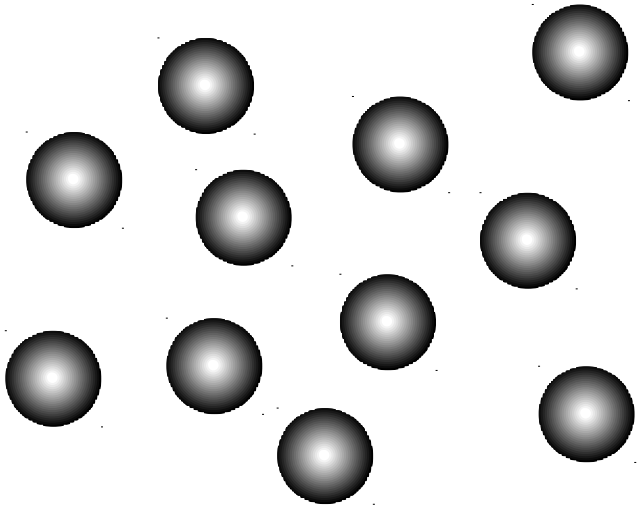
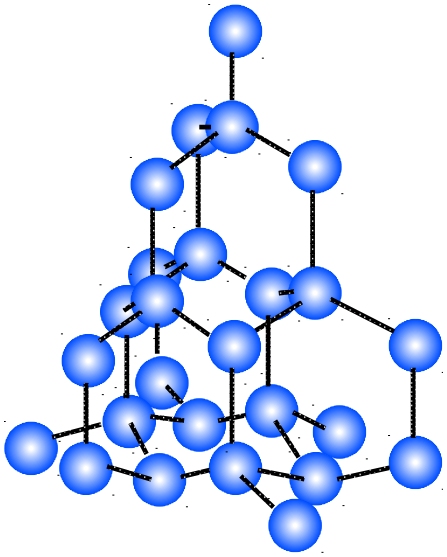
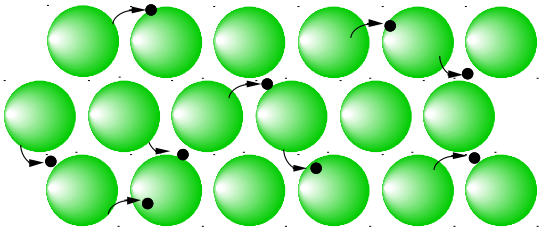
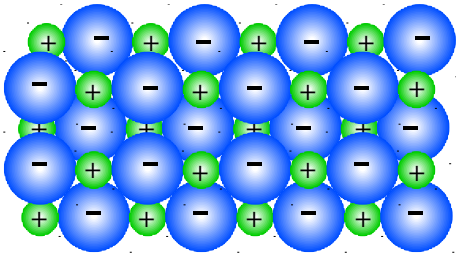
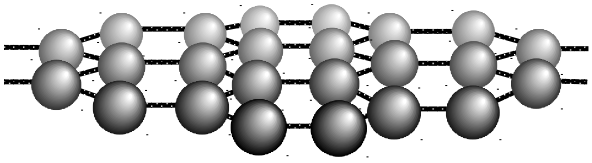


