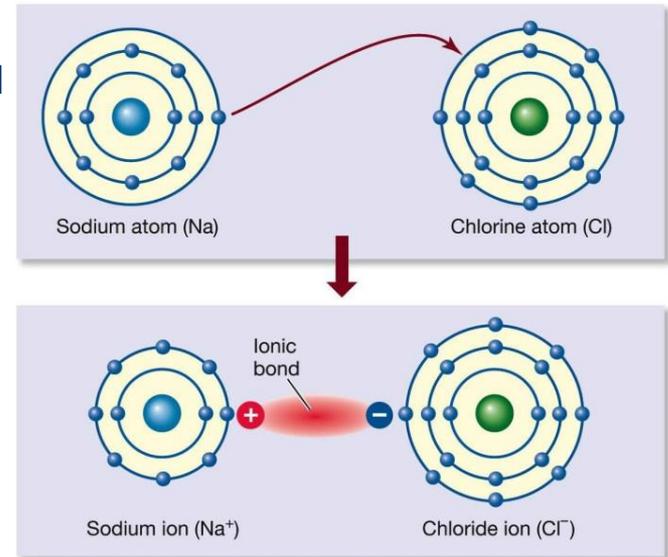


## Problem 1

Explain the ionic bonds, covalent bonds and metallic bonds and give one example for each type of bonds.

### ■ Ionic Bonds

- Two neutral atoms close to each can undergo an ionization process in order to obtain a full valence shell
- Due to ionization, electrons are transferred from one atom to the other
- The atom giving up the electron becomes positively charged (cation)
- The atom taking up the electron becomes negatively charged (anion)
- The ions are bonded due to coulombic forces of attraction
- Generally, metallic atoms donate electrons to non-metallic atoms
- Examples: NaCl, KCl, MgBr<sub>2</sub> etc.



LIFE 8e, Figure 2.10

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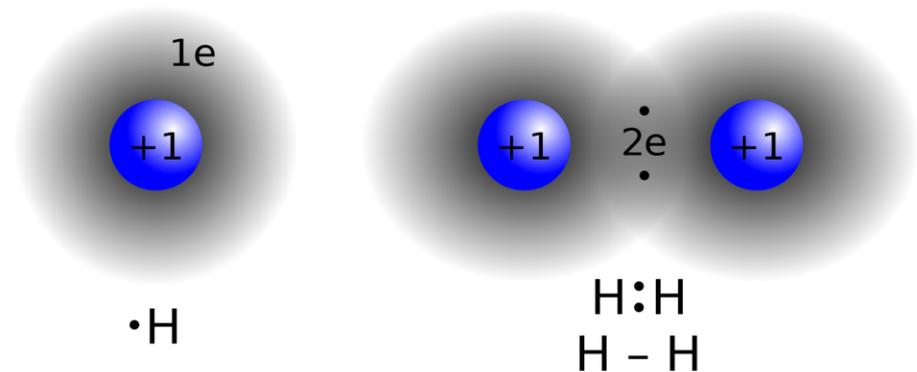
Ionic bond between sodium and chloride forming NaCl

## Problem 1

*Explain the ionic bonds, covalent bonds and metallic bonds, and give one example for each type of bonds.*

### ■ Covalent bonds

- The outer electron levels of atoms, which are close to each other, can interact
- The interaction leads to a sharing of electrons between the atoms
  - One pair of electrons shared => single covalent bond
  - Two pairs of electrons shared => double covalent bond and so on
- The shared electrons are said to be delocalized i.e. they do not belong to any particular atom
- Generally, between non-metallic atoms
- Examples:  $H_2$ ,  $CO_2$ ,  $C_6H_{12}O_6$  and other molecules



