10 Structure, Bonding and Properties

10.1 Structure of Substance

The structure of a substance is a description of what its ____________ ____________ are, and about how they are __________ or __________ __________.

Classification of substances according to structure

Broadly speaking, substances are classified into

(1) **Molecular structures** in which molecules are bonded with weak intermolecular forces.

(a) **Simple molecular structures**

Usually simple non-metallic elements like hydrogen and iodine would exist as simple molecular structures. The melting points and boiling points are ___________ (lower/higher).

(b) **Macromolecules**

Usually polymeric substances like polythene exists as a giant molecule consisting of many molecules joined together.

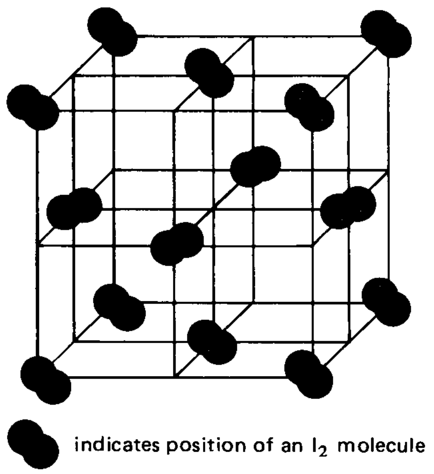
(2) **Giant Structures**

In giant structures, all particles are joined together by strong chemical bonds resulting in a giant lattice in which particles are linked without discrete molecules to exist.

Refer to p. 159 of Book 1A, Figure 10.3 Classification of substances according to structure.

10.2 Simple Molecular Structures

When there are a group of molecules, they tend to arrange themselves in space in the form of a **lattice** (a regular arrangement). Such a structure is called **Simple Molecular Structure**.
Iodine is a good example to show the Simple Molecular Structure



The lattice of iodine consists of a regular arrangement of iodine molecules.

Within each iodine molecule, I-I, there is a very strong covalent bond.

However, between the iodine molecules, there are only weak intermolecular forces.

To **melt** iodine solid, **only the weak intermolecular forces need to be broken** to separate the iodine molecules. The **covalent bonds remains intact** (not-broken).

Properties of Simple Molecular Substances

(1) Simple molecular substances have low melting points and boiling points.

Only weak intermolecular forces between individual molecules have to be broken and as a result the melting and boiling points are lower.

(2) Simple molecular solids are soft

Once again only weak intermolecular forces exist between the molecules and the structures are relatively easy to be cut open.

(3) They are usually insoluble in water but soluble in non-aqueous (organic) solvents

Molecular substances are mostly non-polar and would not dissolve in water (as water is a polar solvent). Since most organic solvents are non-polar and according to the rule – “Like dissolves like”, molecular substances have higher solubility in non-aqueous solvents.

(4) They are non-conductors of electricity whether in solid, liquids or in aqueous solution
The absence of mobile ions of molecular substances does not permit them to conduct electricity.

Q.10.2

(a) Is sulphur high-melting or low-melting? Explain

(b) Are sulphur crystals hard? Explain.

(c) Does molten sulphur conduct electricity? Why?

(d) Is sulphur soluble in (i) water (a polar solvent) or (ii) carbon disulphide, CS_2, an organic solvent? Explain.

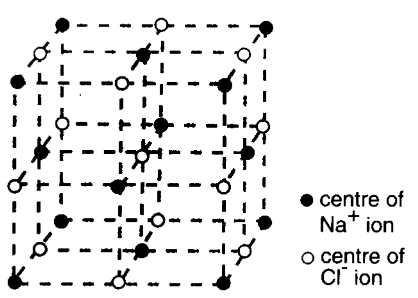
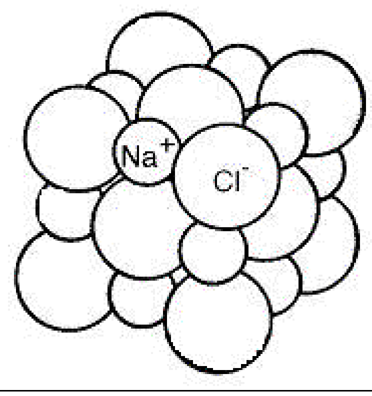
10.3 Macromolecules

Macromolecules are very large molecules each containing thousands of atoms.
There are natural macromolecules like proteins and carbohydrate.
Polymers like plastics are synthetic macromolecules.

10.4 Giant Ionic Structures

Recall from form three studies that when a metal combine with a non-metal an ionic compound is formed.
The forces holding the positive and negative ions are called electrostatic forces.
Electrostatic force is a type of bonding.

The structure of a substance, however, is the **arrangement of the units of the substance in space**.
For an ionic compound like sodium chloride, NaCl, the structure looks like the following figure.

