Chapter-5:

Valency:

A valency is the combining number of an element or a group with other elements or groups to make a compound.

Valency is the number of electrons that an atom ……., or …… Or ……with other atoms or groups.

[loses]

[gains]

[shares]

For ions (in ionic compounds), the valency is the charge on an ion.

For example, the valency of Na^{+}, Mg^{2+}, Al^{3+}, Cl^{-}, O^{2-}, and N^{3-} are 1, 2, 3, 1, 2, and 3 respectively.

The charge (or valency) of a metal ion (cation) equals the number of electrons it has lost and the charge (or valency) of a non-metal ion (anion) equals the number of electrons it has received.

For covalent substances, the valency of an atom is the number of covalent bonds it forms or the number of electrons it shares with other atoms.

1. Video Link: https://www.youtube.com/watch?v=NXfNrvbwXrY

Q. From the above structure deduce the valency of each of the element in the molecule.

Element	Group in PT	Valency
H		
Ca		
N		
O		
Mg		
K		
S		
Al		
Br		
C		

Valency Table:

Valency	1	2	3	4
Elements	Elements of group 1 Elements of group 7	Elements of group 2 Elements of group 6	Elements of group 3 Elements of group 5	Elements of group 4
Ions	OH^- (hydroxide), NO_3^- (nitrate), NO_2^- (nitrite), NH_4^+ (ammonium) Ag^+, etc	SO_4^{2-}(sulfate), SO_3^{2-}(sulfite), CO_3^{2-}(carbonate), Zn^{2+} etc	PO_4^{3-} (phosfate), PO_3^{3-} (phosfite)	

Transition elements have variable valencies, e.g. copper exists as both Cu^+ and Cu^{2+} and iron exists as both Fe^{2+} and Fe^{3+}

Few confusing Names and formulae of some anions:

-ate	-ite	-ide	Examples
SO_4^{2-} (sulfate)	SO_3^{2-}(sulfite)	S^{2-} (sulfide)	Na_2SO_4, $CaSO_3$, ZnS etc
NO_3^- (nitrate)	NO_2^- (nitrite)	N^{3-} (nitride)	KNO_3, $Mg(NO_2)_2$, AlN etc
PO_4^{3-} (phosphate)	PO_3^{3-} (phosphite)	P^{3-} (phosphide)	Li_3PO_4, $Ba_3(PO_3)_2$, AlP etc

An addition of a hydrogen atom to an anion causes it's valency to decrease by 1.

Example:

CO_3^{2-} (carbonate) HCO_3^- (hydrogen carbonate)

SO_4^{2-} (sulfate) HSO_4^- (hydrogen sulfate)

Write the formulae of the following ions:

Name :	Formula:
(hydrogen sulfate)	
(sulfite)	
(phosphite)	
(sulfate)	
(nitride)	
(hydrogen carbonate)	
(nitrate)	
(sulfide)	
(carbonate)	
(zinc)	

Q. Write the chemical name of each of the following compounds:

Formula:	Name:
1. $Ca(HSO_4)_2$	
2. K_2CO_3	
3. CuI_2	
4. $Pb(HCO_3)_2$	
5. $Zn(NO_3)_2$	
6. Li_2SO_4	
7. Na_3N	
8. $Fe(NO_2)_3$	
9. $Al_2(HPO_4)_3$	
10. CuCl	

Chemical Bonding:

Bonding means attractive forces.

In chemistry, all the attraction is due to opposite charges.

So, we always say **electrostatic** force of attraction.

The **electrostatic force of attraction** that holds the atoms, ions or molecules together is called chemical bonding.

Types of chemical bonding:

1) Ionic bonding.
2) Covalent bonding.
3) Metallic bonding
4) Intermolecular forces

No.	Bonding	Type of attraction	Attraction Between
1	Ionic bonding	Electrostatic	Cations and anions
2	Covalent bonding	....	Shared electrons and nuclei of the atoms
3	Metallic bonding	Electrostatic	Cations and sea of electrons
4	Intermolecular forces	Very weak attraction	Two separate molecules

Fill in the blank.....

Why are the bonds formed?

Only the atoms of inert gases can exist on their own.

This is because they have full outer shell electrons, which make them stable.

All other atoms of the elements do not have this type of electron arrangement but they want stability, which can be obtained by either losing (metals lose electrons) or gaining (non-metals receive electrons) or sharing of electrons. When they lose, gain or share electrons, they are no more singles as bonds are formed.

2. Video Link: https://www.youtube.com/watch?v=BpVGYGynwWI

Ionic bonding:

(Condition:)Ionic bonding is formed between **metals** and **non-metals**.

(Way of formation:) Metal atoms lose their valence electrons and the electrons are **transferred** to the non-metals atoms.

After losing electrons, metal atoms become cations and after gaining electrons, the non-metal atoms become anions.

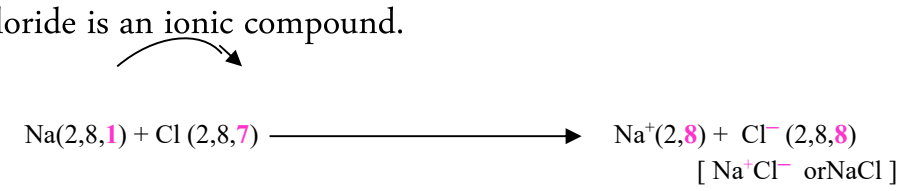
(Outcome:) Then the **cations** and **anions** are arranged themselves in a regular arrangement by strong electrostatic force of attraction.