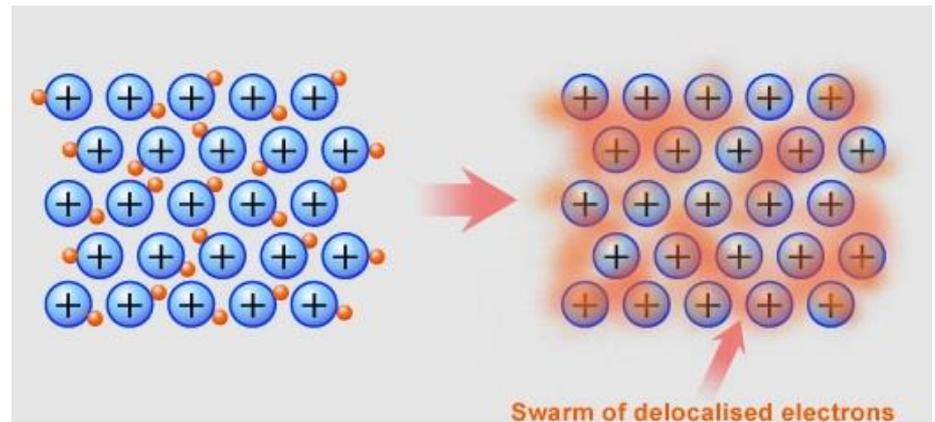
Single hydrogen atom (left) and two hydrogen atoms forming a covalent bond with a shared electron pair (right)

## Problem 1

*Explain the ionic bonds, covalent bonds and metallic bonds, and give one example for each type of bonds.*

### ■ *Metallic bonds*

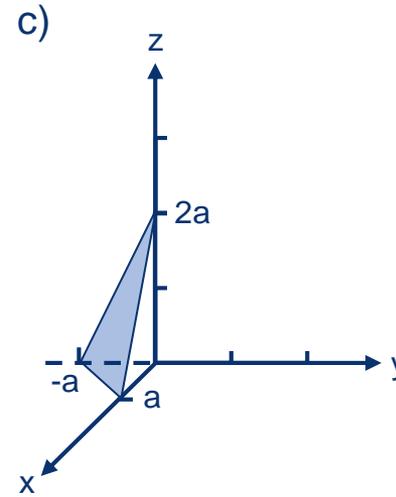
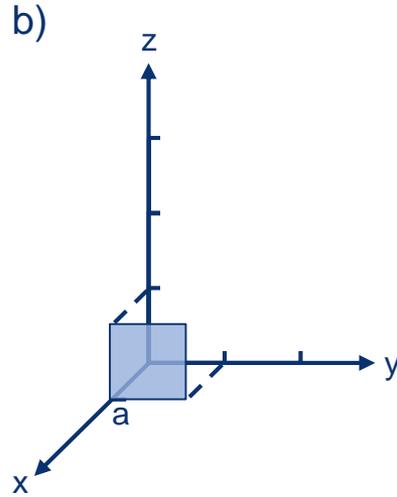
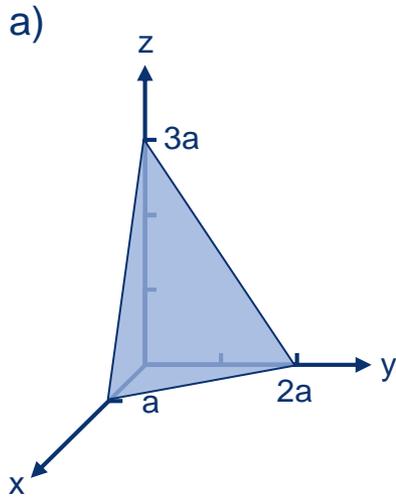
- Atoms come together, electrons from outer shell of atoms share space with neighbouring atoms.
- The electrons can move freely within the atom orbitals.
- Sharing of 'free' electrons among a lattice of positively charged ions (An array of positive ions in a sea of electrons)
- Electrostatic attractive forces between delocalized electrons and positively charged metal ions.
- Between metallic atoms
- Examples: Ni, Fe and other metals



The outer electrons are so weakly bound to metal atoms that they are free to roam across the entire metal. This results in a lattice of positively ions in a sea of communal electrons

## Problem 2

Miller indices: Find the miller indices of the following planes



- Miller indices

a) (632)

b) (100)

c) ( $\bar{2}$ 21)

(Negative integers are written with a bar, as in  $\bar{2}$  for  $-2$ )