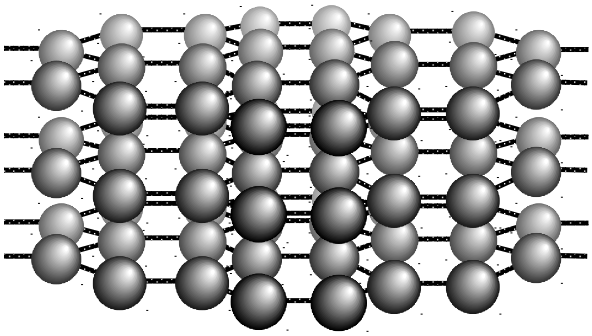


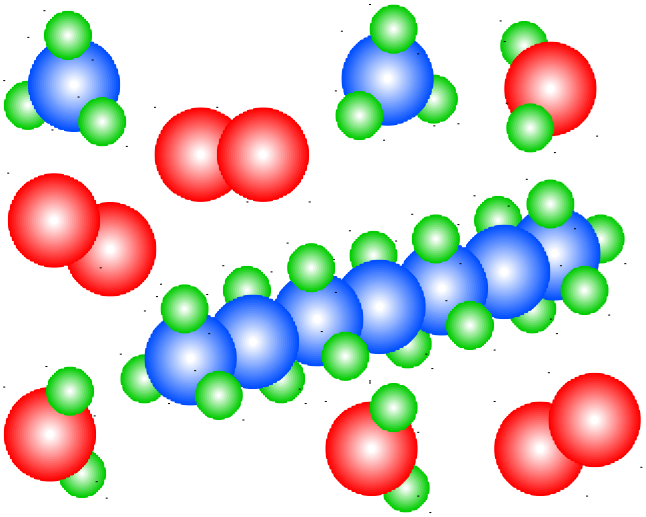
STRUCTURE & BONDING



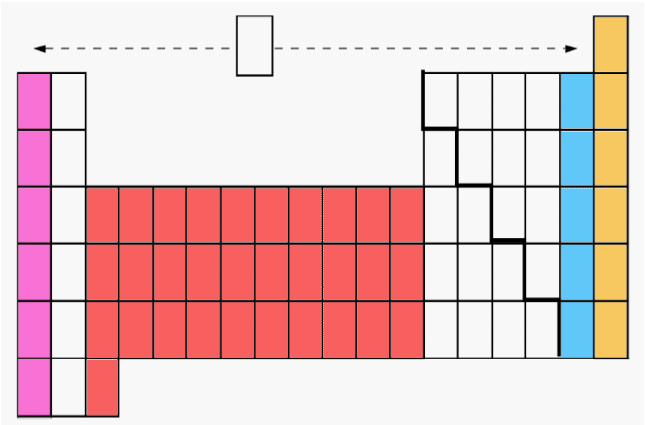








Classifying Substances



In chemistry we often place substances which have similar properties into groups. We say that we are ***class*** them.

Ele and ***com*** are common classifications you have already come across in chemistry.

Elements in turn can also be classified as ***Met*** or ***N -met***.

Other groups such as ***Alk Metals***, ***Tran Metals***, ***Hal*** and ***No Gases*** should already be familiar to you.

To take our classification further you need to know ;

① **Type of Bonding**, *what kind of forces are holding the atoms of different substances together*, and

② **Structure,** *how the atoms or molecules are arranged*.

There are 3 main different types of bond that hold the atoms of substances together;

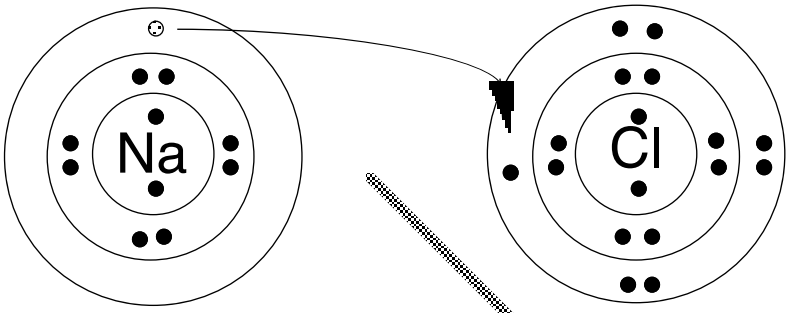
Metallic bonding - bond the atoms in ***Metal ele*** or ***Metal mix*** (***all***).

Covalent bonding- bond the atoms in ***Non-metal ele*** and in ***comp*** containing ***non-metals only***.

Ionic bonding - bond the 'atoms' in ***comp s*** containing ***metals and non-metals***

Ionic Bonding - *Metal/Non-metal Compounds*

This is the 'easiest' and most obvious type of bond: metals want to ***lo*** electrons, non-metals want to ***ga*** electrons; so **electrons are transferred** from the ***met*** to the ***n -met*** . This does, however, change completely the nature of the atoms involved.