The compounds formed by ionic bonding are known as **ionic compounds**.

[Students have to be able to identify ionic compound by seeing their formulae]

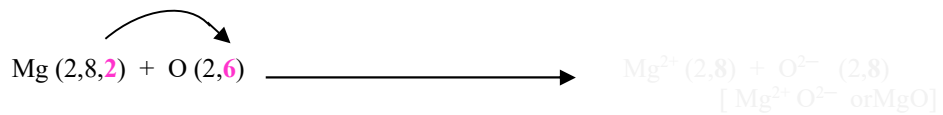
EXAMPLES:

Sodium chloride is an ionic compound.



Similarly,

Magnesium oxide.



Q. Explain, in terms of electrons, what happens to calcium and fluorine when they form CaF_2 [3]

[Ca 2, 8, 8, 2 F 2, 7]

Similar question:

1. (a) What happens to the electron configurations when sodium and oxygen bond?

Or how do the electron configuration changes when they bond? [3]

(b) Explain why the formula of magnesium chloride is $MgCl_2$, not MgCl. [2]

2. Identify which of the following compounds are not ionic ? [2]

Mg_2SO_4 AlN NH_3 NaCl MgF_2 H_2O CO_2

Answer to 1:

Each of the calcium atoms loses 2 electrons. [1]

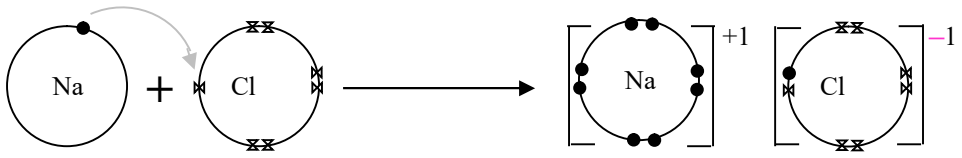
These electrons are transferred to fluorine [1]

Each of the fluorine atoms gains 1 electron [1]

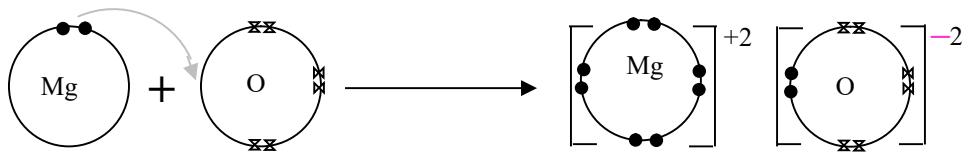
Dot and cross diagrams of some ionic compounds (using outermost electrons only)

3.Video Link: https://www.youtube.com/watch?v=r3ULKXEDSGE&t=3s

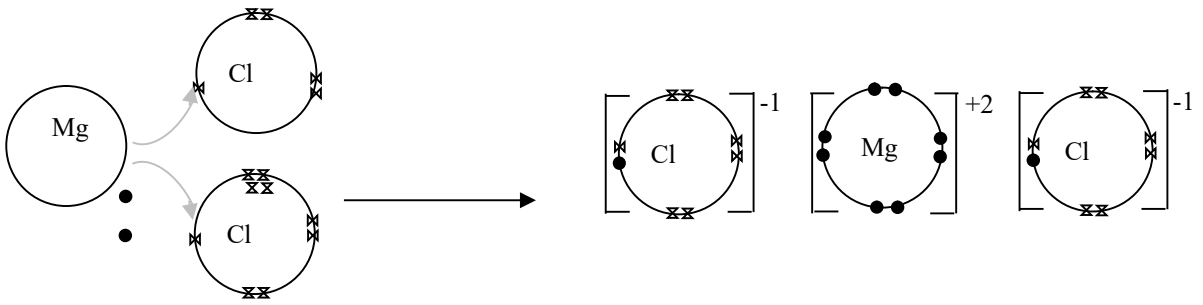
NaCl [Electron configuration: $_{11}$Na:- 2,8,1 ; $_{17}$Cl:- 2,8,7]



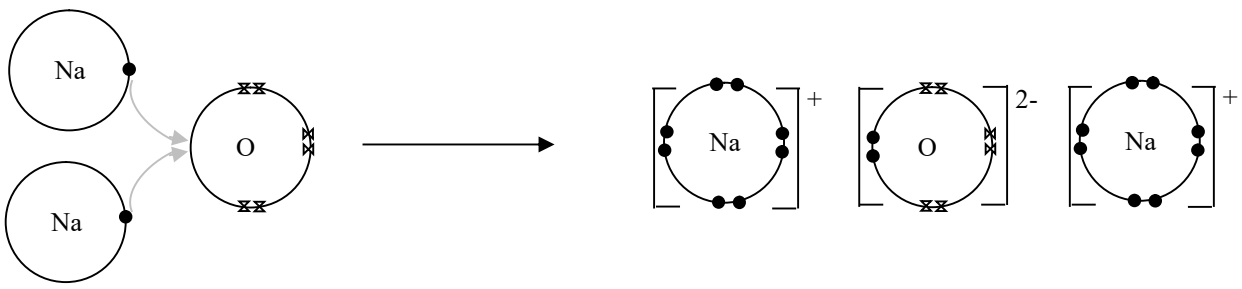
MgO [Electron configuration: $_{12}$Mg:- 2,8,2 ; $_{8}$O:- 2,6]



$MgCl_2$ [Electron configuration: $_{12}$Mg:- 2,8,2 ; $_{17}$Cl:- 2,8,7]



Na_2O Electron configuration: [$_{11}$Na:- 2,8,1 $_{8}$O:- 2, 6]



HW. Draw yourself for CaO K_2S

Ionic Lattice: Ionic compounds do not exist as molecules.

