Different types of solid crystal

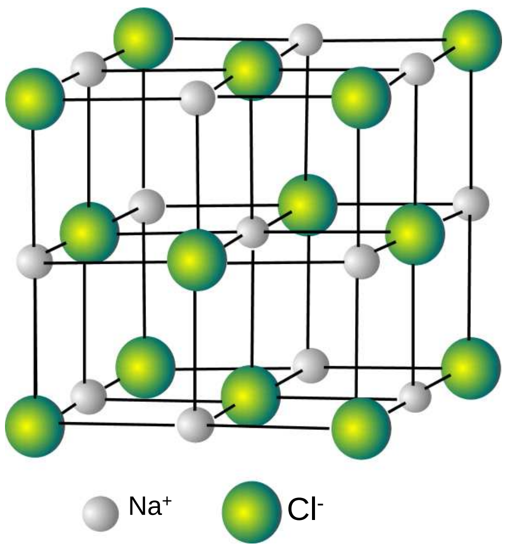
There are 4 types of solid crystal:

1. Ionic Crystals
2. Metallic Crystals
3. Molecular Crystals
4. Macromolecular crystals

KEY

Ionic Crystals: Sodium Chloride

The ions are arranged in a giant ionic lattice structure



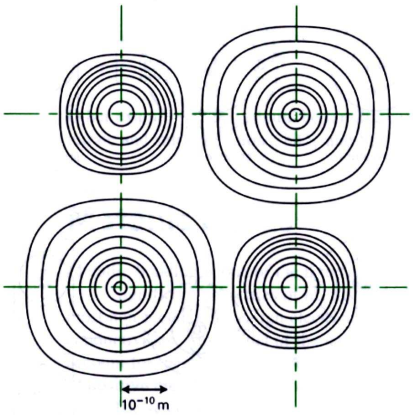
Be able to draw a section of this lattice in the exam

KEY

X-ray diffraction: Electron density map of NaCl

These maps show the likelihood of finding electrons in a region

The contours are lines of equal electron density

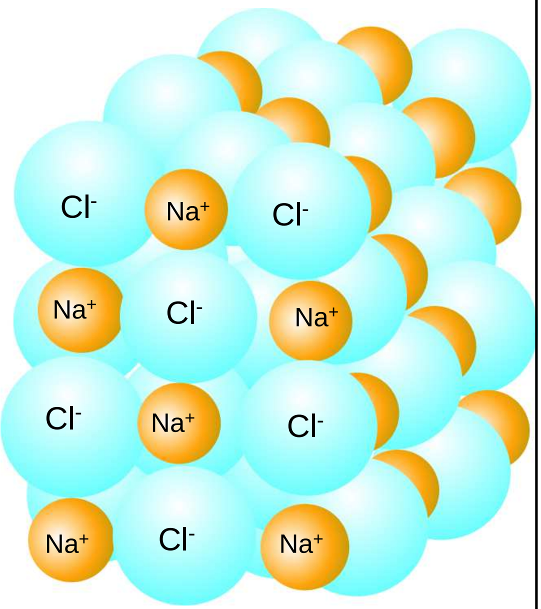


The maps show that for NaCl

- The ions are arranged in a regular pattern.
- The chloride ions are larger than the sodium ions
- The ions are discrete or separate, because the electron density falls to zero between the ions

EXTRA

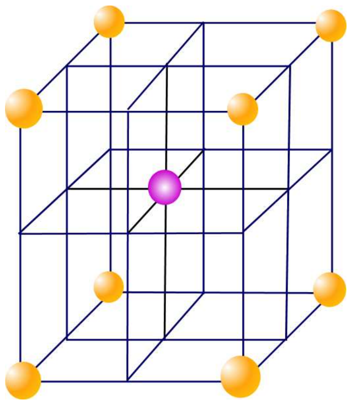
This is a more realistic representation of the arrangement of sodium ions (Na^+) and chloride ions (Cl^-) in the ionic compound sodium chloride.

