDENSED MATTER PHYSICS
(B.Sc. Semester-V)

Prepared By: Mrs. Saloni Sharma

PHYSICS DEPARTMENT

HANS RAJ MAHILA MAHA VIDYALAYA

CONTENTS

- Crystal planes &Miller indices
- Diamond & NaCl structure.

Miller indices

- A Miller index is a series of co prime integers that are inversely proportional to the intercepts of the crystal face or crystallographic planes with the edges of the unit cell.

- It describes the orientation of a plane in the 3-D lattice with respect to the axes.

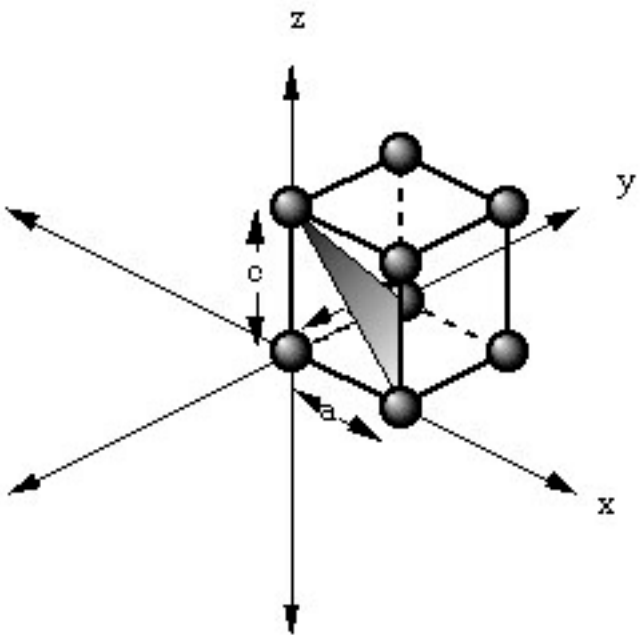
- The general form of the Miller index is (h, k, l) where h, k, and l are integers related to the unit cell along the a, b, c crystal axes.

Miller Indices

Rules for determining Miller Indices:

1. Determine the intercepts of the face along the crystallographic axes, *in terms of unit cell dimensions.*
2. Take the reciprocals
3. Clear fractions
4. Reduce to lowest terms

An example of the (111) plane (h=1, k=1, l=1) is shown on the right.



	a	b	c
intercept length	1	1	1
reciprocal	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$
cleared fraction	1	1	1

Miller indice (111)

Another example:

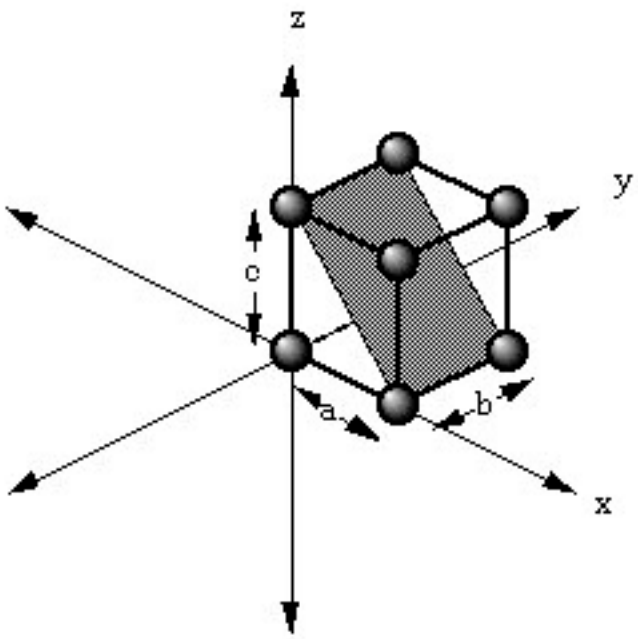
Rules for determining Miller Indices:

1. Determine the intercepts of the face along the crystallographic axes, *in terms of unit cell dimensions.*

2. Take the reciprocals

3. Clear fractions

4. Reduce to lowest terms

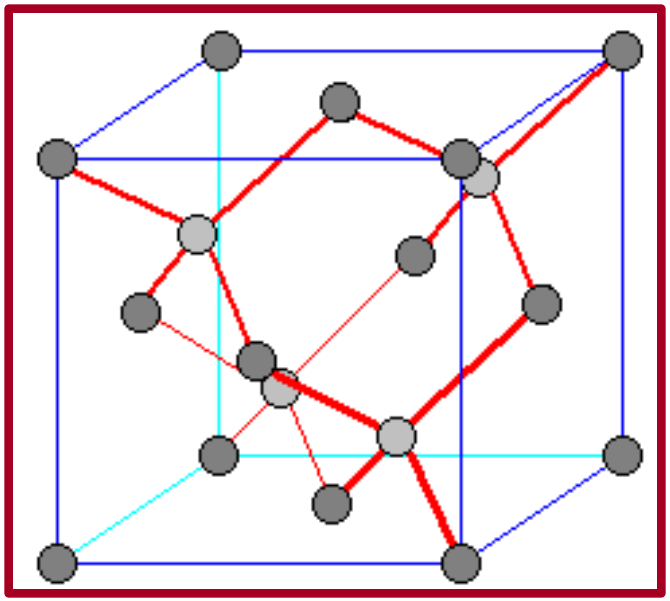


	a	b	c
intercept length	1	∞	1
reciprocal	$\frac{1}{1}$	$\frac{1}{\infty}$	$\frac{1}{1}$
cleared fraction	1	0	1

Miller indice (101)

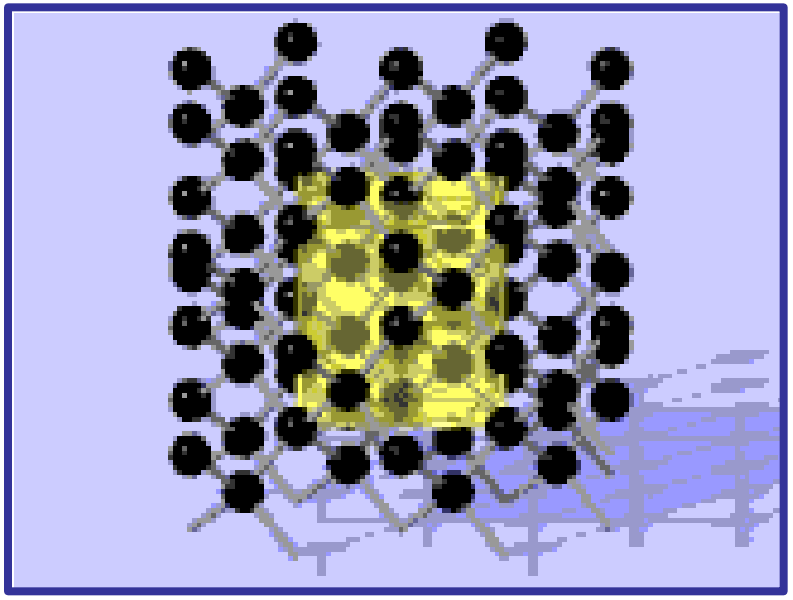
Diamond Structure

- **The *Diamond Lattice*** consists of **2 interpenetrating FCC Lattices.**
- It is not a Bravais Lattice. There are **8 atoms in the unit cell**. Each atom **bonds covalently to 4 others equally spaced about a given atom.**.

