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	Combined using chemical methods	Combined using physical methods
Separation technique	Cannot be separated further	Separation by chemical methods (Decomposition, electrolysis, reduction with carbon)	Separation by physical methods (separation techniques)
Composition	Exist by itself or in diatomic molecule form for gases such as H_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

***A compound is a subset of a molecule, but a molecule does not need to be a compound.**

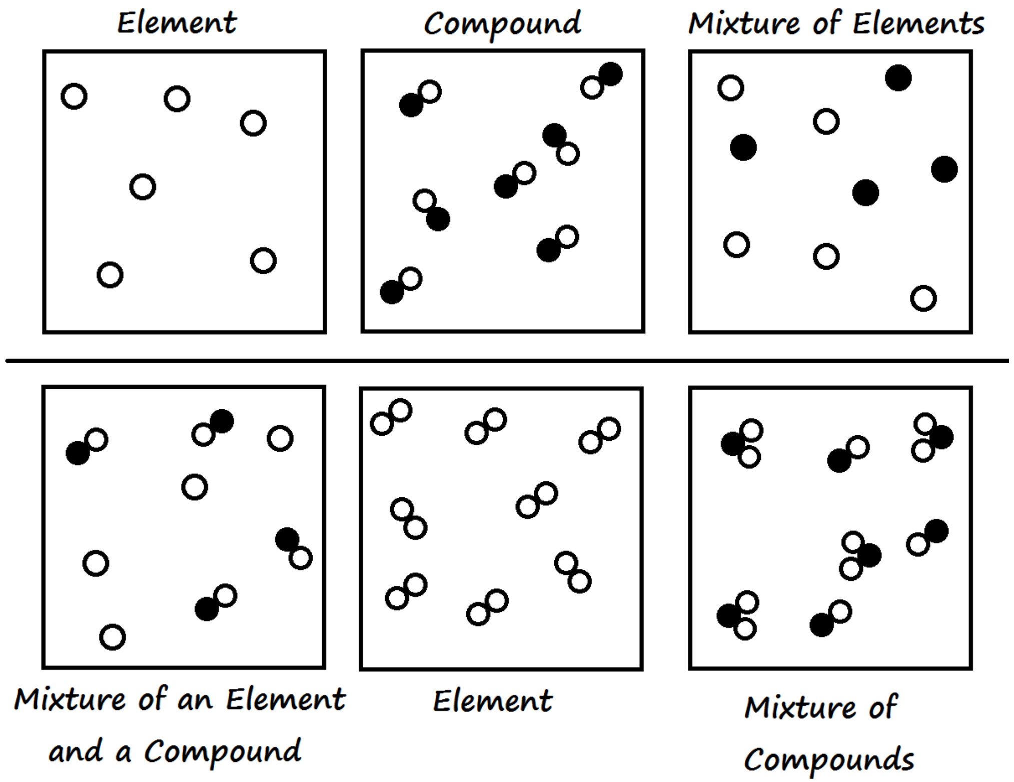
Definition of a molecule is when **2 or more atoms** chemically combined.

An **element** can also exist as a diatomic **molecule**. (N_2, O_2, H_2)

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

Understanding the term 'molecule'

ELEMENTS, COMPOUNDS, MIXTURE



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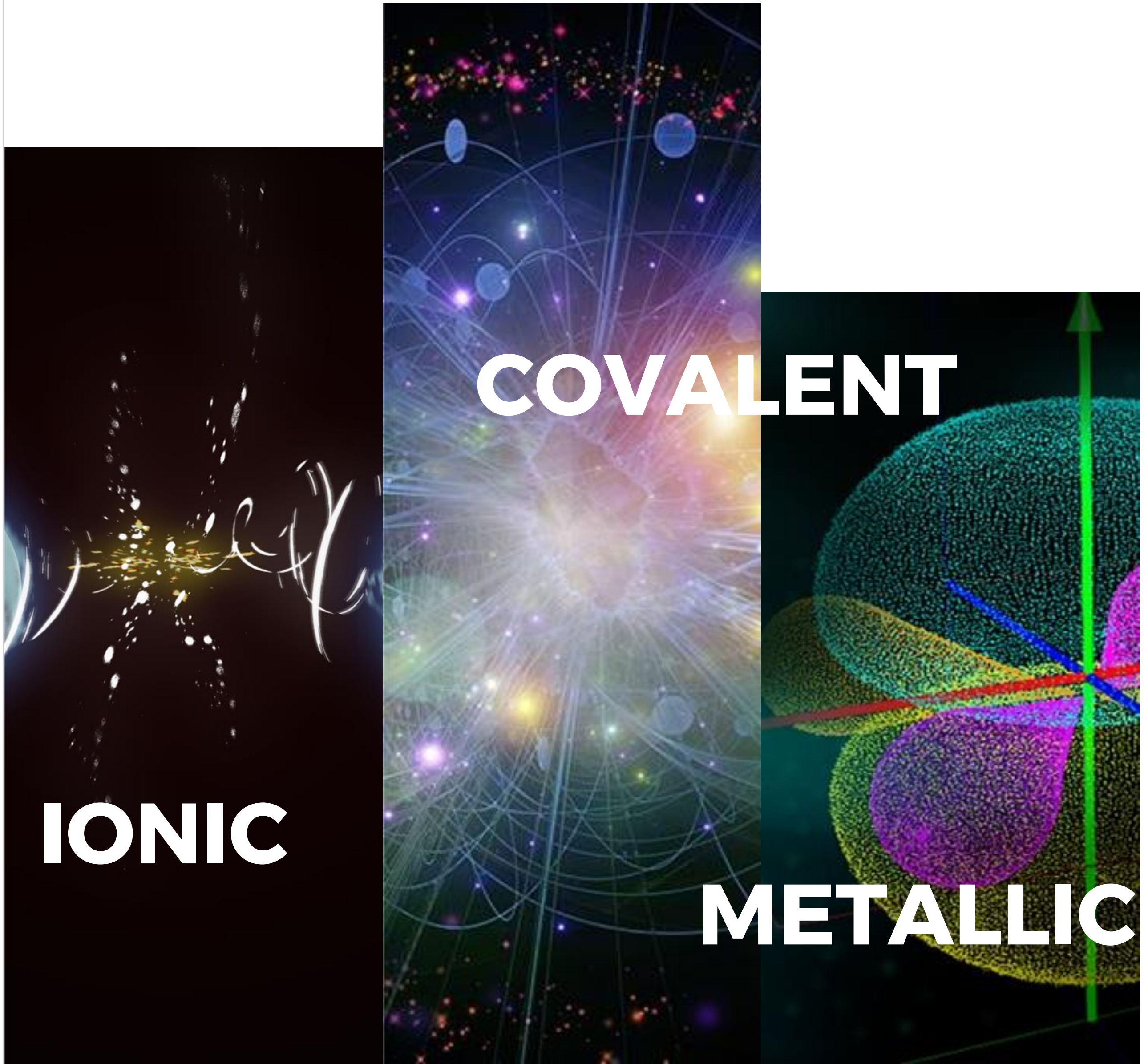


3 types of bonds

Understanding all 3 types of bonds is needed 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 chemical bonds formed?