## Problem 2

- The Miller indices of a plane (hkl) can be found by
  - Determining the intercepts of the plane on the three Cartesian coordinates
  - Measuring the distances of the intercepts from the origin in multiples of the lattice constant  $a$

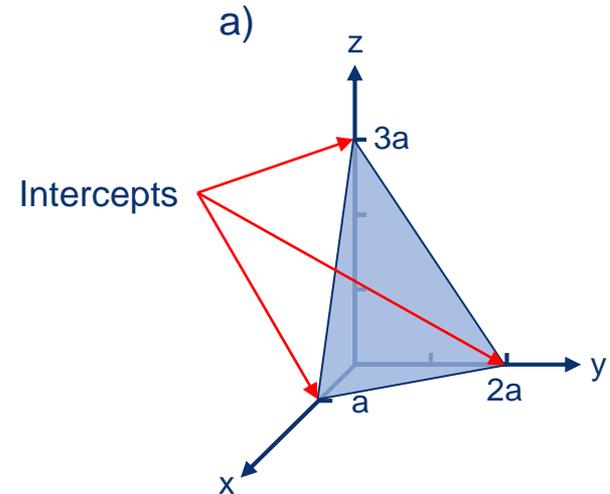
$$\Rightarrow (1 \ 2 \ 3)$$

- Taking the reciprocals of the intercepts

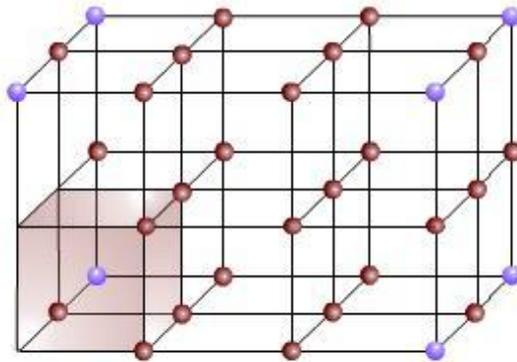
$$\Rightarrow (1/1 \ 1/2 \ 1/3)$$

- Multiply by the least common multiple of the intercepts (here 6)

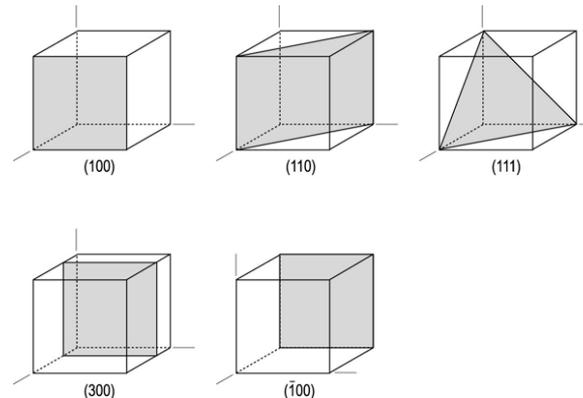
$$\Rightarrow (6 \ 3 \ 2)$$



- Miller indices
  - A crystal structure is characterized by its unit cell. The unit cells are stacked in three-dimensional space to form the crystal
  - The three axes of the unit cell are called the crystallographic axes
  - Miller indices are used to specify directions and planes in a crystal
  - $(hkl)$  a plane,  $\{hkl\}$  a family of planes,  $[hkl]$  a direction,  $\langle hkl \rangle$  a family of directions
  - All planes with the same miller indices are parallel to each other