They are crystalline solids.

4. Video Link: https://www.youtube.com/watch?v=R2fNctc3TYA&t=431s

A large number of cations and anions are held together in a lattice by strong electrostatic force of attraction.
In their crystalline lattice, each of the cations is surrounded by a number of anions, and each of the anions is surrounded by a number of cations.

For example, sodium chloride is an ionic compound. In the crystal of sodium chloride, each Na^+ ion is surrounded by six Cl^- ions and each Cl^- ion is surrounded by six Na^+ ions.

The ratio of sodium ions to the chloride ions in its lattice is 1:1.
So we write the formula of sodium chloride as NaCl, but a single NaCl does not exist individually.

Figure: A single layer of solid NaCl:

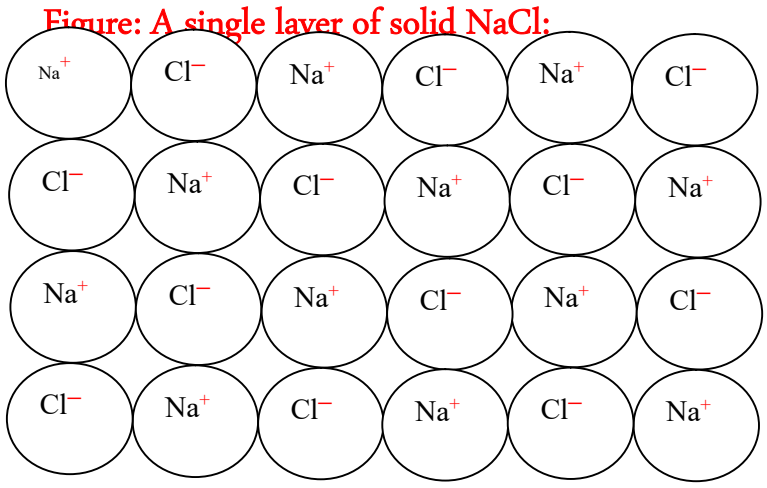
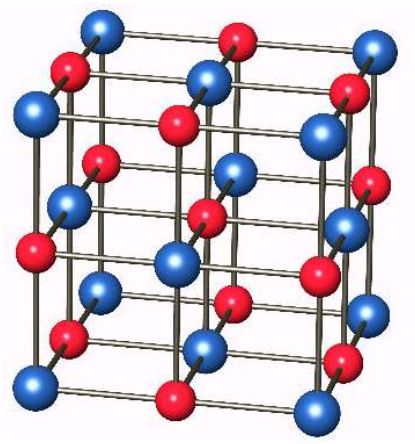
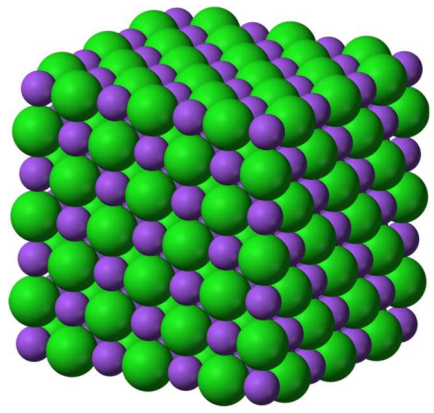


Figure: The crystal structure (or crystal lattice) of sodium chloride.





Giant lattice

Conductivity of electricity:

Electricity is conducted by either

- free electrons or
- mobile ions.

Free electrons are available in-

- Metals
- Graphite& few others allotropes of carbon

Mobile ions are available in

- molten or
- aqueous ionic compounds.

NOTE: Acids and alkalis are good conductors of electricity in **aqueous solution** as they have mobile ions.

Sodium chloride (or any other ionic compounds) is a crystalline solid.
There is no free electron in its crystals and the ions it possesses are closely packed and so cannot move about, hence it does not conduct electricity in solid state. When it is dissolved in water or melted, the ions become mobile which conduct electricity.

H.W.

Q. what is responsible for electrical conductivity of ....

(a) aqueous copper (II) nitrate

(b) copper

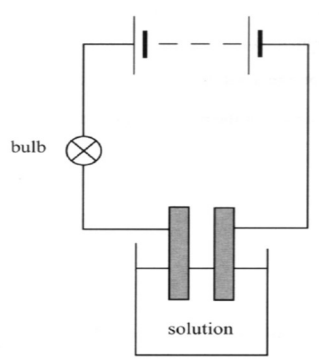
(c) Explain why solid copper (II) nitrate in not good conductor.

Experiment for conductivity test:

Two open ends of an electric circuit with a cell/battery and a bulb are dipped in solid $NaClorPbBr_2$.

The bulb does not light. But when the solid is heated to liquid or water is added to make an aqueous solution the bulb lights.

Diagram:



Q. Describe an experiment to show that aqueous solution of NaCl is a good conductor of electricity.

Melting and boiling points of ionic compounds: **********

Most ionic compounds melt and boil at high temperature.

Because an ionic compound consists of a large number of ions in their giant crystalline lattice.