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

The formation of chemical bonds can be done by **transferring electrons, sharing electrons or forming a metal lattice**.

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

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

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

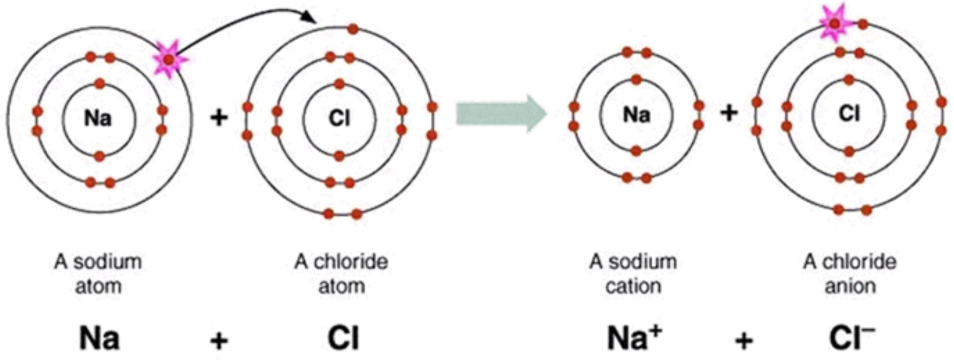
IONIC BONDS

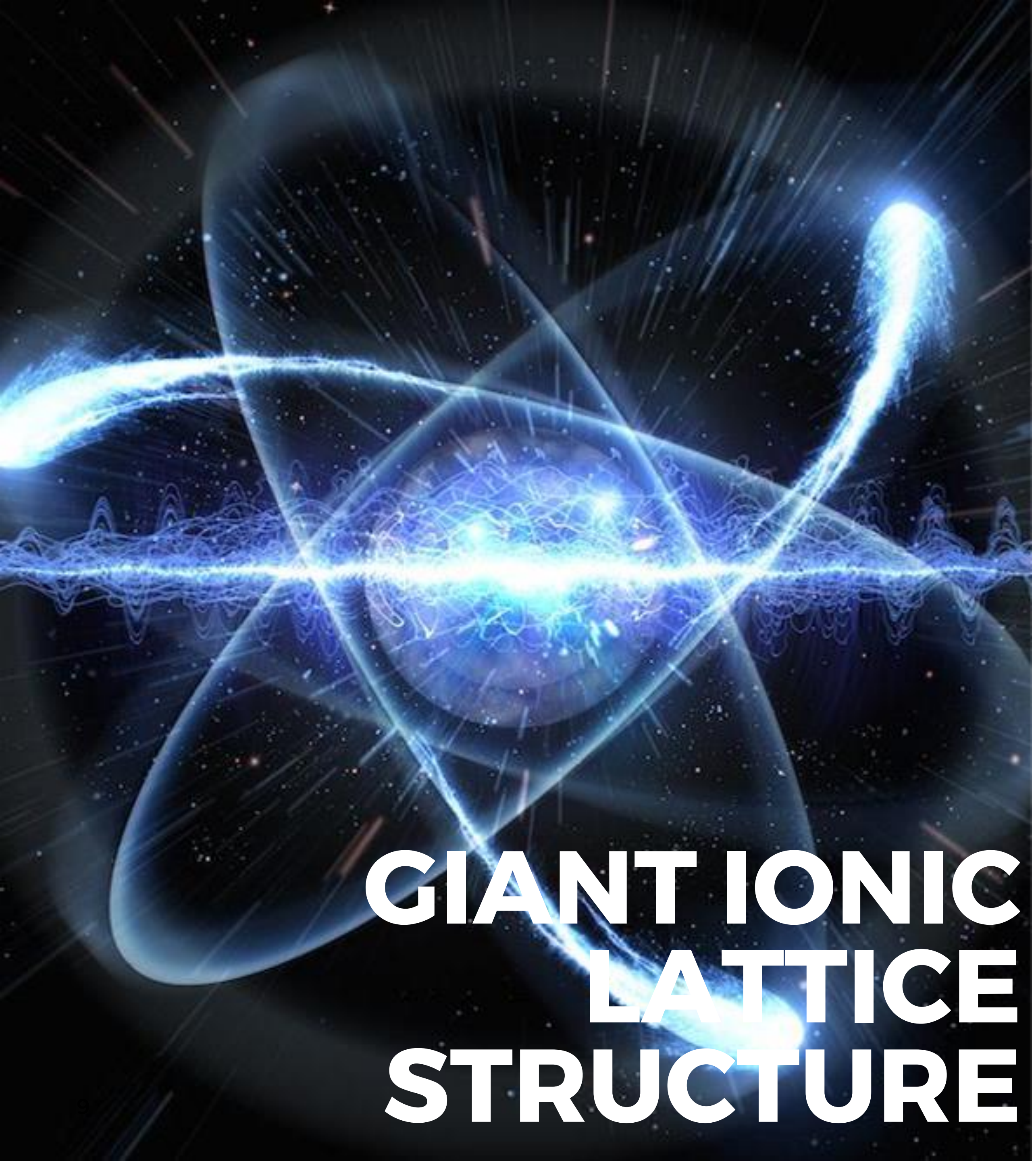
Ionic bonds are formed between **metals** and **non-metals**.

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

The metal would become a **cation** while the non-metal would become the **anion**.

Ionic bond **formed** is the **forces of attraction between oppositely charged ions**.



