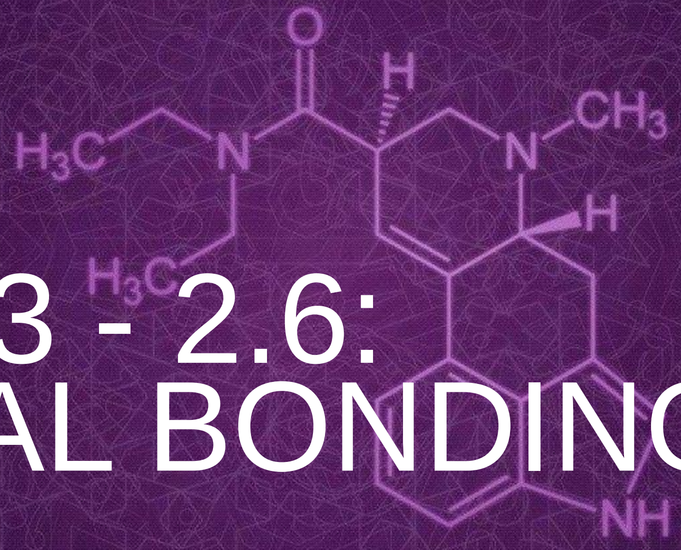
TOPIC 2.3 - 2.6: CHEMICAL BONDING



THE ABOUT

CHAPTER ANALYSIS

TIME

- Important chapter, will always be tested
- 3 **key** concepts
- 1 **advanced** concept

EXAM

- Commonly tested, especially for Section A
- Tested as together with other chapters

  → Atomic Structure, Chemical Equations

WEIGHTAGE

- Medium overall weightage
- Constitute to **4.5%** of marks for past 5 year papers

ELEMENTS, COMPOUNDS, MIXTURE

	Elements	Compound	Mixture
Formation	Naturally found	**Chemically** combined	**Physically** combined
Separation technique	Cannot be separated further	Separated using **chemical methods** (Decomposition, electrolysis, reduction with carbon)	Separated using **physical methods** (separation techniques)
Composition	Exist by itself or as diatomic molecules for gas such as N_2 or O_2.	**Fixed** ratio	**Any** ratio
Melting Point / Boiling Point	**Fixed** MP & BP	**Fixed** MP & BP	Melts and boils over a **range of temperature**

<u>*A compound must be a molecule, but a molecule need not be a compound.</u>

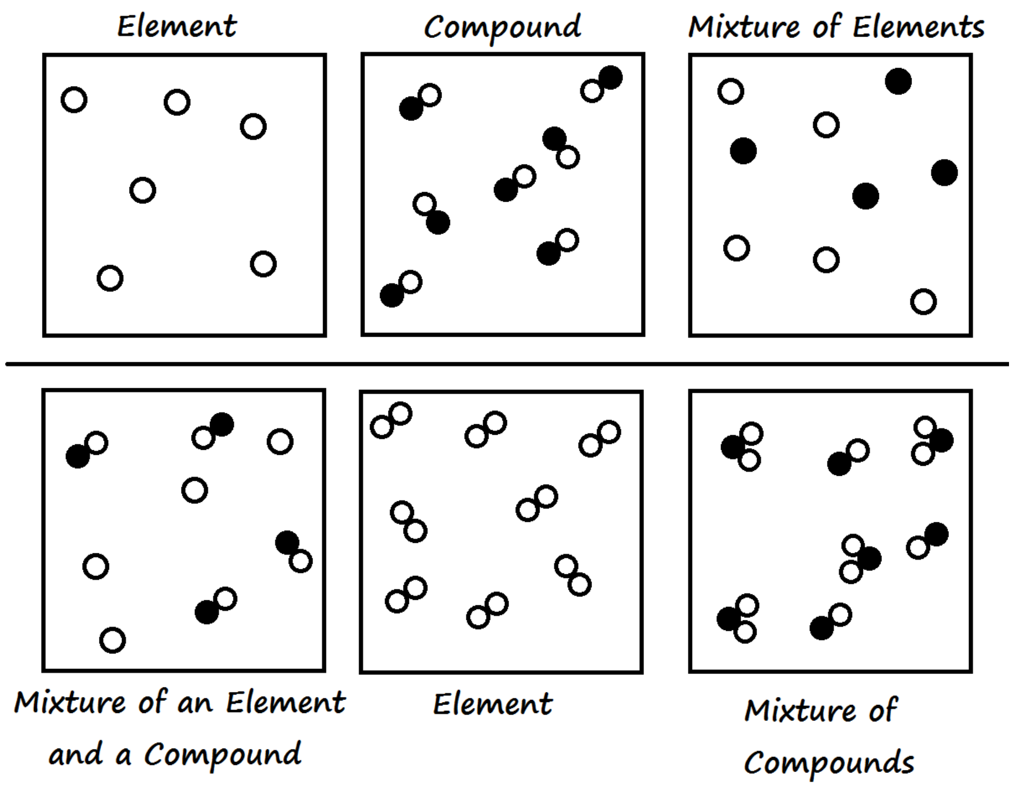
A molecule is defined as **2 or more atoms** chemically combined.

An **element** can exist as a **solid** or as a **molecule** if it is in gaseous form at room temperature. (N_2, O_2, H_2)

A **compound**, however, must be a molecule as a compound is defined as **2 or more elements chemically combined.**

Understanding the term 'molecule'