Sodium ***atom***

protons	=	+
electrons	=	-
overall charge	=	

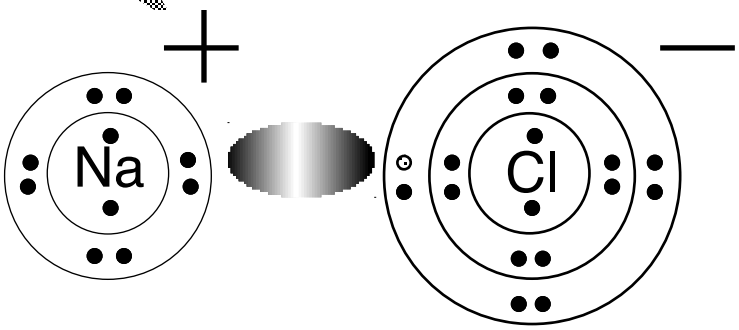
Chlorine ***atom***

protons	=	+
electrons	=	-
overall charge	=	

The sodium atom will ***lo*** ***1*** electron which will be *transferred* to the chlorine atom.

Both 'atoms' now have a full outer shell. The sodium 'atom' becomes a ***pos*** charged ***ion*** .

The chlorine 'atom' becomes a ***neg*** charged **ion**.



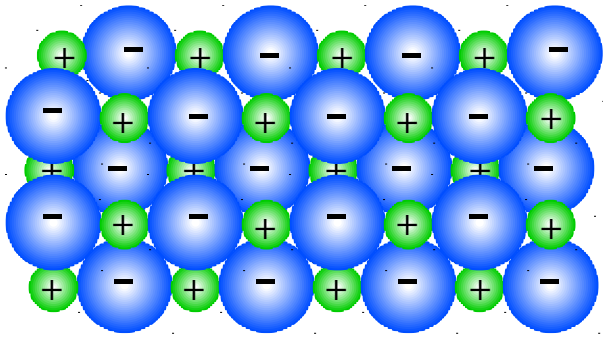
Sodium **ion**

protons	=	+
electrons	=	-
overall charge	=	

Chlorine **ion**

protons	=	+
electrons	=	-
overall charge	=	

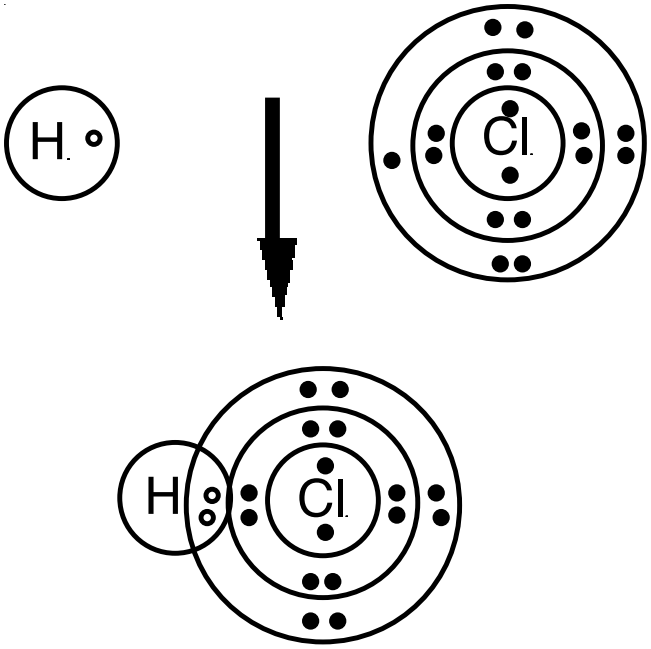
The Ionic Bond is the mutual attraction between positive and negative ions.