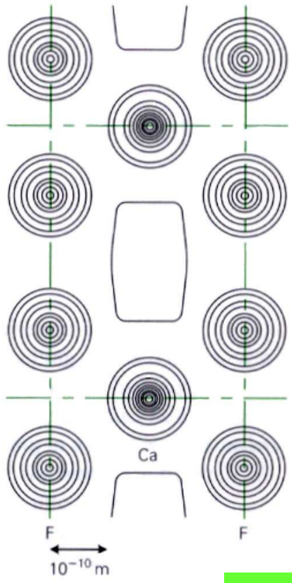


Caesium chloride

Not all ionic substances have the same arrangement of ions in their lattices.

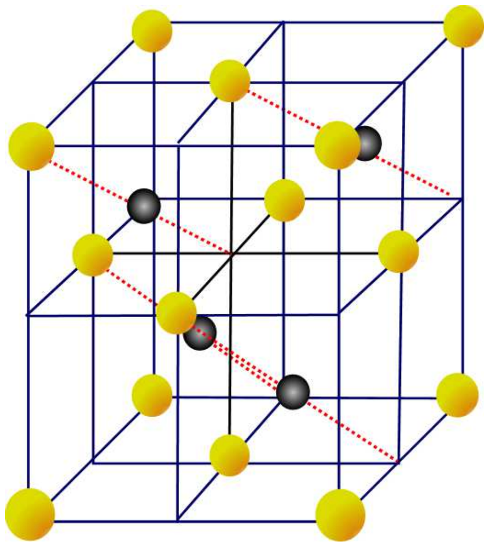
This electron density map of caesium chloride shows a different arrangement of the ions compared to NaCl





EXTRA

Zinc Blende (Cubic ZnS) Unit Cell



Zinc Blende has another arrangement of ions

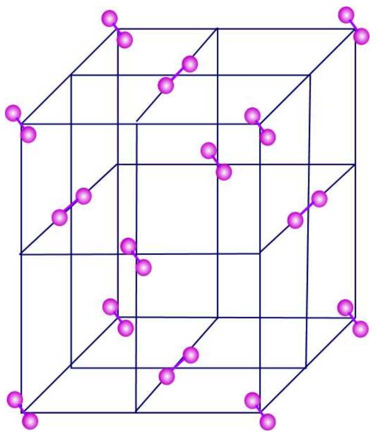
EXTRA

Properties of Ionic Compounds

- Crystalline structure.
- High melting points- because of strong forces between ions.
- Structure is rigid and brittle.
- They are **usually** soluble in aqueous solvents.
- In the solid state, they are non-conductors of electricity
- When molten or in aqueous solution they conduct electricity.

KEY

Molecular Crystals: Iodine



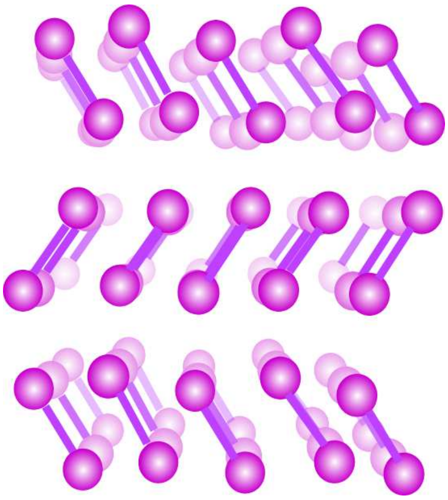
In molecular crystals the molecules are held together by intermolecular forces(van der waals, dipole-dipole or hydrogen bonding).