ELEMENTS, COMPOUNDS, MIXTURE



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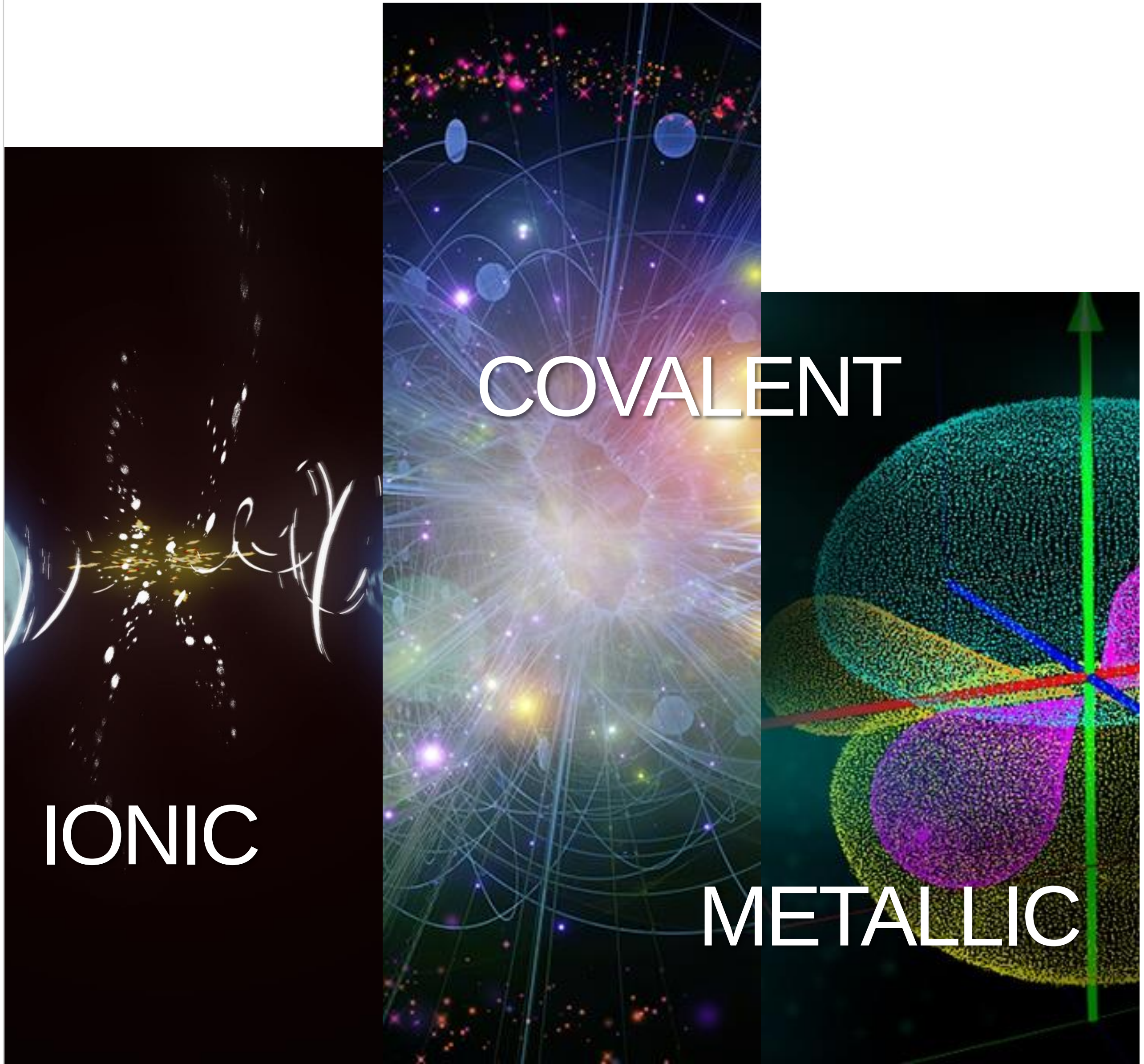


3 types of bonds

Understand all 3 types of bond to master this chapter while paying special attention to **keywords** you must include in your answers.

For each type of bond, you must be able to explain:

- How the bond is formed
- The dot-&-cross diagram
- The structure
- Physical properties (with explanations)

MUST KNOW

BASICS

Why are bonds formed?

Atoms of elements aim to attain **stability*** by achieving a **stable electronic configuration (2,8,8)**. This is achieved by forming chemical bonds with other atoms.

This is done by **transferring electrons, sharing electrons or forming a metal lattice**.

Non-metal atoms, like the Group VII halogens, form **ionic bonds** with metal atoms. They also form **covalent bonds** with other non-metal atoms.

Metal atoms form **metallic bonds** with other metal atoms.

**Recall 'Atomic Structure',*
"atom → ion → compound"
"single → seeking partner → in a relationship"

KEY CONCEPT

IONIC BONDS
METAL ION + NON-METAL ION
GIANT IONIC LATTICE STRUCTURE

Recall:

Cation: positively charged ion
→ t = '+' sign, positive

Anion: negatively charged ion
→ n = negative

KEY CONCEPT

IONIC BONDS

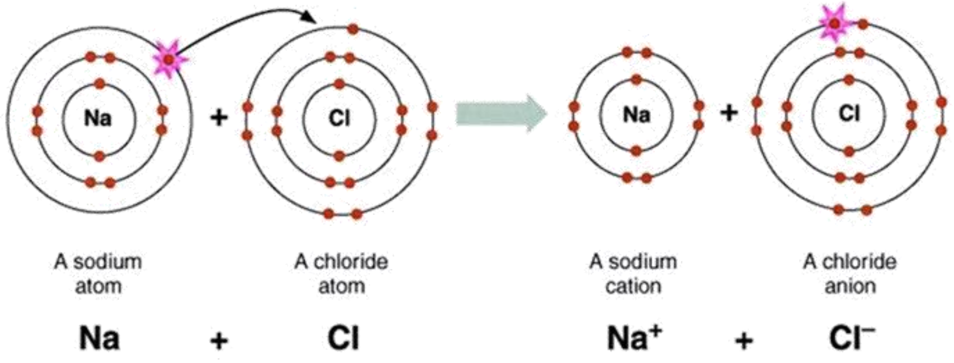
Ionic bonds are formed between **metals** and **non-metals**.

The **transfer of electron** from the metal to the non-metal allow both to have **complete valence shells** and to **attain a stable electronic configuration**.

The metal now becomes a **cation** while the non-metal becomes the **anion**.

These **oppositely charged ions** are attracted to each other by strong **electrostatic forces of attraction**.

This **forces of attraction between oppositely charged ions** is the ionic bond itself.



GIANT IONIC LATTICE STRUCTURE

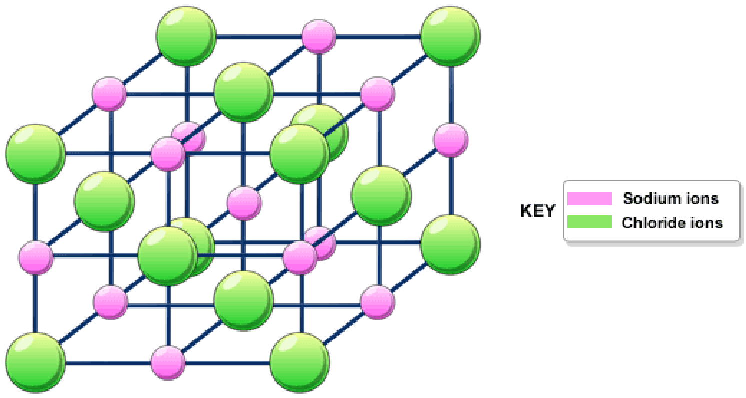
<u>GIANT IONIC LATTICE STRUCTURE</u>

Ionic compounds have a **giant ionic lattice structure** held together by **electrostatic forces of attraction between oppositely charged ions**.

Within the lattice, oppositely charged ions are arranged to be as near to each other as possible. Ions of the same charge are arranged to be as far apart as possible.

This maximises attraction and minimises repulsion, resulting in a highly stable structure.