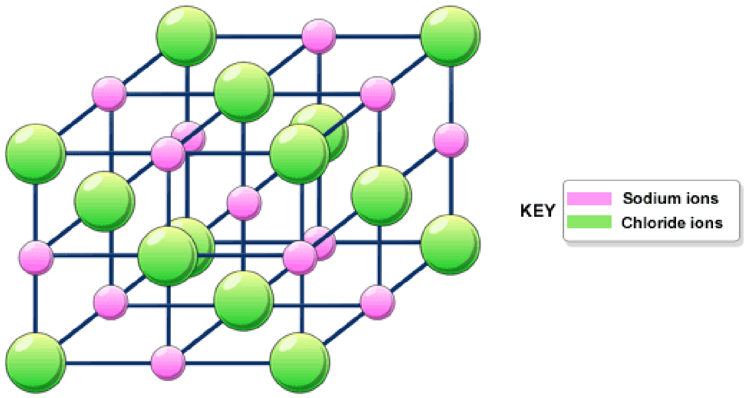


GIANT IONIC LATTICE STRUCTURE

GIANT IONIC LATTICE STRUCTURE

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

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



ADVANCED

giant ionic lattice

Physical properties

- High MP & BP
- Soluble in water
- Able to conduct electricity in molten & aqueous state
- Poor conductor of heat
- Not volatile (does not evaporate easily)
- Strong

High melting and boiling points

Ionic compounds usually have **high melting and boiling points.** (<1000 Degree Celsius)

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

Solubility

Ionic compounds are **soluble in water** because the partially charged (polar) water molecules can attract the ions, causing disruption to the ionic lattice structure.

This results in the ions separating and dissolving in the solution.

Electrical conductivity

To conduct electricity, there needs to be the presence of **mobile charge carriers**.

In its solid state, as the ions are all held tightly in place, **ionic compounds in solid state do not have the ability to conduct electricity**.

However, when **in molten or aqueous state**, the ions are able to move freely, able to act as mobile charge carriers to **conduct electricity**.

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 atoms**.

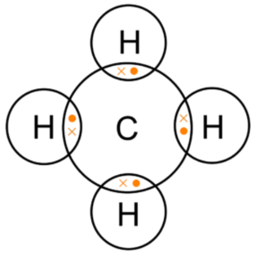
A covalent bond is defined as the **electrostatic force of attraction between the nuclei of the atoms and the shared electrons.**

To attain a stable electronic configuration, the two atoms **share their valence electrons** so that they can both attain stable and full valence shells.

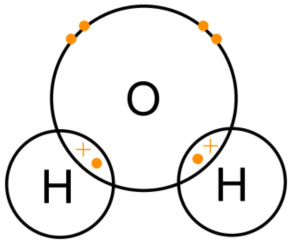
Covalent bond is formed from the sharing of electrons.

Examples:

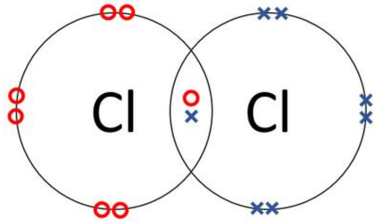
Methane Compound:



Water Compound:



Chlorine molecule:



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

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

ADVANCED CONCEPT

TWO TYPES OF COVALENT STRUCTURES
SIMPLE MOLECULAR
GIANT MOLECULAR

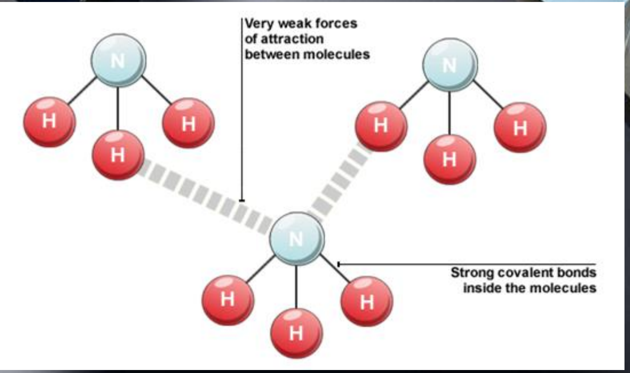
SIMPLE MOLECULAR STRUCTURE

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

Between the small molecules, they are held together by **weak intermolecular forces of attraction**, *AKA van der Waals' forces*.

These weak intermolecular forces can be overcome easily, hence they have **low melting and boiling points.**