Oppositely charged ions are attracted to each other by strong electrostatic force.

Large amount of heat energy is required to weaken the attraction for separating the ions.

Note: Melting and boiling points of ionic compounds with greater charge of their ions

are greater than the compounds with less charge.

For example, the mp of CaO is much greater than that of NaCl.

Because, CaO type compounds have greater charge on their ions (Ca^{2+}& O^{2-}) and so the electrostatic attraction between the cations and anions is stronger than that in NaCl type (Na^{+} & Cl^{-}) compounds.

HW

Q. Explain why KBr has less b.p. than that of CaS?

Solubility of ionic compounds:

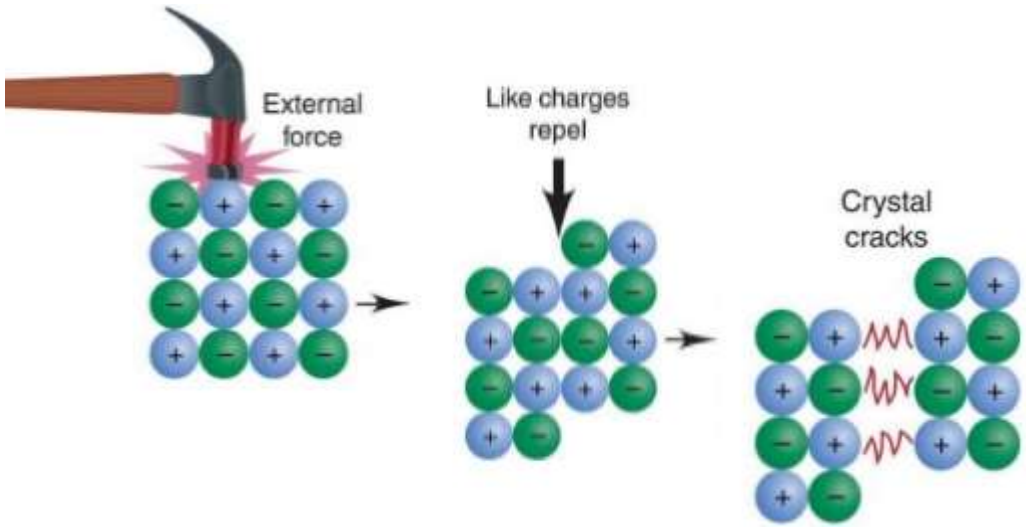
They are often soluble in water but usually insoluble in organic solvents, e.g. ethanol, methylbenzene.

Water is a polar solvent. Water molecules can get into the crystal lattice and separate the ions.
Ions can move about in water.

Note: Salts and bases are ionic compounds, and acids are ionic in aqueous solutions only.

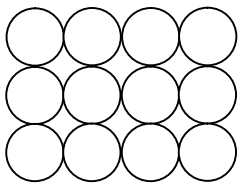
Ionic compounds are brittle:

Under stress when ions of same charge get together, the lattice break down due to .....



Comprehensive Exercise:

Q 1.(i)The following diagram represents a single layer of an ionic lattice of CaO.
Complete the diagram by putting the correct formulae of the ions in the circles below.

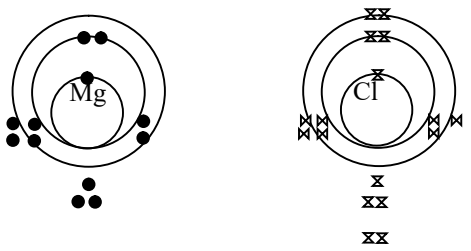


(2)

(ii) State and explain whether calcium oxide or sodium chloride melts at higher temperature.
(3)

Total 5 marks

Q2.The following diagrams represent the electron arrangement of magnesium and chlorine.



(i) Describe what happens to the atoms, in terms of electrons, when they form magnesium chloride.
[2]

(ii) Give the formulae of their ions that are formed.
[1]

(iii) Give the formula of the compound that is formed between magnesium and chlorine. [1]

(iv) Predict the melting point of the compound. Explain your answer. [3]

Total 7 marks

Q 3. Sodium chloride is an ionic compound.

Explain the following properties of sodium chloride.

(i) Sodium chloride has very high melting and boiling points. (3)

(ii) Sodium chloride does not conduct electricity when solid, but molten sodium chloride and aqueous sodium chloride is a good conductor of electricity. (2)

Total 5 marks

Q1. The electron arrangement of two elements, **X** and **Y** are given below.

X (2,8,2) and Y (2,7)

(i) Give the formula of ions formed by both X and Y.

(ii) Write the formula of the compound formed between X and Y.

(iii) Predict with a suitable reason, whether the compound is likely to be soluble in water.

.....

(2)

Total 4 marks

2. (a) The following table shows the properties of five substances labeled A to D.

Substance	Melting point/ ^0C	Boiling point/ ^0C	Conductivity of electricity	
			When solid	When molten
A	High	Very High	Poor	Good
B	High	Very High	Poor	Poor
C	High	Very High	Good	Good
D	Medium	Medium	Poor	Poor

Explain, in terms of the properties in the table, why

(i) A is not water.

(ii) B is not aluminium

(iii) C not NaCl

(iv) D is not Silver

(4)

(b) Complete the table:

No.	Bonding	Type of attraction	Between the particles
1	Ionic bonding	Electrostatic	Cations and anions
2	Covalent bonding	Electrostatic	.....
3	Metallic bonding	.....	Positive ions and the delocalized electron cloud

(iii) You have been given only formula of a compound.