Naming convention: (Cation)(Anion) eg: Sodium Chloride



ADVANCED

giant ionic lattice

Physical properties

- High MP & BP (usually exist as crystals at rtp)
- Soluble in water
- Conducts electricity in molten & aqueous state
- Poor conductor of heat
- Not volatile (does not evaporate easily)
- Hard

High melting and boiling points

Ionic substances generally have **high melting and boiling points.** (<1000 Degree Celsius)

The ions are held together by **strong ionic bonds** which **require a large amount of energy to overcome**.

Solubility

Most ionic compounds are **soluble in polar solvents like water**, but insoluble in organic solvents like acetone and benzene.

Ionic compounds are soluble in water because the partially charged (polar) water molecules attract the ions, disrupting the ionic lattice structure. This causes the ions to separate and dissolve in the solution.

Electrical conductivity & Thermal conductivity

To conduct electricity, the substance needs to have **mobile charge carriers**.

Since the ions in an ionic solid are all tightly held in place, **ionic compounds in solid state do not conduct electricity**.

However, when **in molten or aqueous state**, the ions are free to move, acting as mobile charge carriers, allowing it to **conduct electricity**.

Due to their high melting points, ionic compounds are able to **withstand exceedingly high temperatures** and are often used as refractories, which are materials specially selected due to their **heat-resistant properties**.

KEY CONCEPT

COVALENT BONDS
NON-METAL + NON-METAL ION
SIMPLE MOLECULAR STRUCTURE / GIANT COVALENT STRUCTURE

KEY CONCEPT

COVALENT BONDS

Covalent bonds are formed between **non-metal & non-metal**.

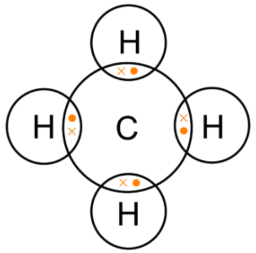
A covalent bond is defined as the **electrostatic force of attraction between the nuclei of the atoms and the shared electrons.**

In order to attain a stable electronic configuration, the atoms **share their valence electrons** so that they can both have full valence shells.

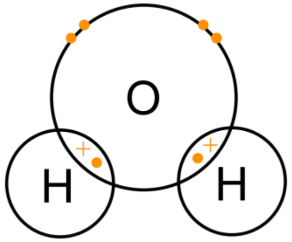
This sharing of electrons is known as a covalent bond.

Examples:

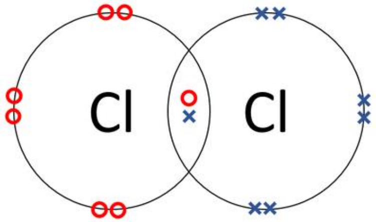
Methane Compound:



Water Compound:



Chlorine molecule:



ADVANCED CONCEPT

Many students are confused when it comes to the differences between the two:

How **exactly are they different** and **when does each one apply**?

TWO TYPE OF COVALENT BONDS
SIMPLE MOLECULAR
GIANT MOLECULAR

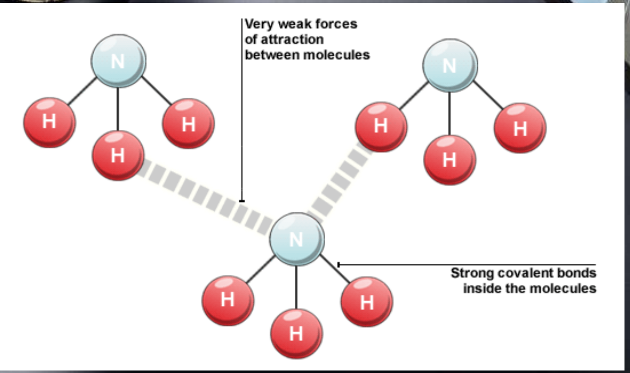
SIMPLE MOLECULAR STRUCTURE

Elements and compounds that are made up of small molecules have simple molecular structures.

Weak intermolecular forces of attraction, *AKA van der Waals' forces*, exist between the molecules that make up the compounds.

These intermolecular forces are easy to overcome, hence they have **low melting and boiling points.**

However, atoms within the molecules itself are held together by strong covalent bonds.