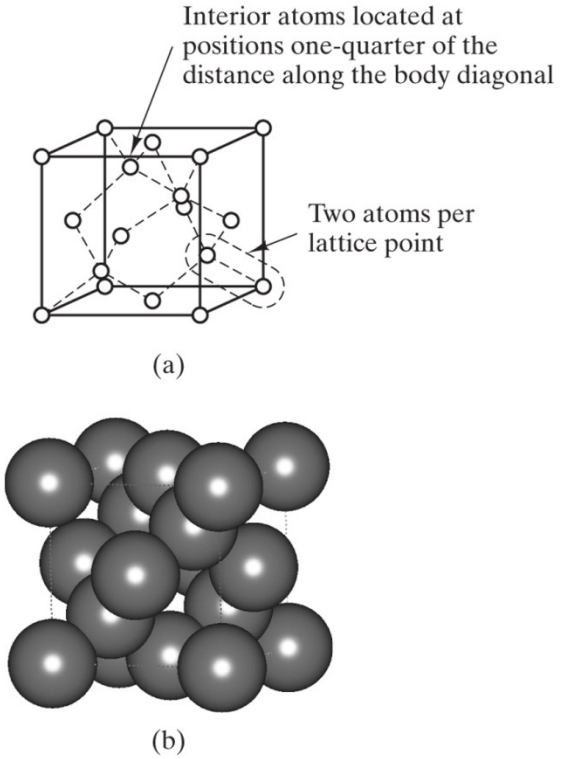


- The ***Diamond Lattice*** consists of **2 interpenetrating FCC Lattices.**
- The **Coordination Number = 4.**
- The diamond lattice is not a Bravais lattice.

C, Si, Ge & Sn crystallize in the Diamond structure.