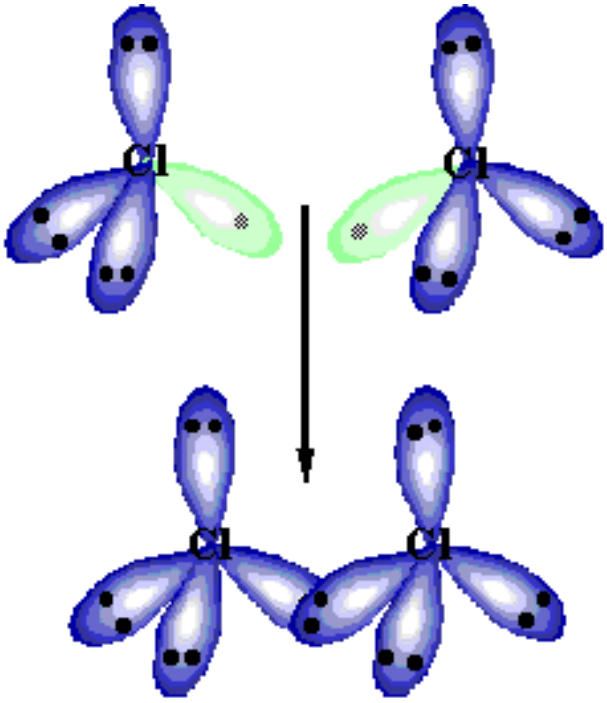
Though ***1 sodium*** atom will give ***1 electron*** to ***1 chlorine*** atom and the formula for sodium chloride will be NaCl, each Na^+ ion will attract several Cl^- ions and vice versa, hence a ***net*** structure.

CovalentBonding - *Non-metal Elements and Compounds*

Here, ***all*** the elements want to ***ga*** electrons but ***none*** are prepared to ***lo*** electrons. They only way that everyone can gain is by **sharing**.



H—Cl



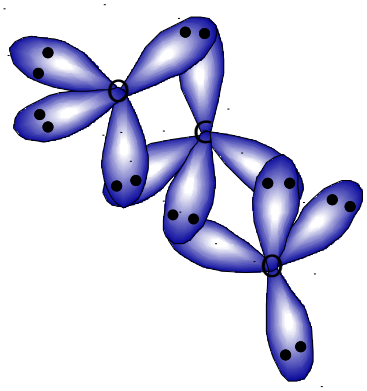
Cl—Cl

Atoms ***ove*** shells in order to ***sha elec*** .

Both atoms achieve a stable electron arrangement (a ***full outer shell***).

Half-filled ***orb*** *can* ***ove*** *to* ***sha elec*** .

The atoms are held together by the forces of attraction between the two positive nuclei and the shared pair of electrons.



O=C=O

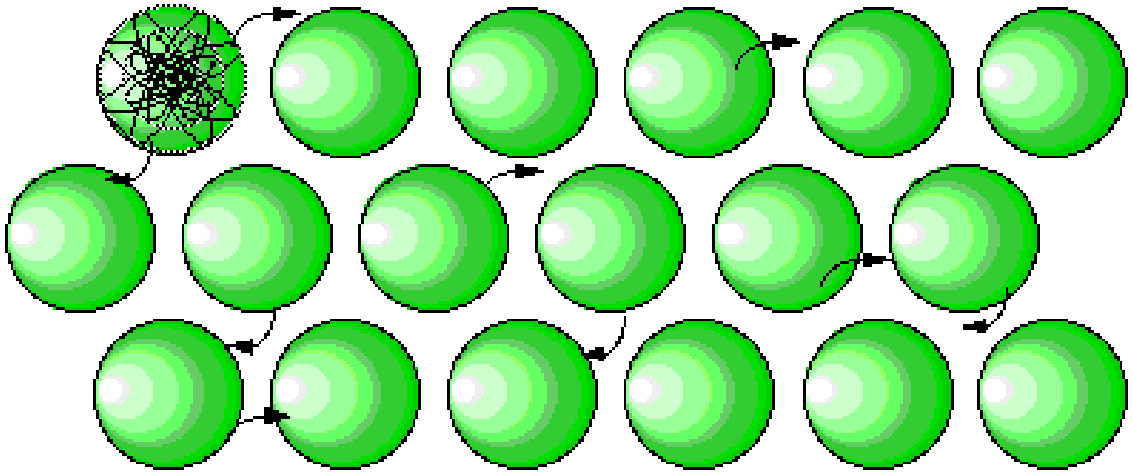
Each shared pair of electrons is a ***cov*** ***bond***. When necessary atoms can share more than one pair and form ***do*** or even ***tri*** covalent bonds.