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

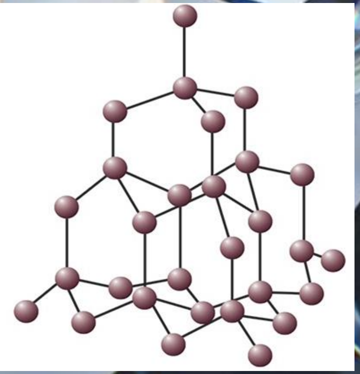


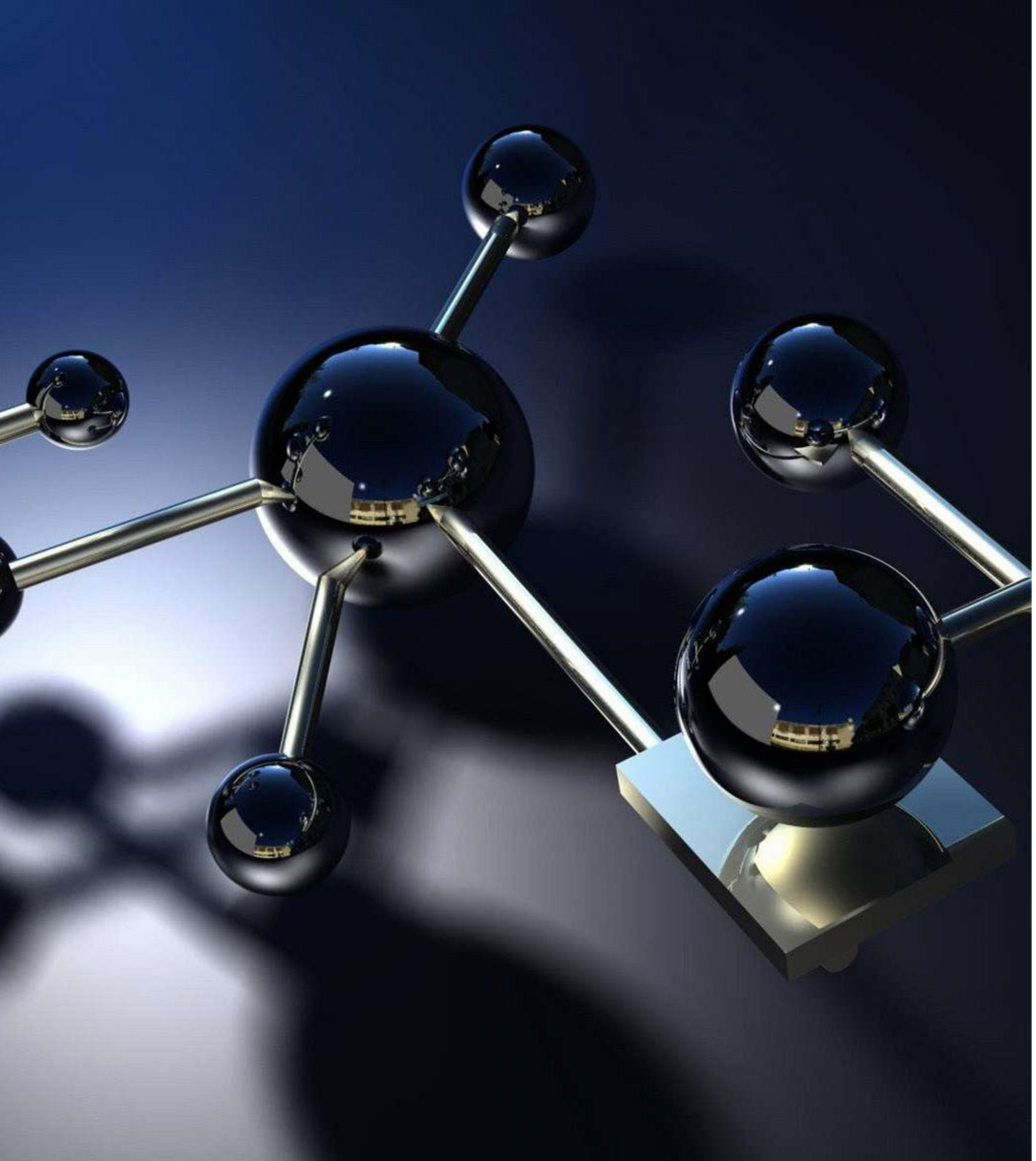
GIANT MOLECULAR STRUCTURE

These molecules and compounds have extensive giant structures of atoms that are held together by **strong covalent bonds**, hence it is referred to as "giant molecular structures".

They have **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)





<u>SIMPLE MOLECULAR STRUCTURE</u>

Covalent compounds that are made up of small, discrete molecules have simple molecular structures.

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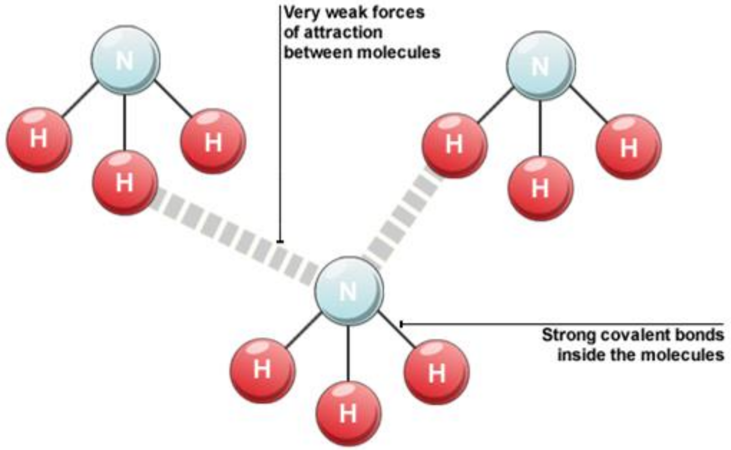
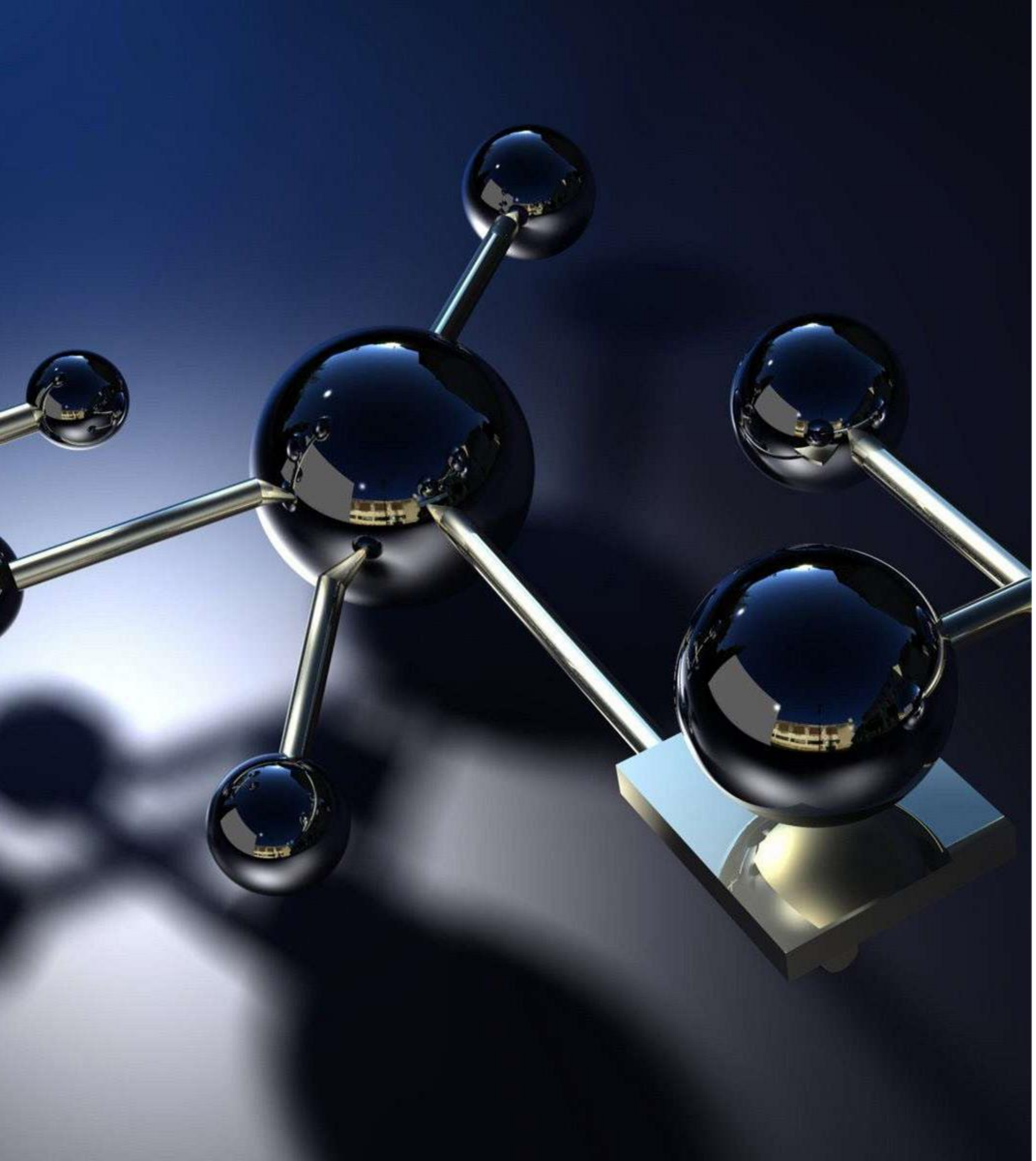