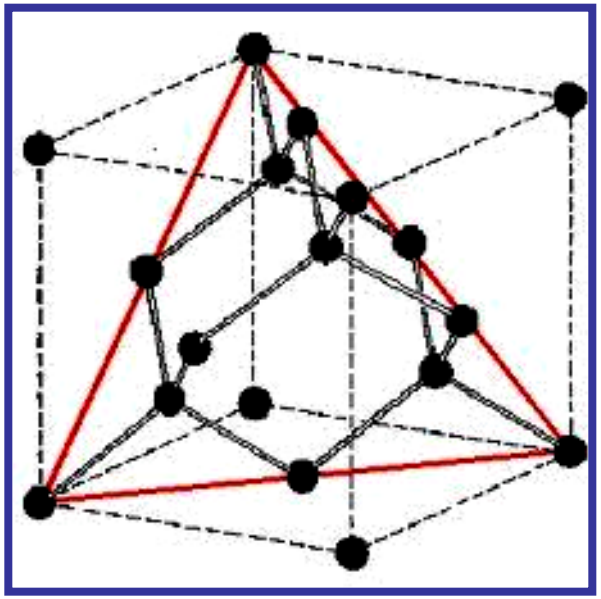


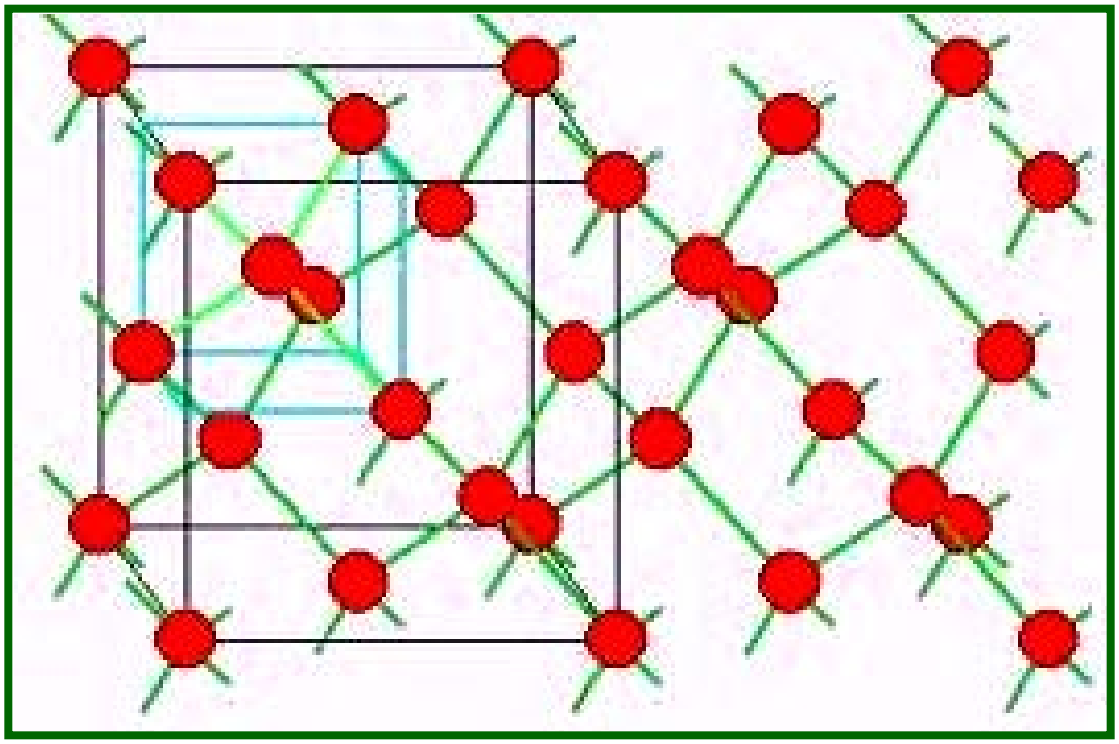
Diamond cubic unit cell showing (a) atom positions. There are two atoms per lattice point (note the outlined example). Each atom is tetrahedrally coordinated. (b) The actual packing of full-size atoms associated with the unit cell. [Part (b) courtesy of Accelrys, Inc.]

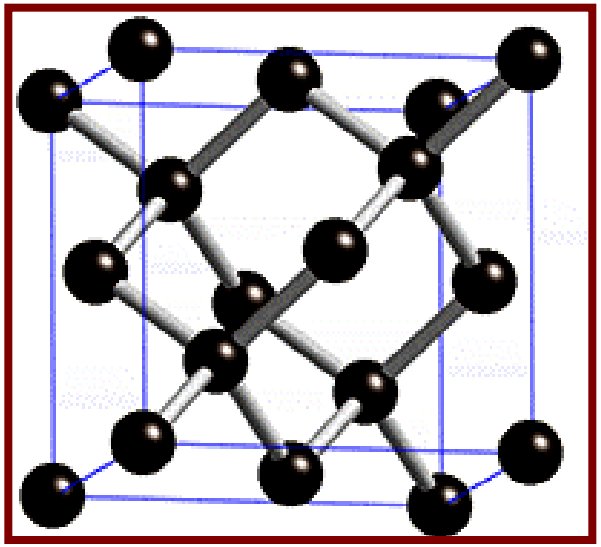


Structure: diamond cubic
Bravais lattice: fcc
Atoms/unit cell: $4 + 6 \times \frac{1}{2} + 8 \times \frac{1}{8} = 8$
Typical semiconductors: Si, Ge, and gray Sn