Metallic Bonding - *Metal Elements and Alloys*

Here, ***all*** the atoms want to ***lo*** electrons but ***none*** are prepared to ***ga*** electrons. At first sight there is no way that this can happen.

However, the next best thing is to *temporarily* '***lo*** ' the outer electron(s) by allowing them to *drift freely* between all the separate metal atoms.

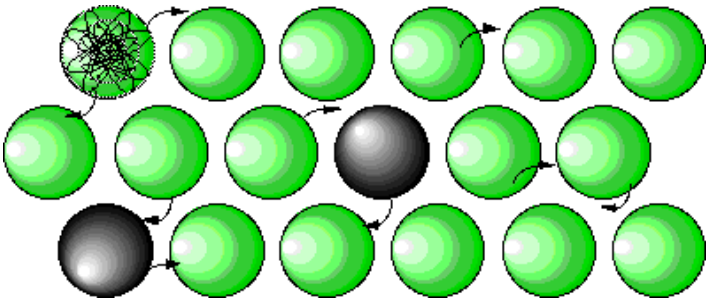
This results in *temporary metal* '***io*** ' forming which immediately attract an electron back to reform the atom.



The outer electrons end up *'belonging'* to more than one atom; **the atoms are bonded together when they attract the same electron at the same time.**

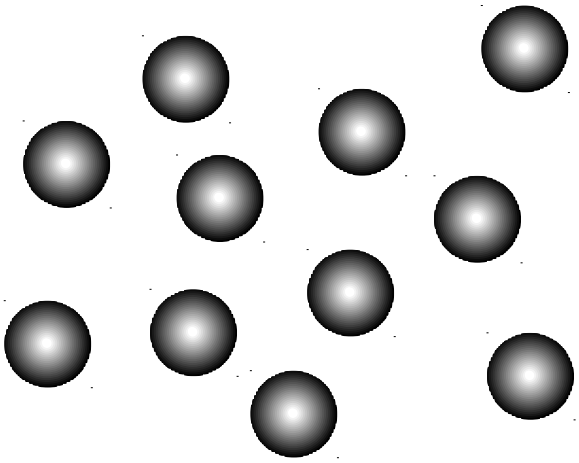
A metallic structure can be described as a regular arrangement (***net*** or ***latt***) of ***pos*** metal ions held together by a 'sea' of *constantly moving* **neg** electrons. The outer electrons are said to be '***del*** '.

Since ***all*** metal atoms bond in this way, introducing atoms of a different metal does not disturb the structure at all. This is why mixtures of metals (***all***) are usually very stable and would be very difficult to separate again.



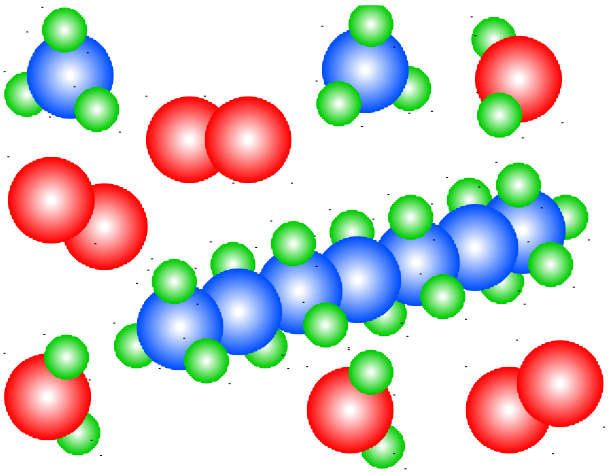
3 Different Structures.