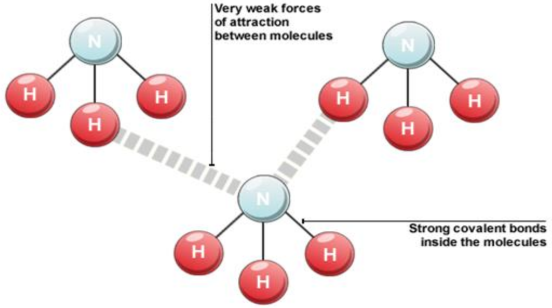


SIMPLE MOLECULAR STRUCTURE

For example, ammonia has a simple molecular structure.

These ammonia molecules experience **weak intermolecular forces of attraction between other ammonia molecules.** Hence, they have low melting point & boiling point.

HOWEVER, within the ammonia molecules are **strong covalent bonds** that holds together a single nitrogen atom and three hydrogen atoms.



TAKE NOTE!

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

Then why the low MP & BP? Because it is the weak **intermolecular forces that are being overcame.**

For example, it is easy to change the state of water (melting/boiling) but **extremely difficult to break a water molecule back into the individual hydrogen and oxygen atoms**, as that would involve breaking the strong covalent bonds.

Covalent bonds & intermolecular forces of attraction are different things!!!

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simple molecular structure

Physical properties

- Low MP & BP (usually exist as gas or liquid state at rtp)
- Insoluble in water
- Unable to conduct electricity in any state
- Poor conductors 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 breaking of the weak intermolecular forces between molecules, and 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

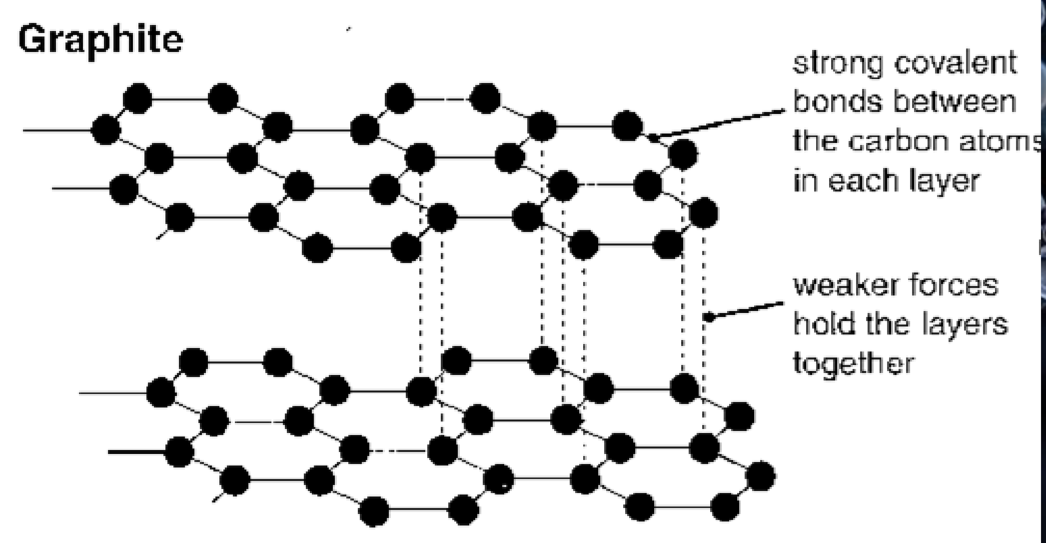
Most simple molecular substances **are soluble in organic (non-polar) solvents**.

Simple molecular substances are **insoluble in water**.

Electrical conductivity & Thermal conductivity

Simple molecular substances **are unable to conduct electricity** due to the absence of mobile charged carriers (electrons or ions).

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

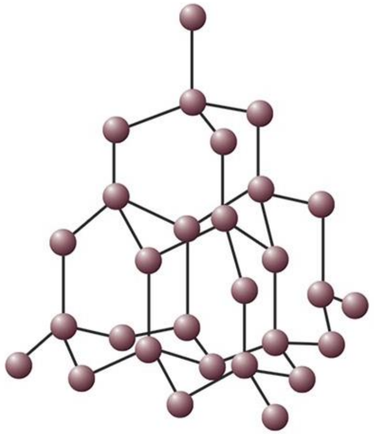


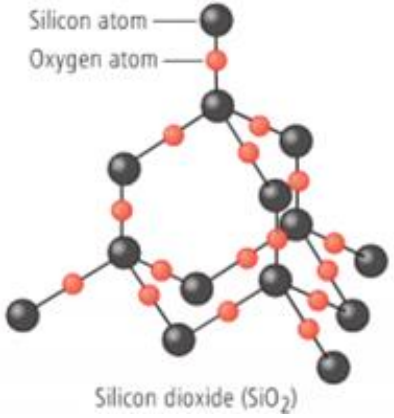
<u>GIANT MOLECULAR STRUCTURE</u>

These molecules and compounds are held together by **strong covalent bonds**, hence it is referred to as “giant molecular structures”.