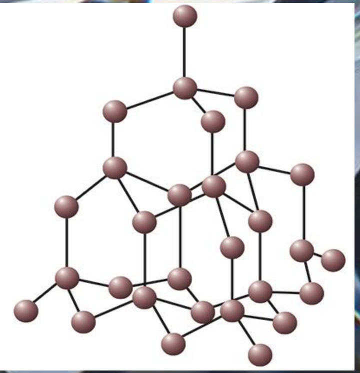


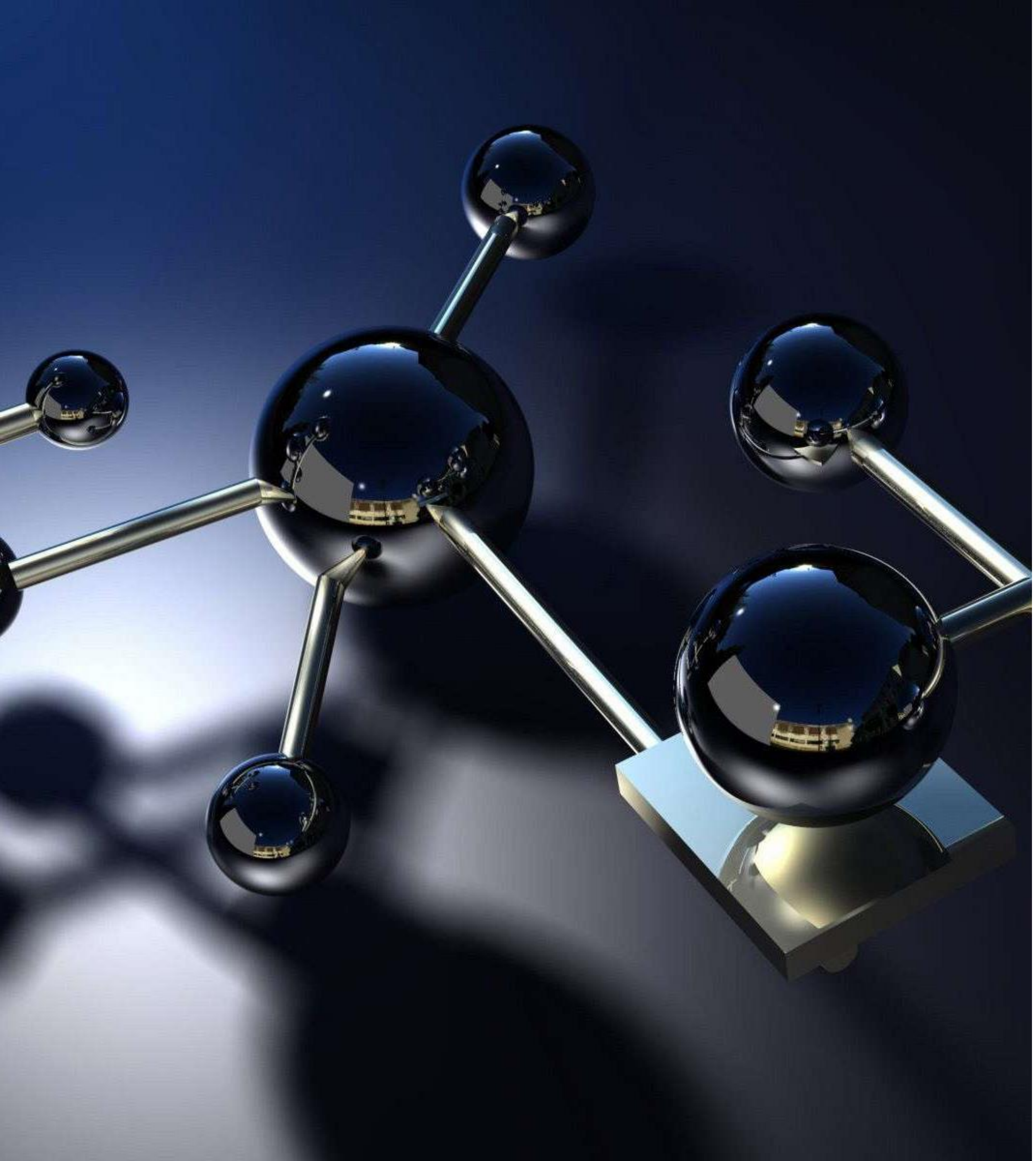
GIANT MOLECULAR STRUCTURE

These substances have extensive giant structures of atoms held together by **strong covalent bonds**, thus giving rise to the name "giant molecular structures".

They **high melting and boiling points** because these covalent bonds are very strong and any change of state requires huge amount of energy to overcome. *(MP & BP <1000 degree celcius)*

There are only 3 that you need to know:
Diamond, Graphite, Silicon Dioxide (Sand)





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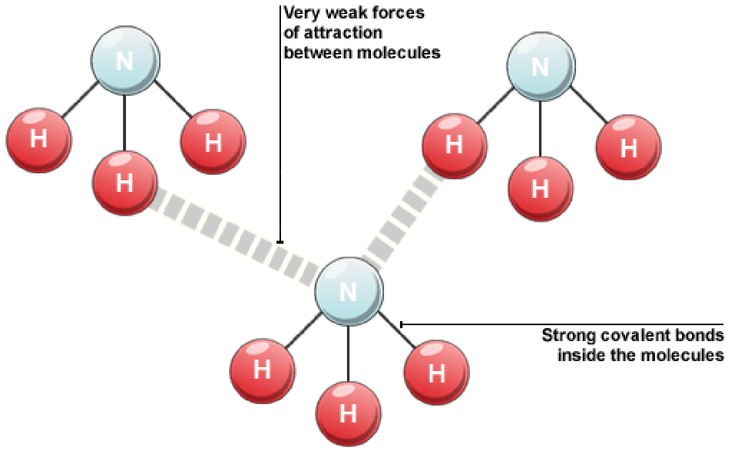
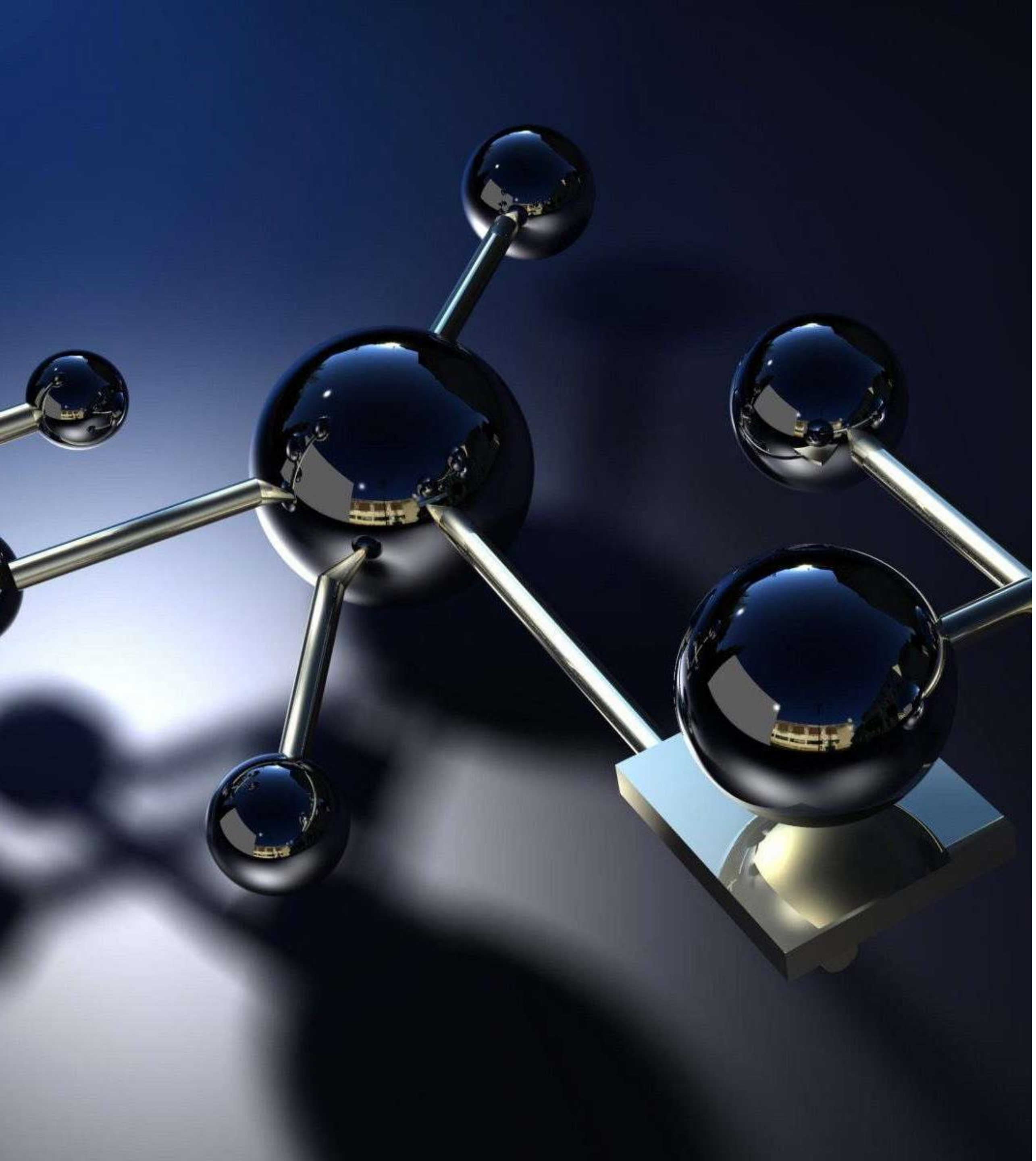