Single atoms - very rare.



Only possible in ***ele*** .
Only the ***no*** ***gases*** have this structure normally, though, at *very high temperatures* other elements can exist as single atoms.

Molecules - groups of atoms joined together in ***fix*** amounts.

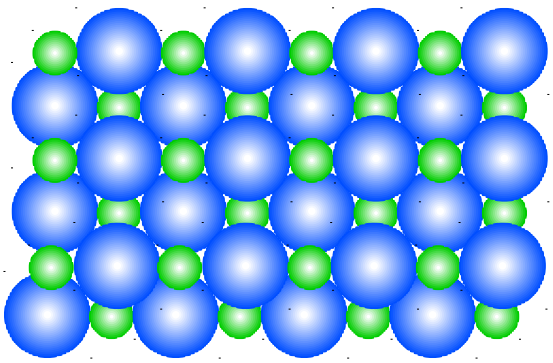


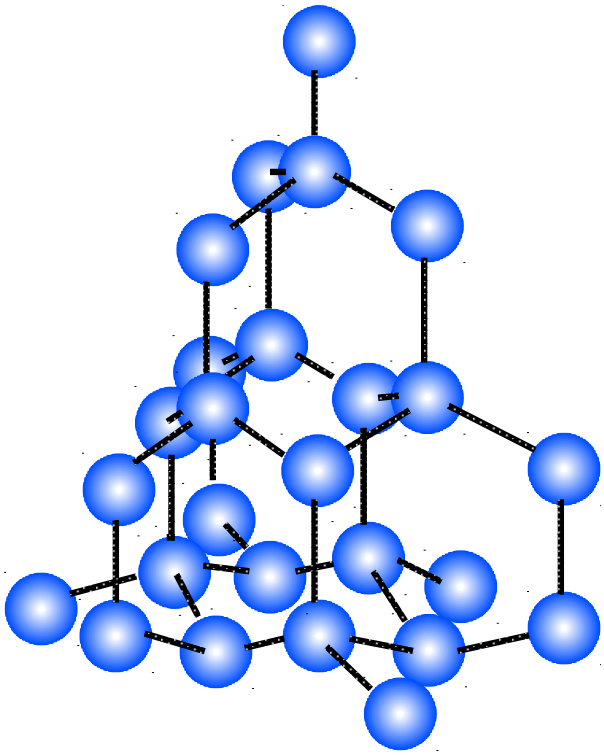
Can be *small* (eg 2 atoms), *medium* (10's of atoms) or *large* (eg 100's of atoms). Large molecules are usually ***Polymers***

Networks - *regular arrangements* limited in size only by the number of 'atoms' available.

Another word for these giant regular arrangements is ***Latt*** .

An ***Io*** ***Net*** is also called a ***Cry*** ***Latt*** .

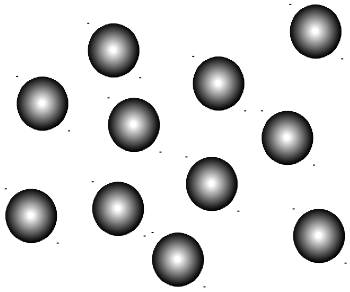




Five Bonding Structures

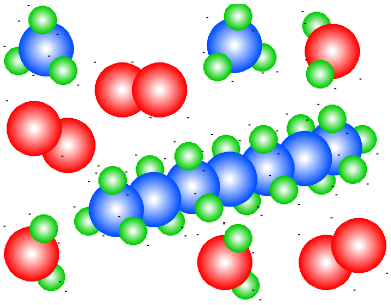
Single Atoms
(*monatomic elements*)