There are covalent bonds between the Iodine atoms in the I_2 molecule

The crystals contain a regular arrangement of I_2 molecules held together by weak van der waals intermolecular forces

KEY

Molecular Crystals: Iodine



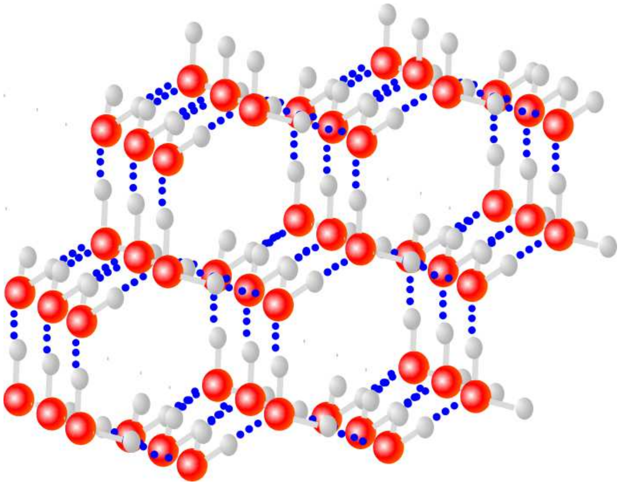
Properties of molecular crystals

- Low melting and boiling points because the van der waals forces are weak
- Non conductor of electricity in any state because no charged particles are present
- Low solubility in water because Iodine cannot form strong forces (hydrogen bonds) with water

KEY

Molecular Crystals: Iodine

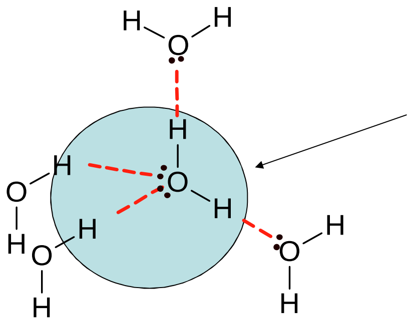
ICE



In ice the hydrogen bonds hold the water molecules together in a regular structure

Ice is less dense than water because the water molecules are held slightly further apart in the ice structure than they are in liquid water.

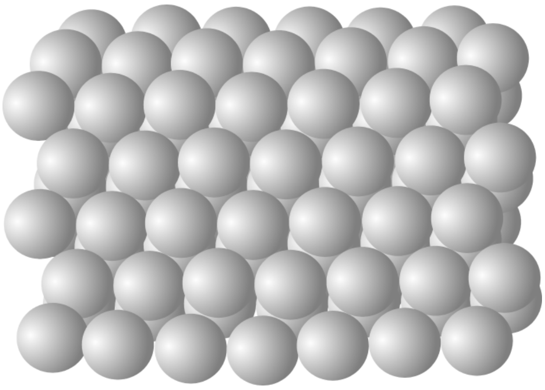
Drawing structure of Ice



This is a difficult diagram to draw.

The main point to show is a central water molecule with two ordinary covalent bonds and two hydrogen bonds in a tetrahedral arrangement

Metallic Crystals



The metal cations are held in place by a sea of delocalised electrons. The cations are packed as closely as possible.

KEY

Typical properties of metals

- High melting points (metallic bonding is a strong type of bonding)
- Malleable
- Conductors of electricity (the delocalised electrons will flow when a potential difference is applied across it)
- Shiny (due to delocalised electrons causing light to be reflected)

KEY

MACROMOLECULAR CRYSTALS

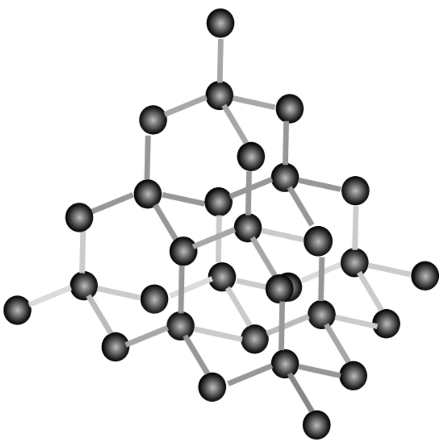
- Macromolecular crystals are giant molecular structures.
- Carbon in the form of graphite and diamond are Macromolecular crystals