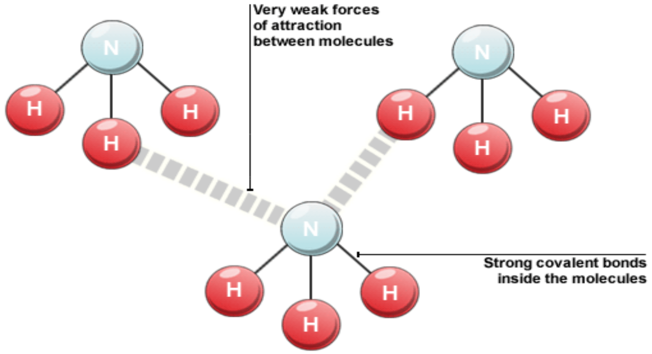


SIMPLE MOLECULAR STRUCTURE

For example, water is a compound with a simple molecular structure, consisting of water molecules.

These water molecules experience **weak intermolecular forces of attraction between neighbouring water molecules.** Hence, the low MP & BP.

HOWEVER, within the water molecules itself are **strong covalent bonds** that are holding together single oxygen atom and two hydrogen atoms.



TAKE NOTE!

Are covalent bonds strong? **Yes, very strong**.

Then why the low MP & BP? Because the **intermolecular forces are weak and easy to overcome.**

It is easy to make water change its state (melting/boiling) but **extremely difficult to break a water molecule back into hydrogen and oxygen atoms**, as that will involve breaking the covalent bond itself.

Covalent bonds & Intermolecular forces are different things!!!

ADVANCED

simple molecular structure

Physical properties

- Low MP & BP (usually exist as gas or liquid state
- Insoluble in water
- Does not conduct electricity in any state
- Poor conductor of heat
- Highly Volatile

Low melting and boiling points

The molecules are held together by **weak intermolecular forces of attraction**.

Melting or boiling only requires the separation of molecules from neighbouring molecules, not breaking the covalent bonds within the molecule itself.

Hence**, little energy is needed to overcome the weak intermolecular forces**, resulting in low melting and boiling points.

Solubility

Most simple molecular substances **are soluble in organic (non-polar) solvents**.

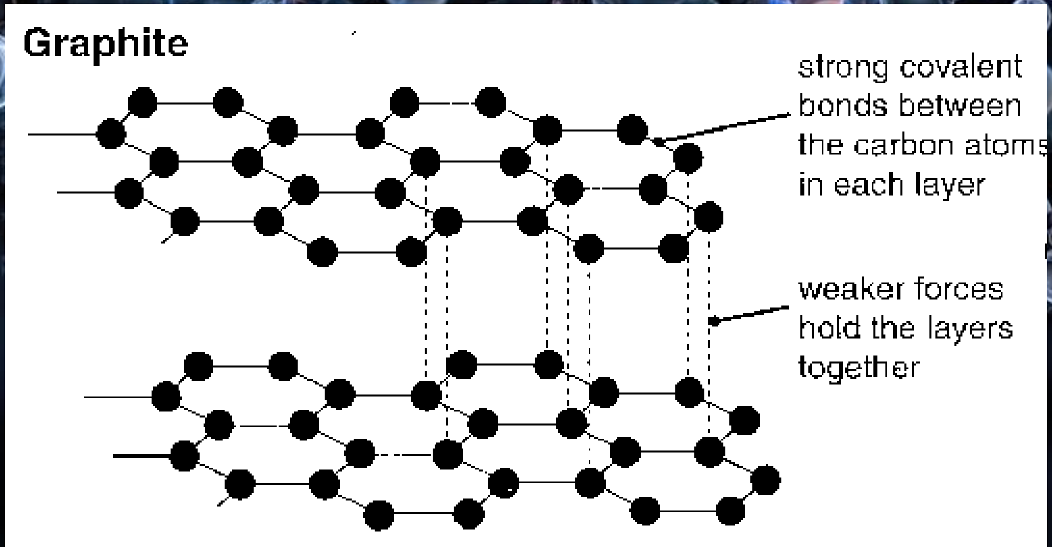
Most simple molecular substances are insoluble in water. The induced partial charges in simple molecular substances are too weak to overcome the attractive forces between permanent partial charges of polar solvents.

Hence, simple molecular substances are **insoluble in water**.

Electrical conductivity & Thermal conductivity

Simple molecular substances **do not conduct electricity** due to the absence of mobile charged carriers (electrons or ions).

They are also **poor conductors of heat**.

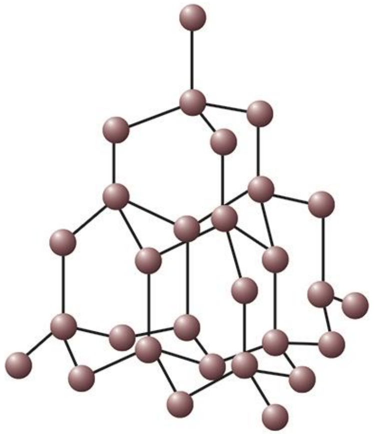


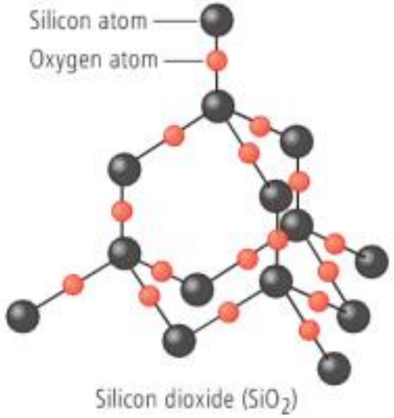
GIANT MOLECULAR STRUCTURE

These substances have extensive giant structures of atoms held together by covalent bonds, thus giving rise to the name “giant molecular structures”.