Diamond Lattice





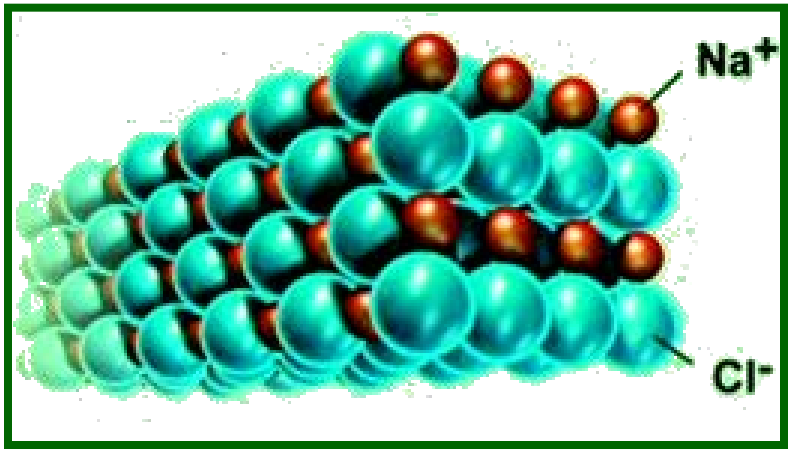


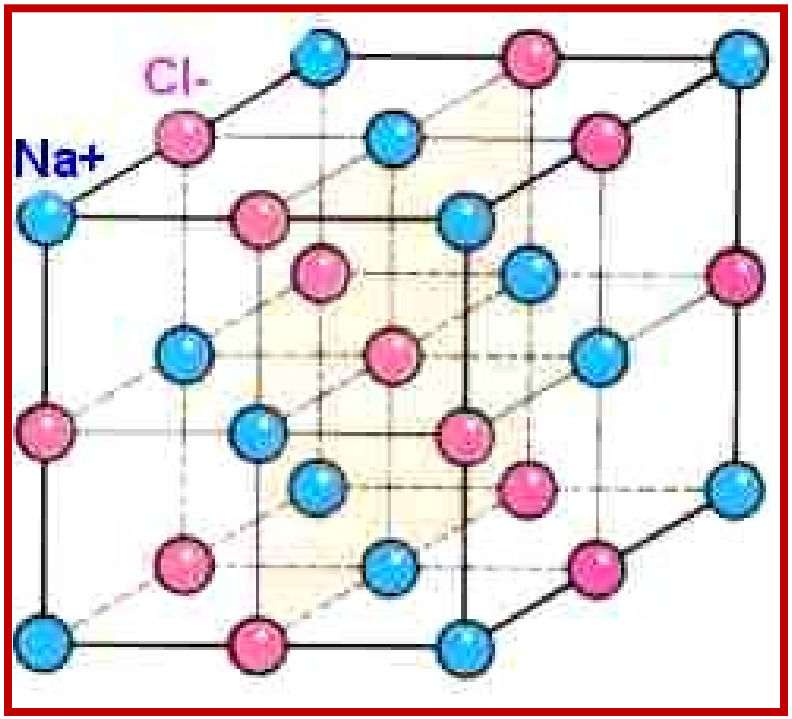
Diamond Lattice

The Cubic Unit Cell

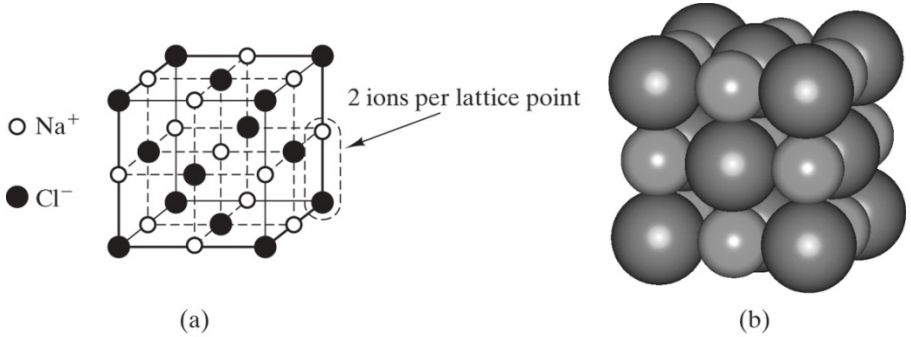
Sodium Chloride (NaCl) Structure

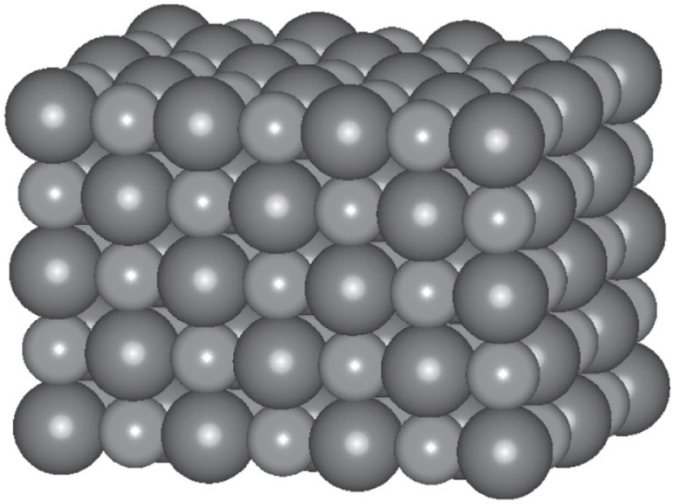
- Sodium chloride crystallizes in a lattice with cubic symmetry.
- This structure consists of equal numbers of sodium & chlorine ions placed at alternate points of a simple cubic lattice.