Carbon can form macromolecular compounds because it can form 4 covalent bonds, whereas Iodine can only form one bond so only forms simple molecules

KEY

Diamond

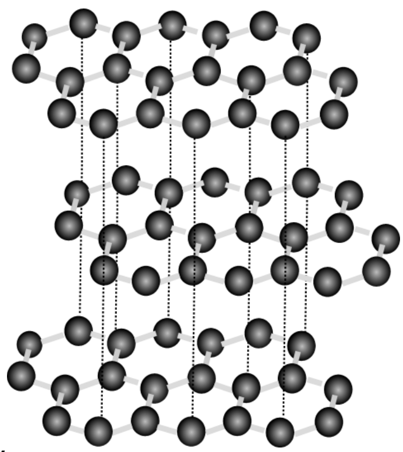
- Diamond has a giant covalent structure that contains many billions of atoms.
- Each carbon atom is bonded to four other carbon atoms.
- The covalent bonds that join the atoms are very strong. This makes diamond very hard, with high melting point. It does not conduct electricity because it has no free electrons.



KEY

Graphite:

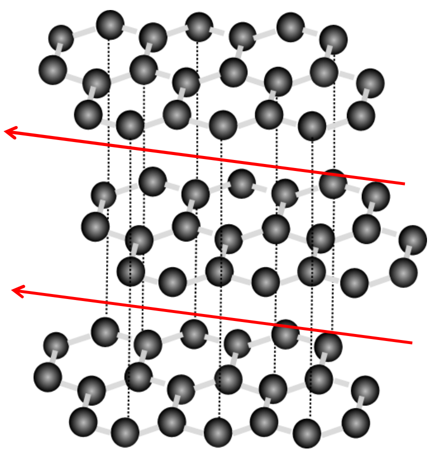
- Graphite atoms are arranged in layers, where each carbon atom is joined to three others. The layers have weak intermolecular forces between them. This means that the layers can easily slide over each other, and graphite therefore has a lubricating action (and is soft).
- Graphite has a high melting point because the covalent bonds within the layers are very strong.



KEY

Graphite Conducting Electricity

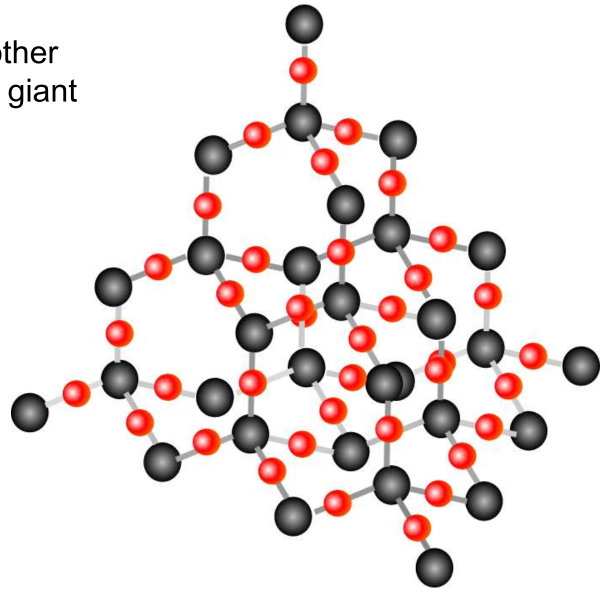
Graphite can conduct electricity because there are free electrons that are delocalised between the layers. The electrons will move if an electric charge is applied.