These structures have high melting points because the covalent bonds are very strong and any change of state requires huge amount of energy to overcome. *(MP & BP <1000 degree celcius)*

There are only 3 that you need to know:
Diamond, Graphite, Silicon Dioxide (Sand)



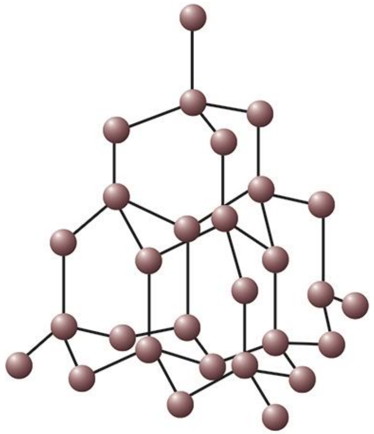


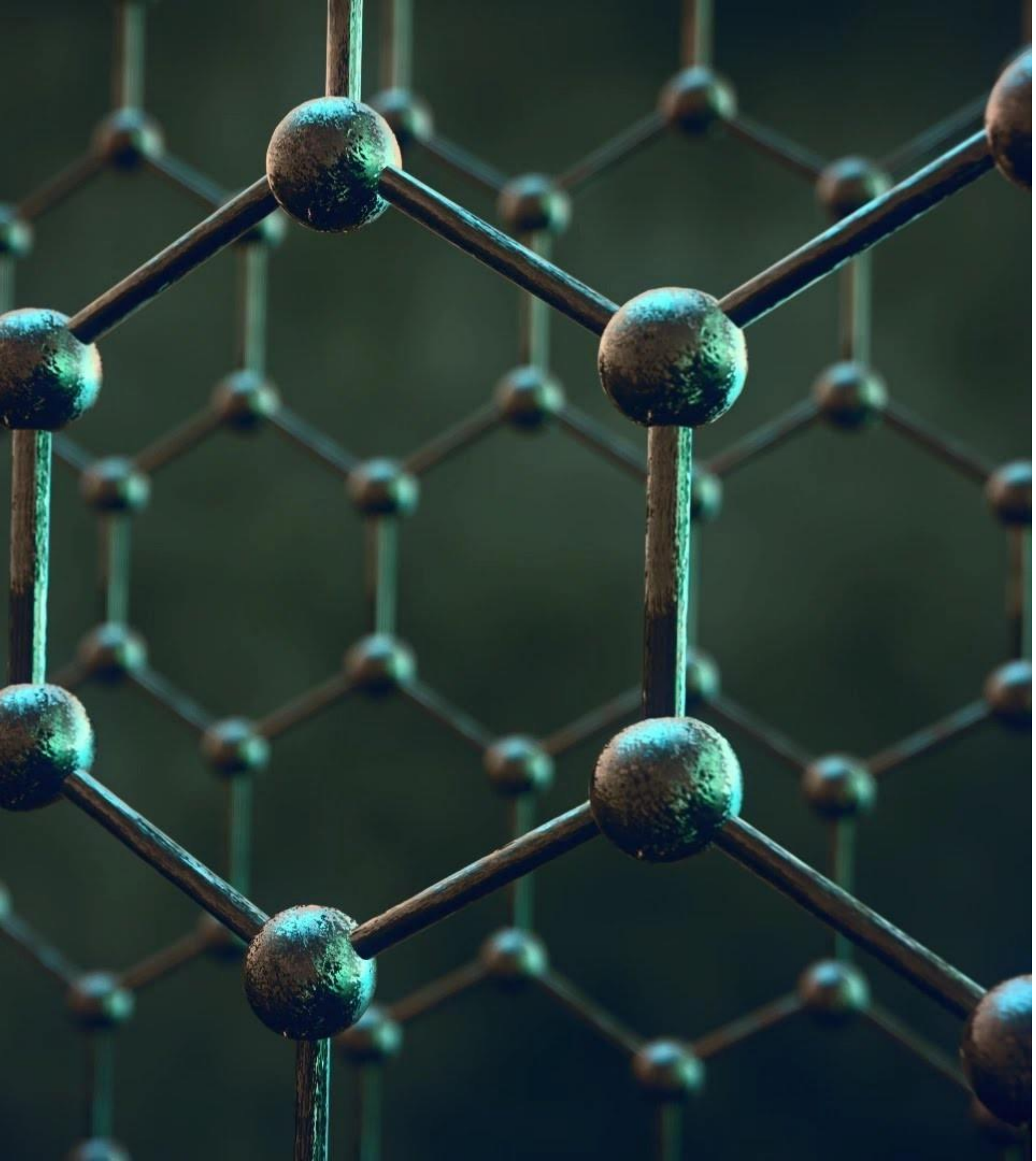
DIAMOND

Diamond is made up of carbon atoms held together by single covalent bonds.

Each carbon atom is bonded to four other carbon atoms to attain a full valence shell, **a tetrahedral structure.**

Due to its rigid lattice, diamond is renowned for its hardness. It has extremely high melting & boiling point as well.

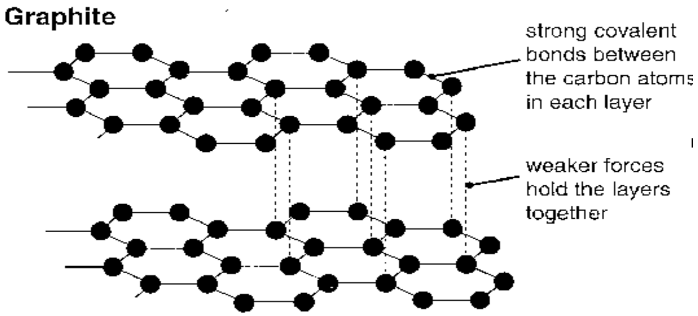




GRAPHITE

Graphite is another substance made up of carbon atoms covalently bonded to each other.

However, unlike diamond, graphite has **flat layers of carbon atoms**. Each layer of graphite comprises a carbon atom covalently bonded to three other carbon atoms to form **regular hexagonal rings**.



While the covalent bonds between the carbon atoms are strong, the **van der Waals' forces of attraction between neighbouring layers are weak**.

Due to this weak force of attraction, layers of graphite are able to **slide past each other easily.**
(Pencil lead is made of graphite. Easily goes onto paper when you exert pressure.)

As each carbon atom in graphite only uses three valence electrons for covalent bonding, the **fourth electron is delocalised** and is able to act as a **mobile charge carrier**.

Hence graphite is able to **conduct electricity in solid state**, even though it is not a metal.

SILICON DIOXIDE

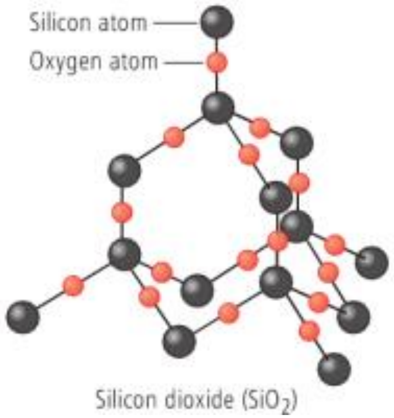
Unlike diamond, silicon dioxide comprises atoms of two different elements – silicon and oxygen.

Each silicon atom is covalently bonded to four oxygen atoms while each oxygen atom is covalently bonded to two silicon atoms.

Thus, the **ratio of silicon to oxygen atoms is 1:2**, resulting in the molecular formula SiO_2.