Explain how would you understand whether compound is ionic.

.....

.....

(1)

Total 4 marks

Covalent bonding:

The electrostatic force of attraction between the **shared pair of electrons** and **nuclei of the atoms** is called covalent bonding.

Diagram:

Video Link: https://www.youtube.com/watch?v=zdi0EfWOtTo&t=124s

A covalent bonding is formed **between two non-metal atoms**. A non-metal atom cannot receive electrons in absence of a metal. So, they share electrons to achieve the electronic configuration of noble gases/ inert gases and become stable.

The number of electrons sent by an atom for sharing with another atom can be estimated from its electron configuration. **Each atom sends the number of electrons that is/are required (in short) to fulfill its outer shell.**

e.g.

$_1H$ [1] needs 1 electrons to fulfill its outer shell, so it always sends 1 electron for sharing with another atom.

$_8O$ [2,6] needs 2 electrons to fulfill its outer shell, so it always sends 2 electron for sharing with another atom.

$_7N$ [2,5] needs 3 electrons to fulfill its outer shell, so it always sends 3 electron for sharing with another atom.

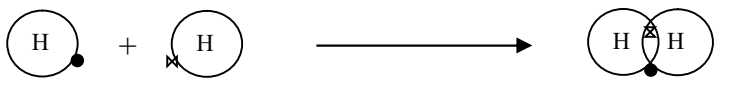
$_6C$ [2,4] needs 4 electrons to fulfill its outer shell, so it always sends 4 electron for sharing with another atom.

Every two shared electrons (one pair) form one covalent bond between the atoms.

So the number of covalent bonds between two atoms is the number of electron-pair shared.

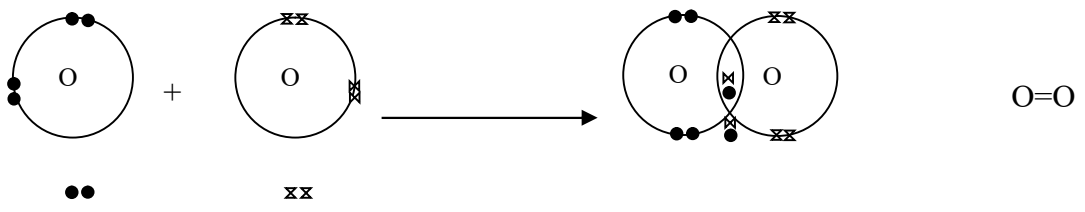
Figure: DOT and CROSS diagrams of covalent bonding: (only outermost shells)

H_2; [$_1H = 1$]



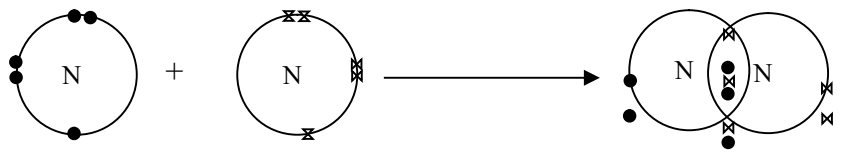
H–H

O_2 : [$_8O = 2, 6$]



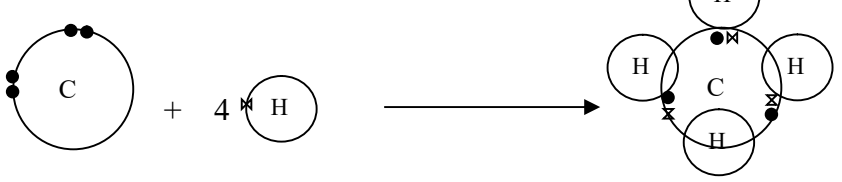
O=O

N_2 : [$_7$N = 2, 5]

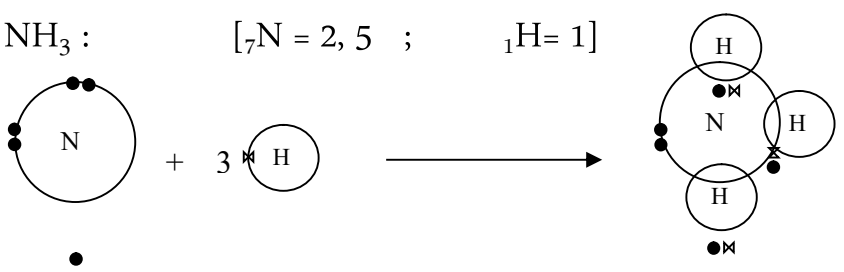


N ≡ N

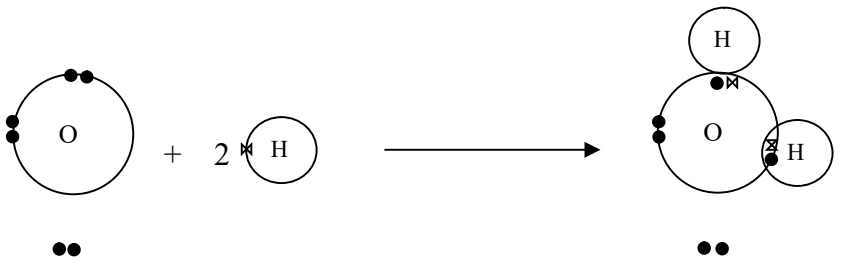
CH_4 : [$_6$C = 2, 4 ; $_1$H= 1]