They have **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 <u>3 that you need to know</u>:
Diamond, Graphite, Silicon Dioxide (Sand)



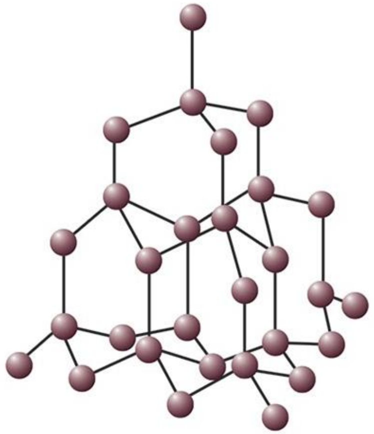


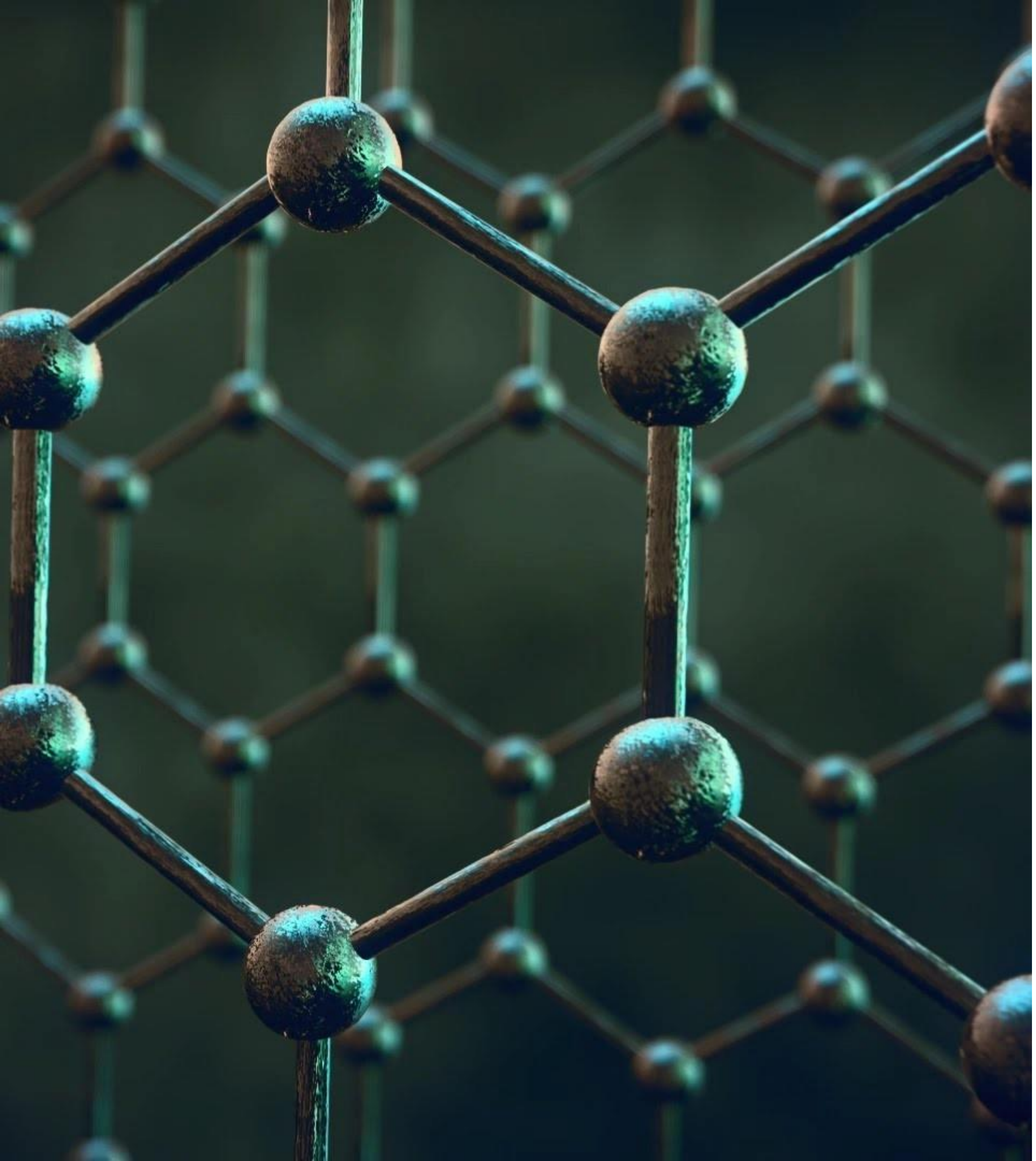
DIAMOND

Diamond is comprised of carbon atoms being held together by strong single covalent bonds.

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

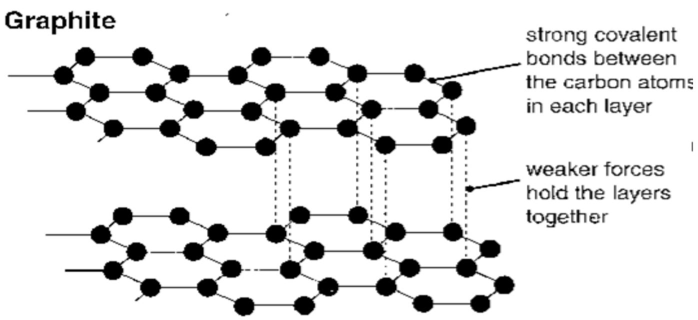
Due to its rigid lattice, diamond is well-known for its hardness. It also has extremely high melting & boiling point.





GRAPHITE

Graphite is made up of **flat layers of carbon atoms**. Each layer of graphite has a carbon atom that is 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 the layers are weak**.

Layers of graphite have the ability to **slide past each other easily** due to the weak forces of attraction**.**
(Pencil lead is made of graphite. Easily goes onto paper when you exert pressure.)

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

As a result, graphite is able to **conduct electricity in solid state**,.

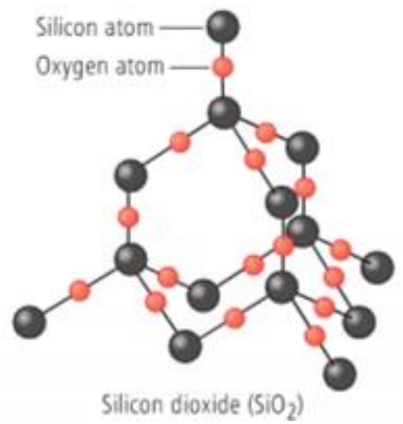
SILICON DIOXIDE

Unlike diamond, silicon dioxide is made up of atoms of two different elements – silicon and oxygen.

Each silicon atom forms covalent bonds with four oxygen atoms while each oxygen atom forms covalent bonds with two silicon atoms.

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

Silicon dioxide is the major constituent of **sand.**



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giant molecular structure

Physical properties

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

High melting and boiling points

Covalent molecules with giant molecular structure have **extremely high melting and boiling points**.

They are connected by strong covalent bonds, which requires a **large amount of heat energy to overcome**.

Hence, melting and boiling points are exceptionally high.