Silicon dioxide, commonly known as silica, is the major constituent of **sand.**

Silica is the most abundant mineral in the Earth's crust, most commonly found in nature in the form of quartz or sand.



ADVANCED

giant molecular structure

Physical properties

- High MP & BP (usually exist in solid state)
- Insoluble in water
- Does not conduct electricity in any state (except graphite)
- Poor conductor of heat (except graphite)
- Not Volatile
- Hard

High melting and boiling points

Giant covalent substances have **extremely high melting and boiling points**.

These covalent bonds are very strong, requiring a **large amount of energy to overcome**.

Hence, melting and boiling points are exceptionally high.

Solubility

Giant covalent substances are **insoluble in polar and organic solvents** due to the strong covalent bonds holding the structure together.

Hardness

Giant covalent substances tend to be hard, with the exception of graphite.

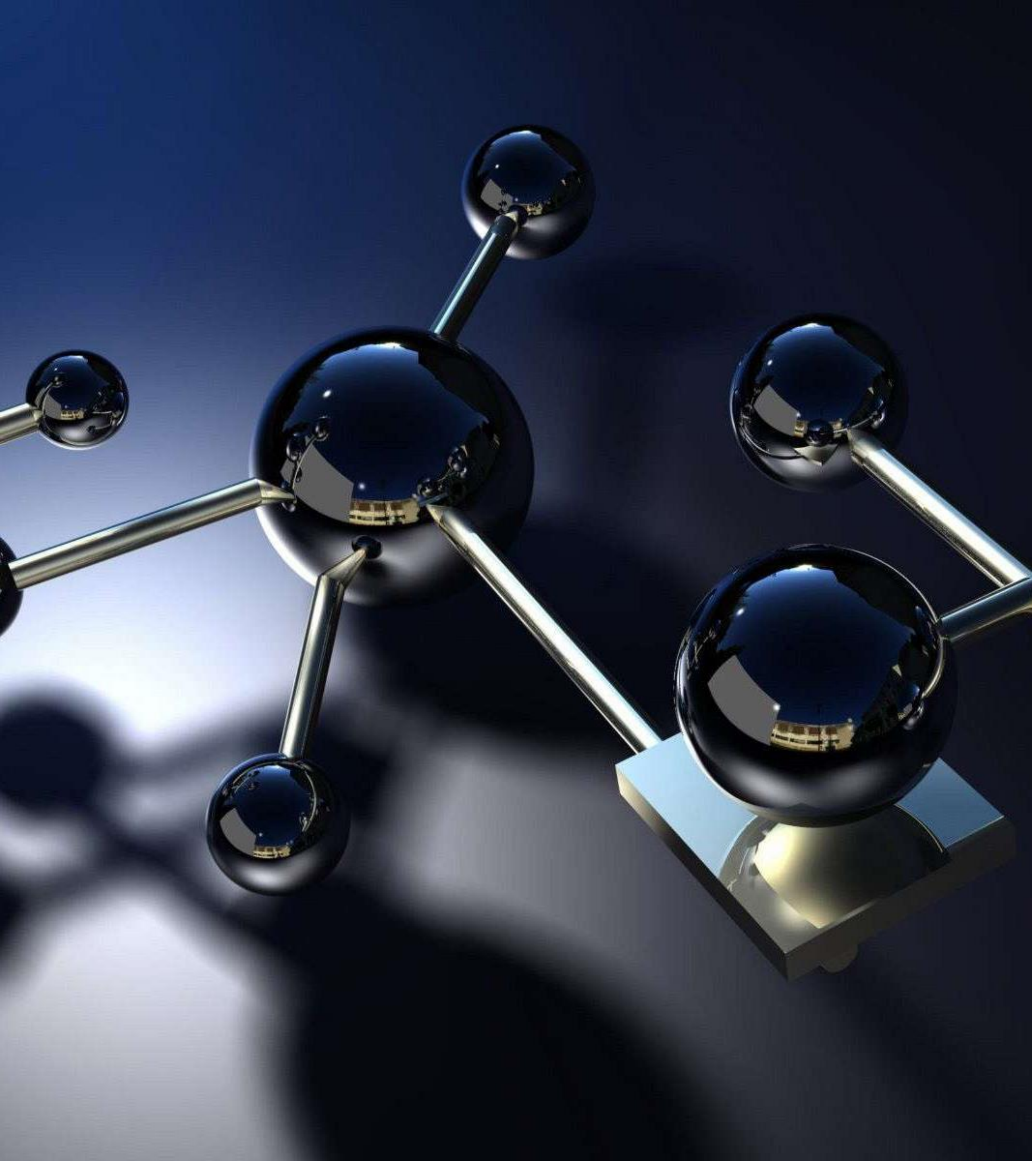
Atoms within the substance are **held rigidly in place by strong covalent bonds**, preventing them from shifting position easily.

Electrical conductivity & Thermal conductivity

With the exception of graphite, giant covalent substances **do not conduct electricity.**

This is due to **the absence of mobile charge carriers** as the valence electrons of the atoms are used to form covalent bonds, while the atoms themselves are held in place by strong covalent bonds.

Giant covalent structures are also **poor conductors of heat**.