- Each ion has six of the other kind of ions as its nearest neighbors.





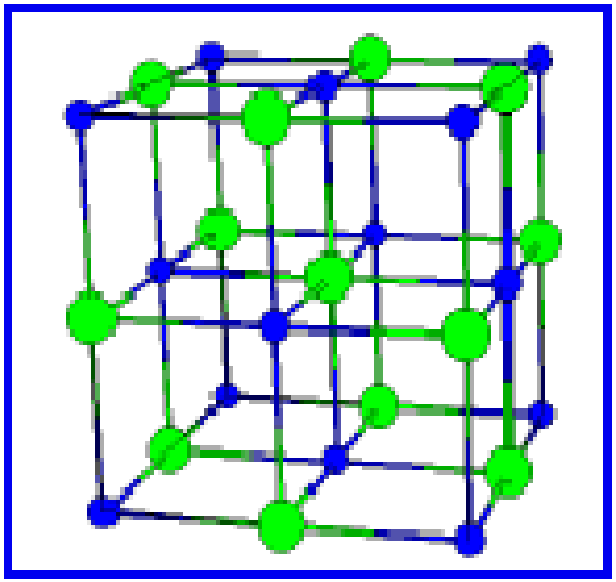
Sodium chloride (NaCl) structure showing (a) ion positions in a unit cell, (b) full-size ions, and (c) many adjacent unit cells. [Parts (b) and (c) courtesy of Accelrys, Inc.]





Structure: NaCl type
Bravais lattice: fcc
Ions/unit cell: $4Na^+ + 4Cl^-$
Typical ceramics: MgO, CaO, FeO, and NiO