	
Lattice view showing the regular arrangement of the Na^+ and Cl^- ions	Space-filling view showing the tight contact among Na^+ and Cl^- ions

It is easier to draw the lattice view than the space-filling view. However the space-filling view shows a more **realistic** picture of the arrangement of ions in space.
The crystal structure of sodium chloride is described as an ionic giant lattice.
The structure is giant because there are **many units of Na^+ and Cl^-** ions forming a giant structure.

Properties of Ionic Compounds
(1) All ionic compounds are solids. This is as a result of the strong electrostatic attraction between the cations and anions in the ionic lattice.
(2) They usually have high melting points and boiling points.
(3) Most of them are soluble in water, but insoluble in non-aqueous solvents.
(4) They are electrolytes and can conduct electricity when molten or in aqueous solution.

Question for discussion :
Based on the structure of NaCl, explain why
(i) it dissolves in a polar solvent like water

(ii) it has a very high melting point (about 800° C)

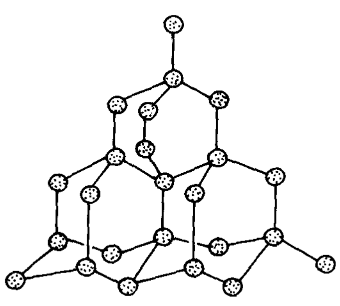
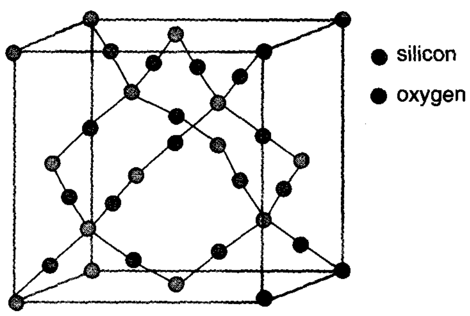
10.5 Giant Covalent Structures

In giant covalent structures, usually non-metal elements join together by covalent bonds to form a 3-dimensional giant network, called giant covalent structure. There are no discrete molecules and the covalent bonds extend throughout the whole structure.

Diamond
In diamond, each carbon atom forms single bonds with 4 other carbon atoms. The bonds are tetrahedrally distributed. This bonding extends throughout the crystal to form a three-dimensional giant stucture.

As all the outermost electrons of the carbon atom are used up in bonding, there are no free electrons in the diamond structure, hence diamond is an **insulator**.
Because of a giant structure, diamond is **hard** and possesses **very high melting point**.

Quartz
Quartz is a form of silicon(IV) oxide, SiO_2.
In quartz, each silicon atom is bonded to 4 oxygen atoms. But each oxygen atom is bonded to 2 silicon atoms only.
Each Si-O bond is arranged tetrahedrally in space.
This regular tetrahderal arrangement is repeated to give a covalent giant structure.

	
Structure of diamond A regular arrangement of carbon atoms tetrahedrally.	Structure of quartz A regular arrangement of silicon and oxygen atoms with the Si-O bonds tetrahedrally arranged

Properties of Giant Covalent Structures

(1) They are all solids with very high melting and boiling points. Many strong covalent bonds within the giant covalent structures have to be broken down during the melting and boiling processes.
(2) Almost all giant covalent structures are hard, graphite is an exception.
(3) Giant covalent substances are insoluble in any solvent, including aqueous and non-aqueous solvents.
(4) Almost all giant covalent substances are non-conductors of electricity, graphite is an exception.

Q.10.3

(a) Is tridymite (a form of silicon(IV) oxide, SiO_2) soluble in
(i) water

(ii) methylbenzene (a non-aqueous solvent)?

(b) Does molten tridymite conduct electricity? Why?

Complete the following table
A comparison of the properties of different structures

Property	Ionic giant structure	Simple molecular	Covalent giant structure
Melting and boiling points			
Hardness			
Solubility in water			
Electrolytic conduction			

Hint: Use words like high/low, hard/soft/brittle, soluble/insoluble, conductor/insulator.

Q.10.4

The following table gives information about some properties of substances A to D.

Substance	M.p. (°C)	Electrical conductivity	
		solid	molten
A	70	poor	poor
B	375	poor	good
C	98	good	good
D	1610	poor	poor

Answer the following questions, and explain your answers.
(a) Which substance has a giant metallic structure?

(b) Which substance has a giant ionic structure?

(c) Which substance has a simple molecular structure?

(d) Which substance has a giant covalent structure?

(e) Which substance is likely to be soluble in methylbenzene?

Refer to the **Summary** on p.168 of Book 1A

	Simple Molecular Structure	Giant Ionic Structure	Giant Covalent structure
(1) Examples	H_2, I_2, H_2O, etc		
(2) Structure		giant lattice of ions	
(3) Bonds holding constituent particles			covalent bonds link atoms throughout the network structure
(4) Physical properties (a) State at room conditions		solid	
(b) M.p. and b.p.			very high
(c) Hardness of solid form	soft		
(d) Solubility in (i) water (ii) non-aqueous solvents			insoluble insoluble
(e) Conduction of electricity	Non-conductors		