NH_3 : [$_7$N = 2, 5 ; $_1$H= 1]

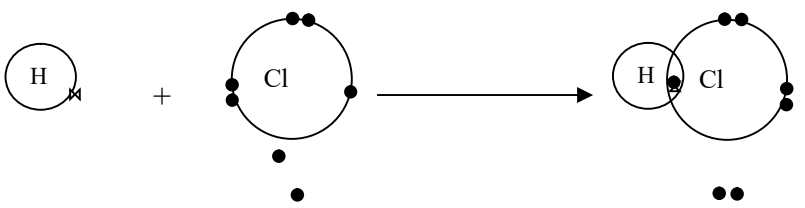


H_2O [$_1$H= 1; $_8$O= 2, 6]

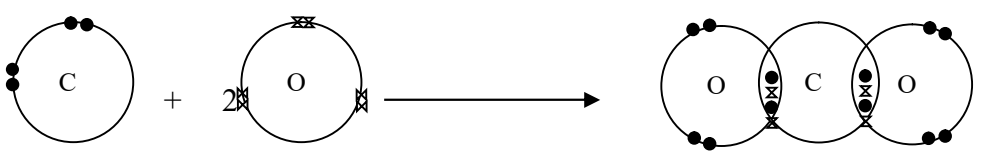


SCl_2

HCl [$_1$H= 1; $_{17}$Cl= 2, 8,7]



CO_2 : [$_6$C = 2, 4 ; $_8$O= 2,6]



Draw DOT and CROSS diagrams

for H_2 , O_2 , CH_4 , NH_3 , H_2O , HF , CO_2 , HCl.

Intermolecular Force a WEAK force:

Covalent bonding holds the non-metal atoms together resulting a group of atoms is known as molecules.

6. Video Link: https://www.youtube.com/watch?v=i9tYuRdIczg&t=159s

A sample of a covalent substance contains a large number of molecules held together by weak force of attraction, named intermolecular forces, sometimes, this is also known as Van-der-Waals' force.
So a sample of a covalent substance has two different types of bondings--one is strong covalent bonding between the atoms within a molecule and the other is weak intermolecular force of attraction that holds the molecules together.

It is generally a weak attractive force, but different substances have different amount of intermolecular forces.
With increasing size of the molecules intermolecular forces increases which result in increasing their melting and boiling points BECAUSE their number of electrons increases.

The substances which are gaseous at room temperature have a very (negligible) weak intermolecular forces and it is stronger in a liquid and strongest in a solid.

A solid simple covalent substance can be converted into a liquid or a gas by heating.
During this state-change, their strong covalent bonds are not broken, only the intermolecular forces are overcome.

Q. Explain, why water melts at a very low temperature. (2) HW

Why oxygen is a gas at room temperature. (2)

Why bromine is a liquid, but chlorine is a gas at room temperature. (2)

Why melting temperature of sodium chloride is much greater than that of water. (5)

Properties of simple covalent substances:

(a) Melting and boiling points:

The simple covalent substances (e.g H_2O, HCl, CO_2, NH_3etc) are often liquids or gases at room temperature, as their melting and boiling points are low.

- A sample of simple covalent substance consists of distinct small molecules.
- The molecules are held together by intermolecular force which is a very weak force of attraction.
- A small amount of heat energy is enough to separate the molecules.
  [*Not to break the bonds]

(b) Conductivity of electricity of simple covalent substances:

Covalent compounds usually do not conduct electricity, because they have neither mobile ions nor free electrons to carry electricity.

(c) Solubility:

Simple covalent substances are fairly soluble in non-polar solvents (e.g. in petrol, octane etc), but less likely to be soluble in water (polar).

Exercise: Differences between ionic and covalent bonding:

No.	Property	Ionic bonding	Covalent bonding
1	Elements involved in bonding	Between metals and	between non-metal atoms
2	Way of formation	by transferring electrons	.....
*3	Attraction	Electrostatic attraction between cations and anions	Electrostatic attraction between ..... and nuclei of the atoms
4	Type of Particles formed	Ions (cation and anion)	.....
5	Structure	Giant .....lattice	Simple Molecular or macromolecular
6	Type of Compounds	ionic compounds	..... compounds
7	Melting and boiling points	.....	Low (except the macromolecules)
8	Electrical Conductivity	Molten and aqueous solutions are good conductor	..... conductor (except graphite etc)
9	Solubility in water	Many of the compounds are ..... in water.	Soluble in organic solvent and few of them are water soluble.
10	Hardness	Hard and brittle	Usually .....

Fill in the blank to test your knowledge

Q. Explain, why water melts at a very low temperature. (2) HW

Why oxygen is a gas at room temperature. (2)

Why bromine is a liquid, but chlorine is a gas at room temperature. (2)

Why melting temperature of sodium chloride is much greater than that of water. (5)

Answer:

Q. Explain, why water melts at a very low temperature. (2)

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

A small amount of heat is enough to separate the molecules to boil.

Q. Explain, Why oxygen is a gas at room temperature. (2)

The molecules of oxygen have a very weak intermolecular forces of attraction.

The room temperature has been enough to separate the molecules to boil.

Q. Explain, Why bromine is a liquid, but chlorine is a gas at room temperature. (2)

The molecules of bromine are bigger than the molecules of chlorine.

So the intermolecular forces of bromine are greater than that of chlorine.