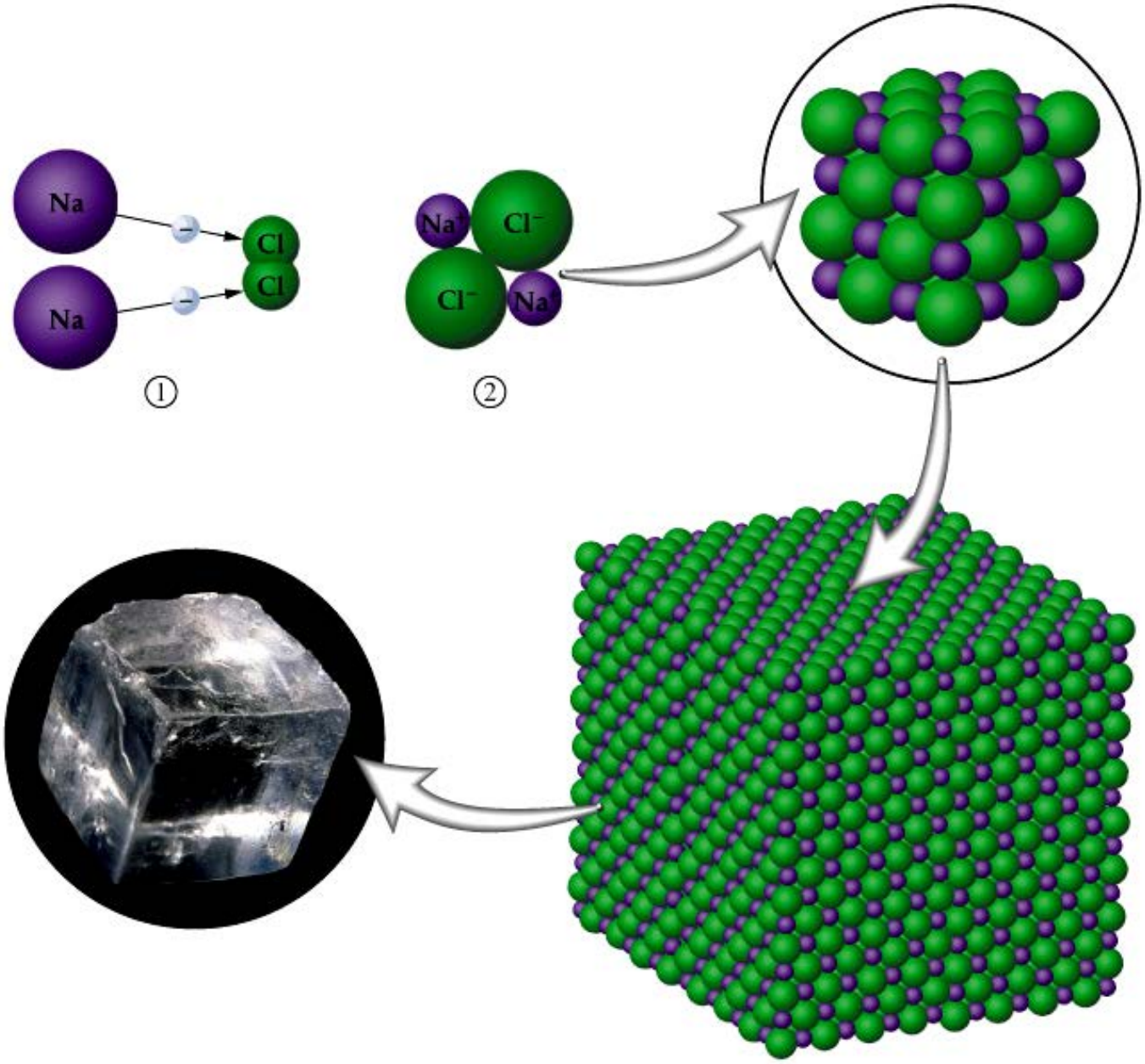
NaCl Structure

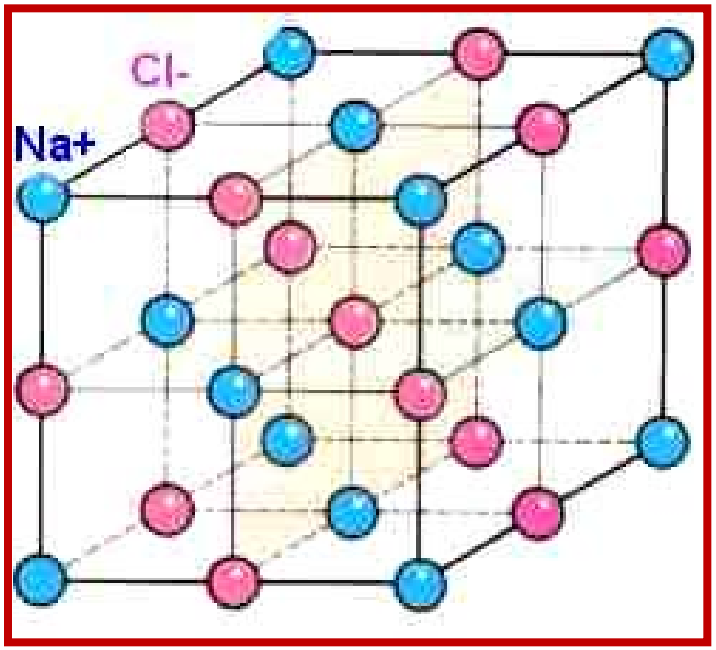


1 (Sodium Chloride) Structure

Cl: 000 ; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$,

Na: $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; $00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$,