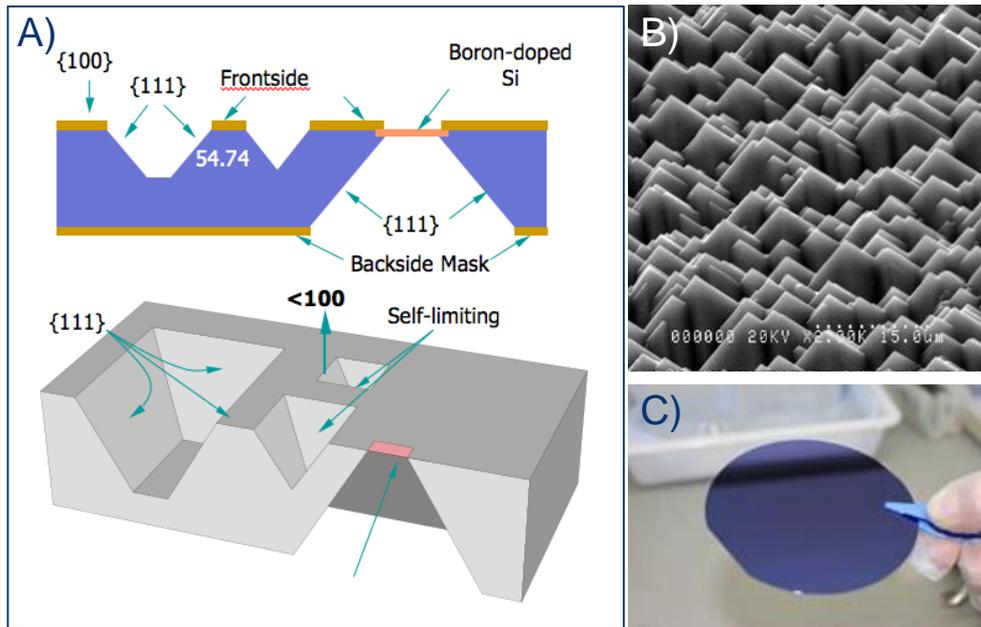
Representation of space lattice and unit cell



Different planes through the unit cell and the corresponding Miller indices

## More Insight: Miller indices (Example)

- An example of miller indices
  - For silicon crystal, (111) plane has more atoms per area than (100)
  - Etching rate of (111) is lower than (100)
  - Pyramid-shaped surface of solar cells
  - Silicon wafers are usually cut along a {100} plane with a flat or notch.



A) Slower etching rate of the {111} plane leads to pyramid-shaped structure in silicon. B) Surface of a silicon solar cells  
C) Silicon wafer

## Problem 3

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■ Which of these statements related to carbon allotropes are true?

a) Graphite consists of multiple layers of graphene ✓

b) Fullerene C<sub>60</sub> is the chemically most reactive form of carbon x

*(Graphene is the chemically most reactive form)*

c) Electrons travel through graphene as if they would have no mass ✓

*(with a new “speed of light” given by the fermi velocity  $v_F = 10^6$  m/s)*

d) Diamond is the hardest form of carbon x

*(Graphene is harder than diamond)*

e) Graphene can be harvested from graphite using Scotch tape ✓

*(Andre Geim and Konstantin Novoselov were the first to isolate graphene using only adhesive tape (“Scotch tape”) and the lead of pencils in 2004 (They won the noble prize in 2010 for their research on graphene))*

*How does superparamagnetism differ from paramagnetism?*

- Paramagnetism

- Paramagnetic materials have a magnetic susceptibility only in the presence of an external magnetic field, i.e. there is no remanence once the field is removed
- Ferromagnetic materials (i.e. materials that display remanence even after the external field is removed) become paramagnetic when they are heated beyond their Curie temperatures. The heating randomizes the magnetic orientation and removes any remanence

- Superparamagnetism

- The material in its bulk form is ferromagnetic
- Well below its Curie temperature, as the size is reduced to a few nanometers, the material becomes a cluster of nanoparticles
- Each particle will be a magnetic domain, and the overall cluster will have no remanence, i.e. it behaves like a paramagnetic material

*How does superparamagnetism differ from paramagnetism?*

- Differences

- i)

- Paramagnetism is found in paramagnetic material and in ferromagnetic material at temperature beyond their Curie temperature.
- Superparamagnetism is found in a ferromagnetic material below its Curie temperature as the size is reduced to a few nanometers.

- ii)

- The random magnetic orientation of atoms in the absence of a magnetic field removes any remanence in a paramagnetic material
- The random magnetic orientation of small particles in the absence of a magnetic field removes any remanence in a superparamagnetic material

- iii)

- The magnetic susceptibility of superparamagnetic materials is much larger than that of paramagnets.