Q. Explain, why melting temperature of sodium chloride is much greater than that of water. (5)

Sodium chloride is an ionic compound with giant ionic lattice.

The electrostatic attraction between the cation, Na^+ and the anion, Cl^- is very strong.

So, a large amount of heat is required to weaken the attraction.

The molecules of oxygen have a very weak intermolecular forces of attraction.

The room temperature has been enough to separate the molecules to boil.

Metallic Bonding:

In a solid of metals, the metallic atoms are held together by metallic bonding.

The atoms of a metal have generally few electrons (1, 2, 3) in their valence shells.

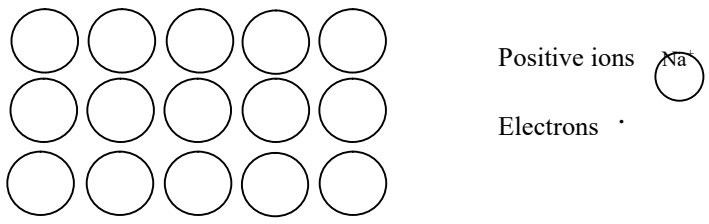
The valence electrons are loosely held in their atoms as they are relatively distant from their nuclei.

7. Video Link: https://www.youtube.com/watch?v=sYnhmQtlfEk&t=187s

In a piece of metal, all the atoms lose their **valence electrons** to form (residual) positive ions which are closely packed together. The delocalized electrons form an **electron cloud**(sometimes called **sea of electrons**) which can move freely throughout the lattice.

The electrostatic attraction between the positive ions and the delocalized electron cloud is very strong.

Figure: A l**ayer** of a typical metallic lattice (Na)



The properties of metals:

1) Metals have usually high melting and boiling points. *

Reason: The electrostatic attraction between the (residual)positive ions and negative electron cloud is very strong.
Huge energy is required to overcome this attractive force to melt and boil metals.

2) Metals are good conductors of electricity.*

Reason: Metals have delocalized electrons which are free to move in their lattice.
When an electric potential is applied to one end of a metallic rod, the electrons move towards the positive end of the rod.

3) Metals are good conductors of heat.

Reason: Mobile electrons convey heat energy throughout the lattice.

4. Metals are malleable and ductile.

Reason: The positive ions of metals are slide-relative to one another.
Under stress, without shattering, the lattice takes new shape, because the ions are still surrounded by their delocalized electrons.

Worksheet: Name of Student:

Differences between ionic and covalent bonding:

No.	Property	Ionic bonding	Covalent bonding
1	Elements involved in bonding		
2	Way of formation		
*3	Type Attraction		
4	Type of Particles formed		
5	Structure		
6	Type of Compounds		
7	Melting and boiling points		
8	Electrical Conductivity		
9	Solubility in water		
10	Hardness		

Options: Fill in the Table with the Letters A to I for the properties of different substances.

A Simple molecular structure

B High melting and boiling points

C Good conductor of electricity in solid state

D need to break covalent bonds for melting

E Need to break only intermolecular forces for melting and boiling

F Have both intermolecular forces and covalent bonding

G Good conductor of electricity only in liquid state

H is not a molecule

I neither have covalent bonding nor ionic bonding

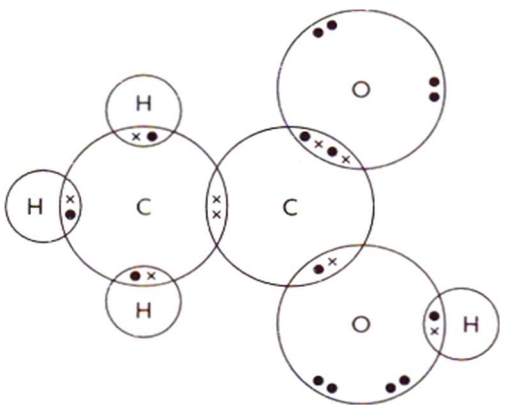
Different types of substances:

H_2O/ Water	Calcium chloride	Aluminium

Name of The Student: .....

Comprehensive Questions:

1.



(a) Name the different elements found in this compound. [1]

(b) What is the total number of atoms present in this molecule? [1]

(c) Between which two atoms is there a double covalent bond? [1]

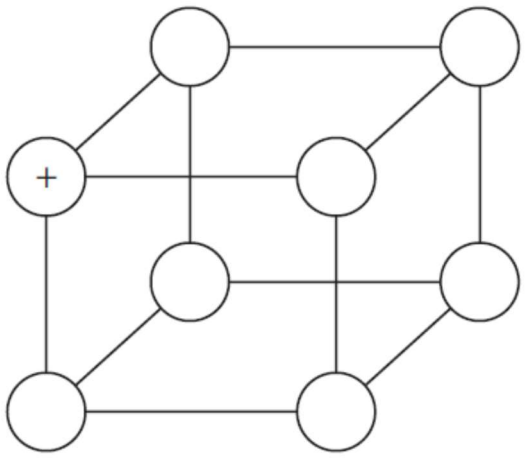
(d) How many covalent bonds does each carbon atom make? [l]

(e) Would you expect this compound to be a solid or a liquid at room temperature? Give a reason for your answer. [2]

(f) Ethanoic acid will dissolve in methylbenzene. Would you expect the solution to conduct electricity? Give a reason for your answer. [2]

2. Potassium chloride, KCl, is very similar to sodium chloride, NaCl. They have the same type of crystal structure, and their aqueous solutions can be electrolysed to give similar products.