Na
Na
Cl
Cl
①
Na⁺
Cl⁻
Cl⁻
Na⁺
②



- This structure can also be considered as a face-centered-cubic Bravais lattice with a basis consisting of a sodium ion at **0** and a chlorine ion at the center of the conventional cell, **at position**

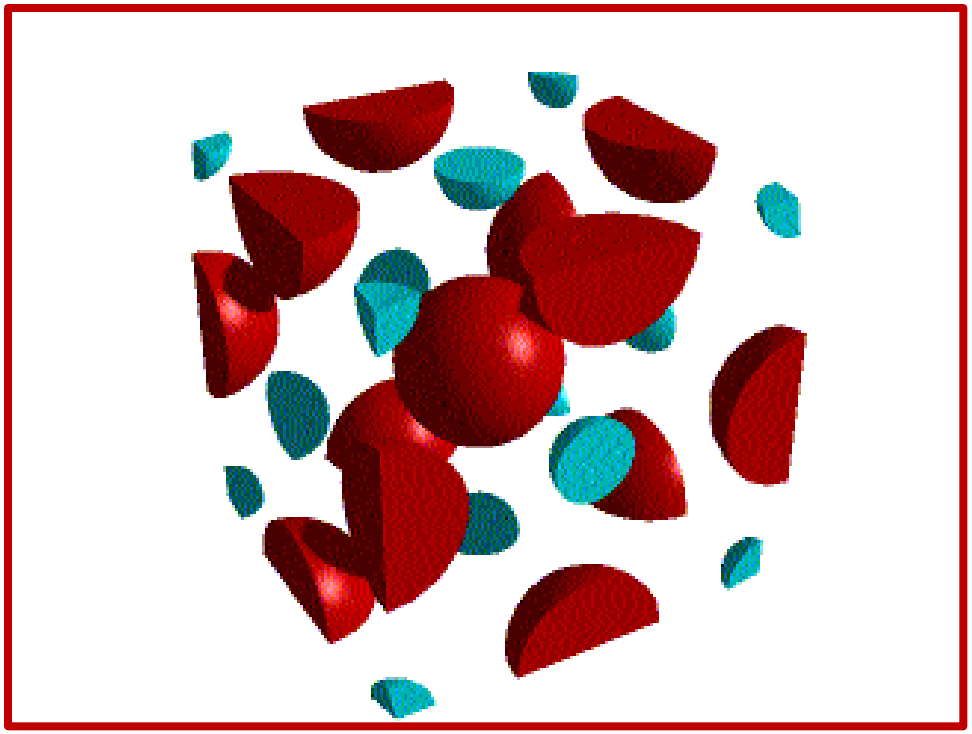
$$a/2(\vec{x}+\vec{y}+\vec{z})$$

LiF, NaBr, KCl, LiI, have this structure.

- The lattice constants are of the order of 4-7 Angstroms.

NaCl Structure

- Take the **NaCl unit cell** & remove all **"red" Cl** ions, leaving only the **"blue" Na**. Comparing this with the **FCC unit cell**, it is found to be that they are identical. So, the **Na ions** are on a **FCC sublattice.**



NaCl Type Crystals

Crystal	a	Crystal	a
LiH	4.08 Å	AgBr	5.77 Å
MgO	4.20	PbS	5.92
MnO	4.43	KCl	6.29
NaCl	5.63	KBr	6.59

REFERENCES

- Introduction To Solid State Physics- Kittle
- Elementary Solid state Physics- Omar
- Solid state Physics- S. O. Pillai

THANK YOU !