Solubility

Giant covalent molecules are **insoluble in both inorganic and organic solvents** due to the strong covalent bonds that holds the structure together.

Hardness

Giant covalent molecules tend to be strong and hard, with the exception of graphite.

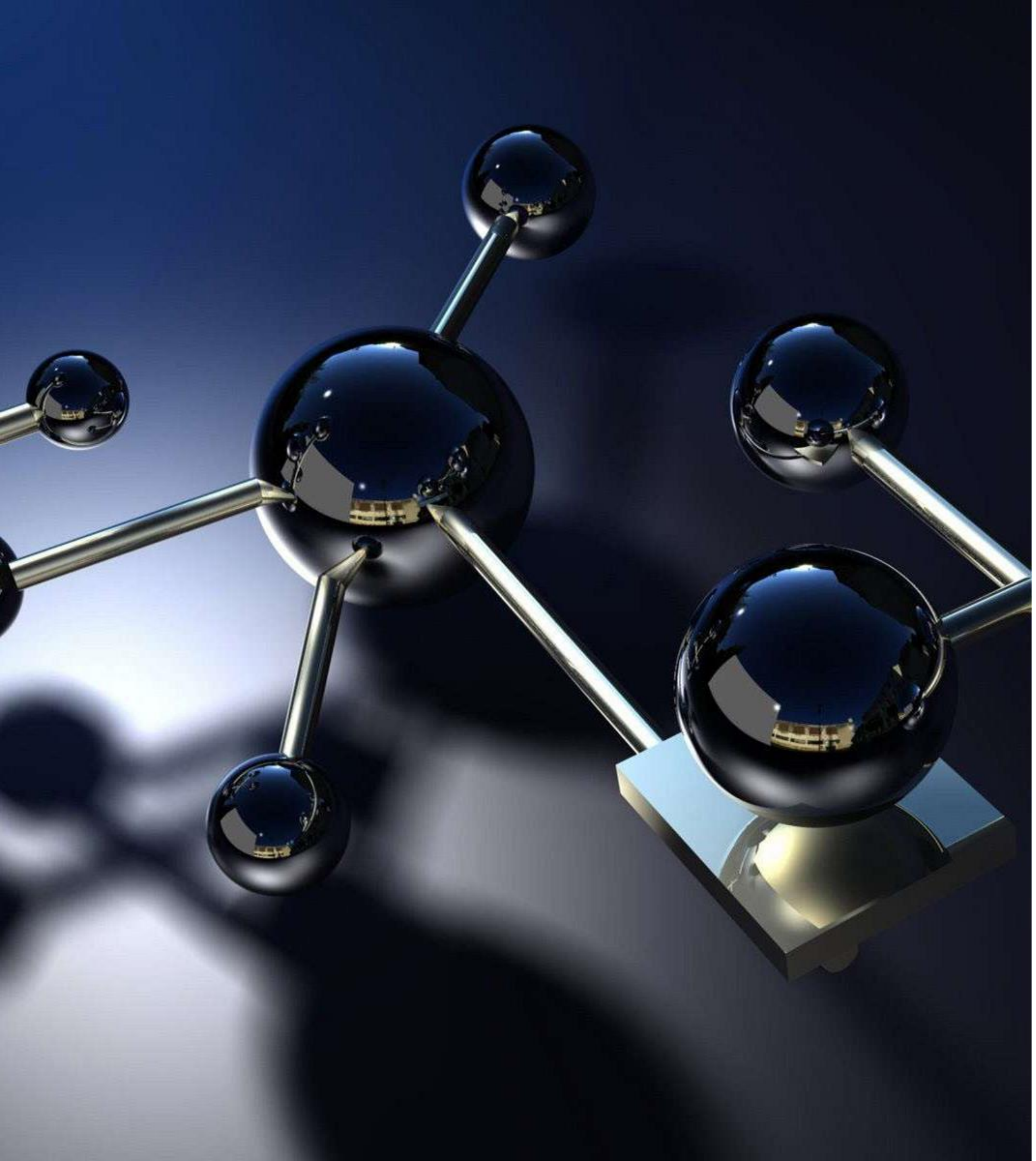
Atoms within the molecules are **held rigidly in place by strong covalent bonds**, preventing them from moving around easily.

Electrical conductivity & Thermal conductivity

With the exception of graphite, giant covalent molecules **do not have the ability to conduct electricity.**