(a) The diagram shows part of the structure of potassium chloride.

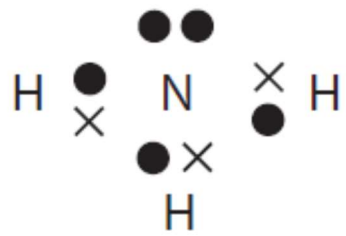


The plus (+) sign shows the position of one potassium ion.

Complete the diagram using a plus (+) sign to show the position of each potassium ion, and a minus (–) sign to show the position of each chloride ion.

(2)

(b)The diagram represents a particle of ammonia.



(i) This particle of ammonia is (1)

A an atom **B** an ion **C** a lattice **D** a molecule

(ii) Which type of bonding is present in this particle of ammonia? (1)

A covalent **B** hydrogen **C** ionic **D** metallic

(iii) What is the formula of ammonia? ..... (1)

(Total for Question 1 = 5 marks)

3.Potassium sulfide is an ionic compound.

(a) Complete the table to show the arrangement of electrons in the ions formed when potassium and sulfur react to form potassium sulfide.

Give the charge on each of the ions.

Element	Arrangement of electrons in atom	Arrangement of electrons in ion	Charge on ion
$_{19}K$			
$_{16}S$			

(6)

(b) (i) Explain why potassium sulfide conducts electricity when molten. (1)

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(ii) Explain why potassium sulfide has a high melting point. (3)

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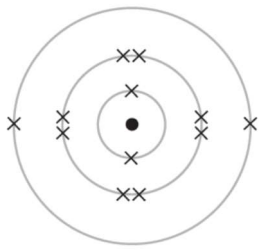
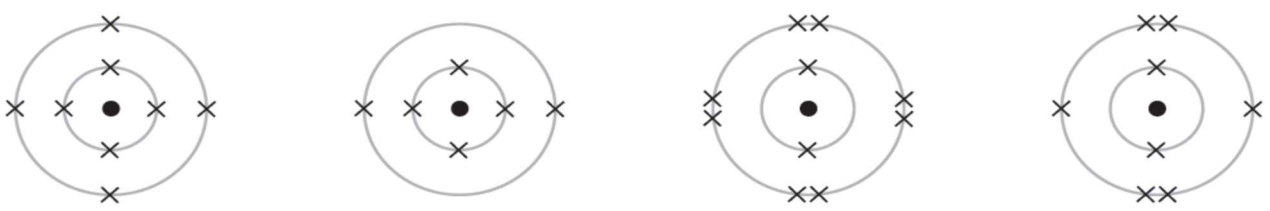
(Total for Question = 10 marks)

4. Distress flares are used to attract attention in an emergency. The flares contain magnesium, which burns with a bright, white flame to form magnesium oxide.
The reaction between magnesium and oxygen is exothermic.

(a) The diagram shows the electronic configuration of a magnesium atom.

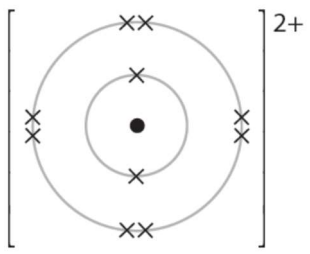


Put a cross in a box to indicate the diagram that shows the electronic configuration of an oxygen atom.

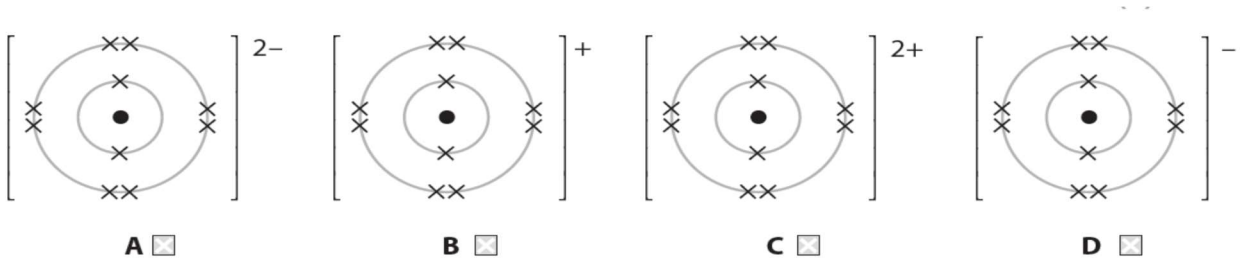


(1)

(b) Magnesium ions and oxide ions are formed when magnesium reacts with oxygen.
The diagram shows the electronic configuration and charge of a magnesium ion.



Put a cross in a box to indicate the diagram that shows the electronic configuration and charge of an oxide ion.



(1)

(c) Explain, in terms of electron configuration, what happens to the magnesium and oxygen when they bond.

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(3)

(Total for Question 3 = 5 marks)

5. Various parts of the helicopter below are made out of metal, because metals are strong and malleable.

(a) Draw a diagram to show the **metallic bonding** present in aluminium metal. (2)

(b) Use your knowledge of the structure of metals to explain why:

(i) they are strong (2)

.....

.....

.....

(ii) they are malleable (2)

.....

.....

(c) As the blades of the helicopter rotate, heat produced in the joints is conducted away along the blades.

Explain how metals conduct heat. (1)

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(Total for Question 7 marks)