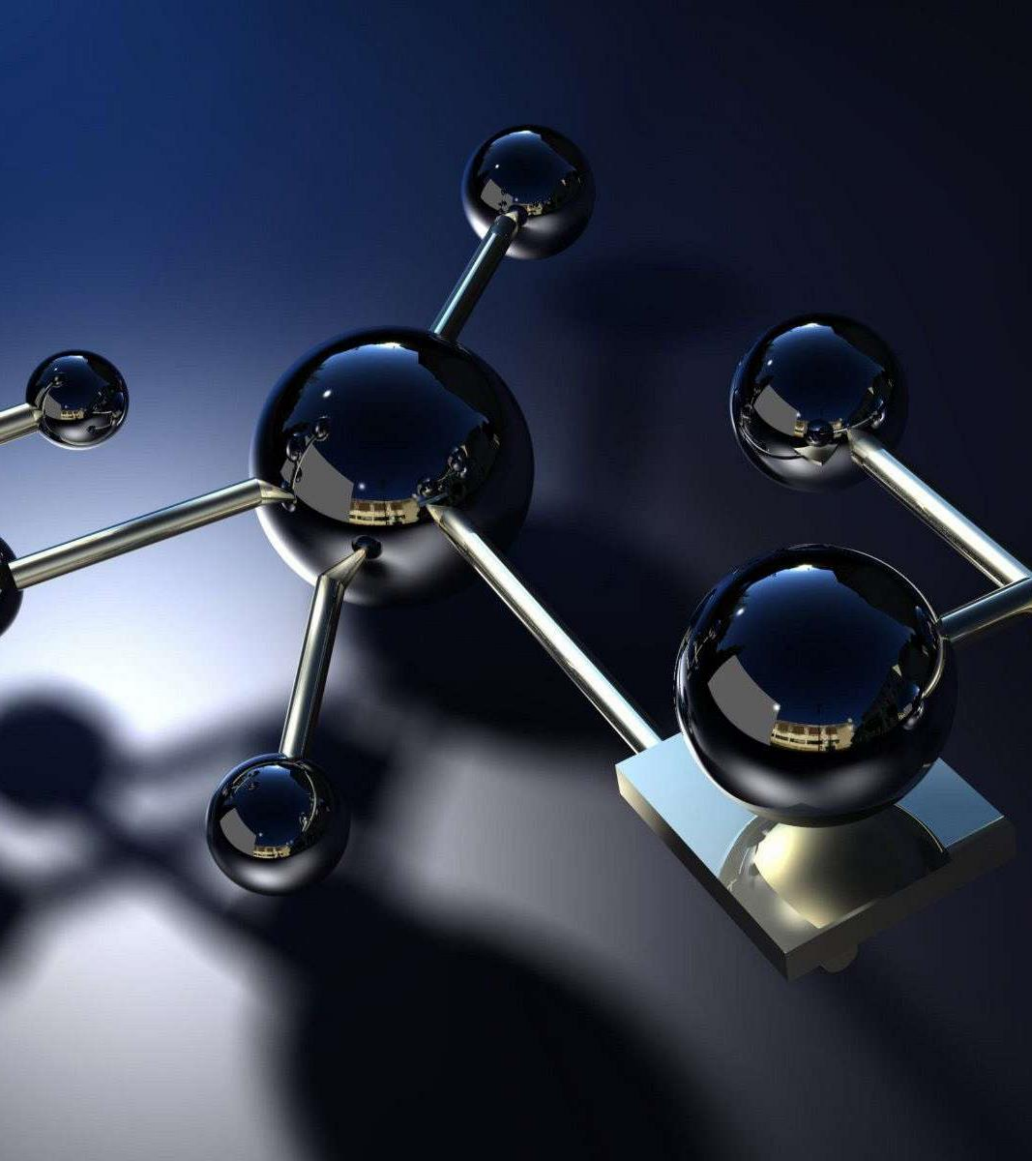


QUICK CHECK

Why does molecules in simple molecular structure have low melting & boiling point while compounds with giant molecular structure have such high melting & boiling point? Explain.

Answer on next slide.

20% of students get this wrong. **Be the 80% please.**



QUICK CHECK

Why does molecules in simple molecular structure have low melting & boiling point while compounds with giant molecular structure have such high melting & boiling point? Explain.

For simple molecular structure, a small amount of energy is needed to overcome the **weak intermolecular forces of attraction** between molecules, hence melting point & boiling point for simple molecular structure is low.

However, a large amount of energy is needed to overcome the **strong covalent bonds** that exist within a **giant molecular structure**. Hence, its melting point & boiling point is very high.

For example, *water* is a compound with a simple molecular structure, consisting of water molecules.

These water molecules experience weak intermolecular forces of attraction between neighbouring water molecules. Only a small amount of energy is required to overcome these forces for a change in state.

However, giant covalent substances like *diamond and graphite* have covalent bonds that are very strong, requiring a large amount of energy to overcome.

Hence, melting and boiling points are exceptionally high.

KEY CONCEPT

METALLIC BONDS
METALS
GIANT METALLIC LATTICE STRUCTURE

KEY CONCEPT

METALLIC BONDS

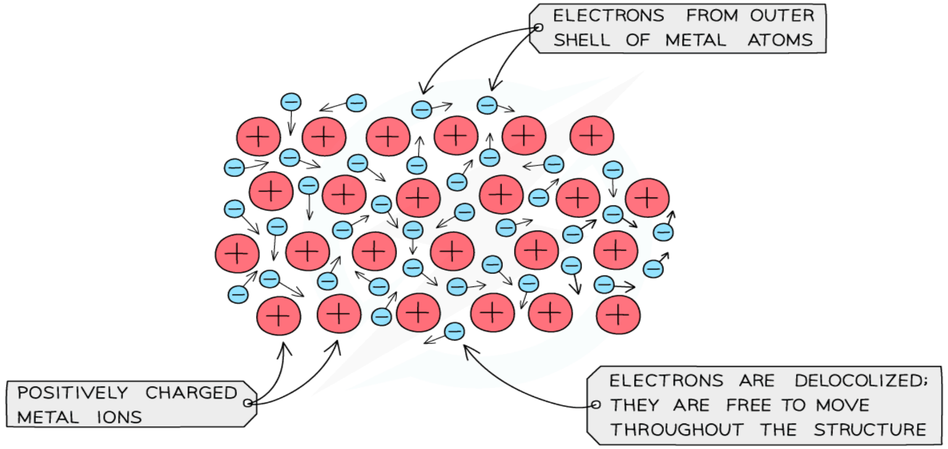
To form the metallic bond, metal atoms give up their valence electrons, hence becoming positively charged cations.

The metallic bond is defined as the **electrostatic force of attraction between the cations and the 'sea of delocalised electrons'.**

The metallic bond refers to the electrostatic force of attraction between the cations and the delocalised electrons. These bonds are strong and require much energy to break, hence metals, in general, have **high melting points**.

The delocalised electrons serve as **mobile charge carriers** within the metals. Hence, metals **conduct electricity**.

Moreover, metals are **malleable** and **ductile** because the cations are able to slide over one another easily.



Malleable: can be molded into different objects/shapes

Ductile: can be made into wires

ADVANCED

giant metal lattice structure

Physical properties

- High MP & BP (usually exist in solid state)
- Insoluble in water
- Conductor of electricity
- Conductor of heat
- Not Volatile
- Malleable
- Ductile
- Shiny, opaque

High melting and boiling points

Metals have **high melting and boiling points**.

The metallic bond comprises **strong electrostatic forces of attraction between the 'sea of delocalised electrons' and the lattice of metal cations**, hence requiring a large amount of energy to overcome.

Solubility

Metals are largely insoluble in water as the strength of the metallic bond is much stronger than the attraction by the polar water molecules.

Hardness

Metals can be bent and stretched, hence they are **malleable and ductile.**

The metallic structure is made of layers of metal cations which can **slide over one another easily.**

Electrical conductivity & Thermal conductivity

Metals are **conductors of electricity**.

The '**sea of delocalised electrons'** act as **mobile charge carriers** to conduct electricity. Works in both solid and liquid state.

Metals are also good conductors of heat as well because the metal cations in the lattice are **closely packed together** allowing kinetic energy to be transferred rapidly from one metal cation to another.

Furthermore, the '**sea of delocalised electrons'** also help to **transfer heat** across the metal more efficiently.

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