KEY

Silicon Dioxide

Silicon dioxide is another substance that has a giant molecular structure

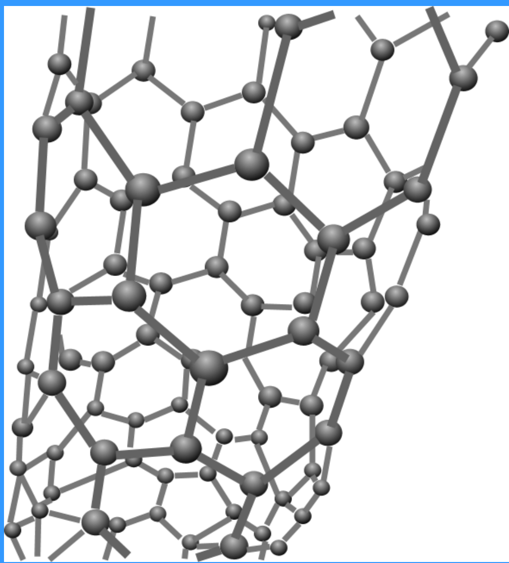


What Properties would you expect SiO_2 to have?

Silicon Dioxide

- It has a high melting point. The very strong silicon-oxygen covalent bonds have to be broken throughout the structure before melting occurs.
- It is hard. This is due to the very strong covalent bonds.
- It does not conduct electricity. There are not any delocalised electrons. All the electrons are held tightly between the atoms.
- It is insoluble in water and organic solvents. There are no possible attractions which could occur between solvent molecules and the silicon or oxygen atoms which could overcome the covalent bonds in the giant structure.

Carbon nanotube



By comparing the structure with graphite and diamond make predictions about the properties of carbon nanotubes.
-melting point
-electrical conductivity
-strength

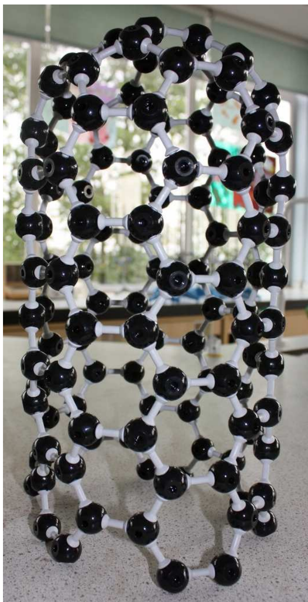
EXTRA

Properties of carbon nanotubes?

Carbon nanotubes have many useful properties, including:

- very high tensile strength
- unique electrical properties, including superconductive at low temperatures
- good heat conductance

Multi-walled nanotubes exist, where several concentric tubes lie within in each other. The inner tubes can rotate and slide within the outer tube almost without friction.



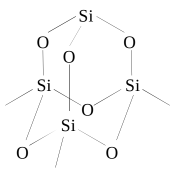
EXTRA

Exam Questions

1. State and explain the similarities and differences in electrical conductivity of sodium, graphite and diamond.
2. Why is molten sodium chloride a good conductor of electricity?
3. Silver and sodium chloride melt at similar temperatures. Give two physical properties of silver which are different from those of sodium chloride and, in each case, give one reason why the property of silver is different from that of sodium chloride.

Exam Questions

1. The diagram here represents a section of a crystal of silicon dioxide.



(a) Name an element which has a structure similar to this.

(b) Name the type of bonding between silicon and oxygen in this crystal.

(c) Name the type of structure illustrated by this diagram.

(d) Describe the motion of the atoms in this crystalline solid.

(e) In terms of structure and bonding, describe what happens to the atoms in this crystal when it melts.

(f) Explain why this crystal is a non-conductor of electricity in the solid state and why graphite is a good conductor.

Exam Questions

1. Describe, with the aid of diagrams, the structure of, and bonding in, sodium chloride, iodine, diamond and graphite. How do the properties of these different types of crystal enable you to distinguish between them?

(20)

2. Explain, in terms of their bonding and structures, why both graphite and tungsten have good electrical conductivities and high melting points.

(6)

3. With the aid of diagrams, describe the structure of, and bonding in, crystals of sodium chloride, graphite and magnesium. In each case, explain how the melting point and the ability to conduct electricity of these substances can be understood by a consideration of the structure and bonding involved. (23)