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

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

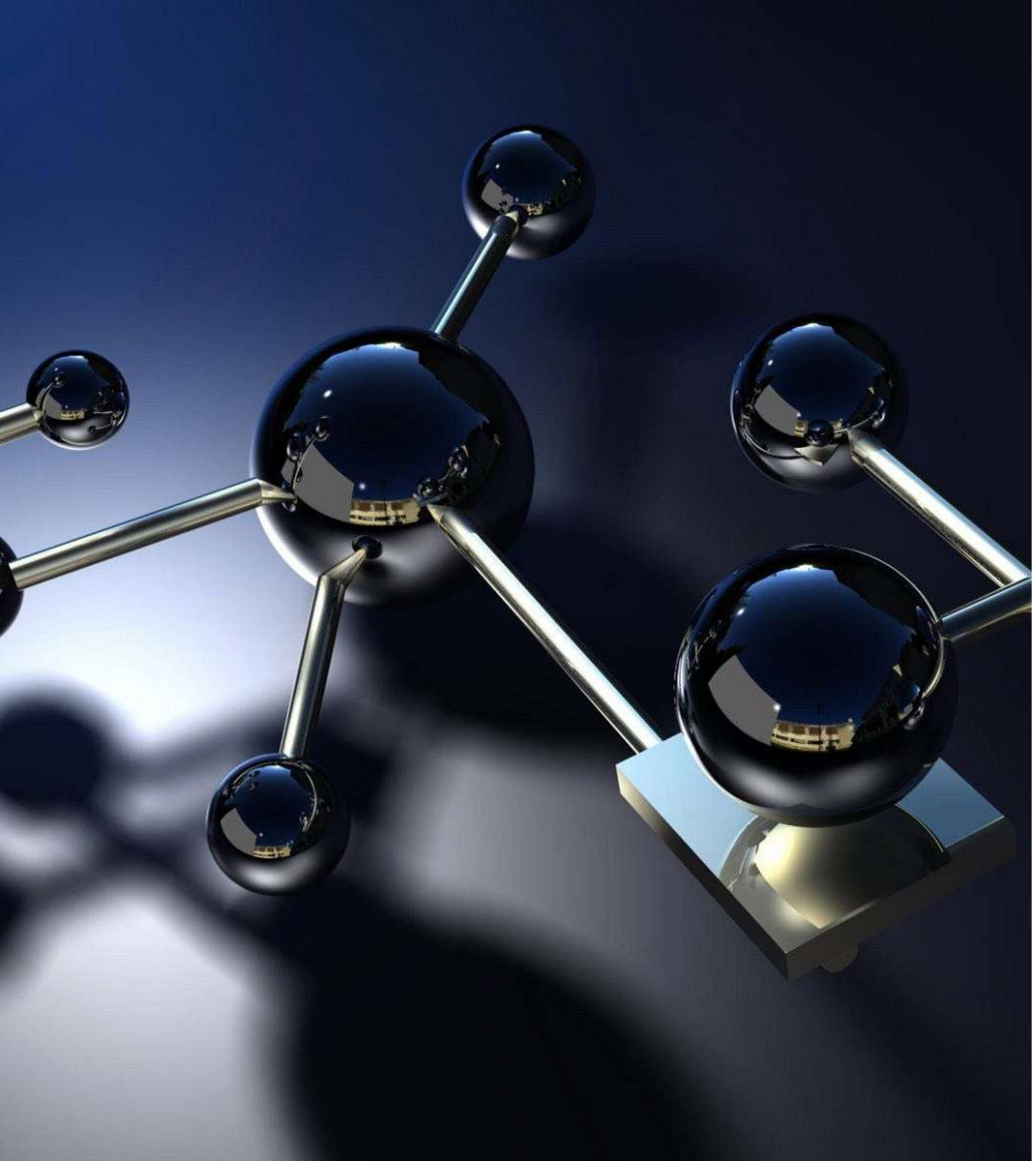


QUICK CHECK

Why do molecules that have simple molecular structure have low melting & boiling point while molecules 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 do molecules that have simple molecular structure have low melting & boiling point while molecules with giant molecular structure have such high melting & boiling point? Explain.

For molecules with simple molecular structure, **little energy is required** to overcome the **weak intermolecular forces of attraction** between molecules, hence they have low melting point & boiling point.

However, for molecules with giant molecular structure, large amount of energy is required to overcome the **strong covalent bonds** between atoms within a **giant molecular structure**. Hence, they have high melting point & boiling point.

For instance, *water* is a covalent compound with a simple molecular structure.

These water molecules are held together by weak intermolecular forces of attraction with other water molecules. It only requires a small amount of energy to overcome these forces for a change in state.

However, in giant covalent molecules like *diamond and graphite,* they have strong covalent bonds that are requires a huge amount of energy to overcome.

Hence, they have exceptionally high melting and boiling points.

KEY CONCEPT

METALLIC BONDS
METALS
GIANT METALLIC LATTICE STRUCTURE

KEY CONCEPT

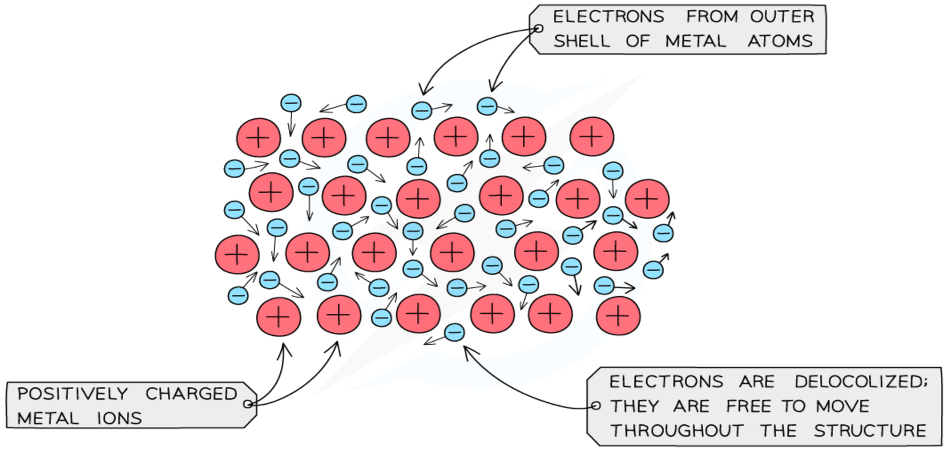
METALLIC BONDS

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

These metallic bonds are strong and require huge amounts of energy to break, hence metals, in general, have **high melting points**.

Metals have the ability to **conduct electricity** as the delocalised electrons can act as **mobile charge carriers** within the metals.

Also, metals are **malleable** and **ductile** because the cations have the ability to slide over one another easily.



Malleable: can be molded into different objects/shapes

Ductile: can be made into wires

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giant metal lattice structure

Physical properties

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

High melting and boiling points

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

The metallic bond contains **strong electrostatic forces of attraction between the 'sea of delocalised electrons' and the lattice of metal cations**, hence it requires a huge amount of energy to overcome.

Solubility

Metals are largely **insoluble in water.**

Hardness

Metals are **malleable and ductile.**

The metallic structure has orderly layers of metal cations which has the ability to **slide over one another easily.**

Electrical conductivity & Thermal conductivity

Metals are good **conductors of electricity**.

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

Metals are also good conductors of heat as well due to the **closely packing** of metal cations in the lattice which allows kinetic energy to be transferred quickly from one metal cation to another.

In addition, the **'sea of delocalised electrons'** can help to **transfer heat** across the metal more efficiently as well.

Try it yourself! (TYS Question)

34. Which two substances have similar three-dimensional arrangements of their atoms?

(N2020/P1/Q8)

A diamond and silicon dioxide
B graphite and diamond
C iodine and graphite
D silicon dioxide and iodine

( )

Answer:

34. **A**

Diamond and silicon dioxide have a giant molecular structure with a tetrahedral arrangement.

Try it yourself! (TYS Question)

35. How many electrons are involved in the bonding between carbon and one of the oxygens in carbon dioxide, CO_2, and between carbon and oxygen in ethanol, C_2H_5OH?

(N2020/P1/Q32)

	number of electrons involved	
	CO_2	C_2H_5OH
A	2	2
B	4	4
C	4	2
D	8	2

( )

Answer:

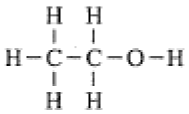
35. **C**

CO_2:

O=C=O

There are (2 × 2 =) 4 electrons shared between C and one of the O.

C_2H_5OH:



There are (1 × 2 =) 2 electrons shared between C and O.

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