Very rare - only the ***Noble Gases*** exist as single atoms

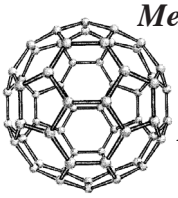


He Ne Ar Kr Xe

Covalent Molecular
(*non-metal elements & compounds*)



Small - H_2 O_2 N_2 etc
HCl H_2O NH_3 CH_4

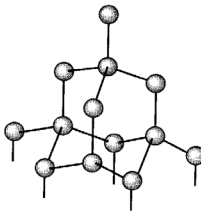


Medium - $C_6H_{12}O_6$
C_6H_{14} C_{60}

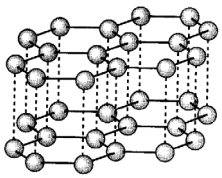
Large - starch
polythene etc

Covalent Network
(*non-metal elements & compounds*)

Only 3 examples

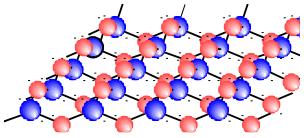


the ***element carbon*** (diamond)



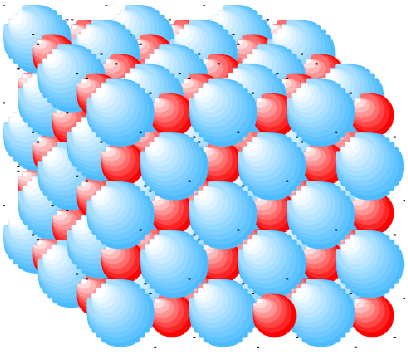
the ***element carbon*** (graphite)

the ***compound*** SiO_2



Ionic Network
(*metal/non-metal compound*)

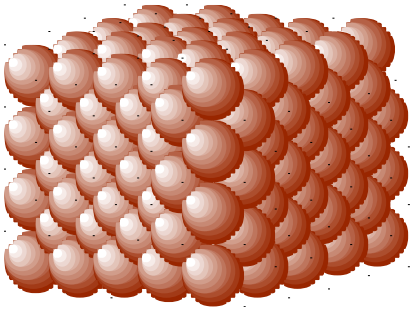
All metal/non-metal ***compounds***



Na^+ Cl^-
Mg^{2+} O^{2-}
Cu^{2+} $(NO_3^-)_2$

Metallic Network
(*metal elements & alloys*)

All metals elements & metal alloys



Cu Na
Mg Fe
brass

Properties

To be of any value our Bonding Theory must be able to explain the properties observed for a substance.

We will concentrate on 2 properties that are closely linked to the **bonding** and **structure** of a substance;

- ➤ Melting and Boiling Points
- ➤ Conductivity

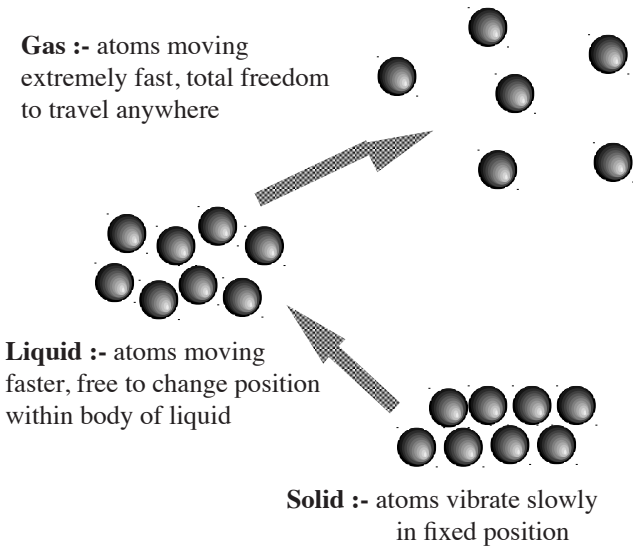
Melting Point & Boiling Point

Mel ***Point*** tells us the ***temp*** at which a substance changes state from ***so*** ⇔ ***liq*** and ***Boi*** ***Point*** the ***temp*** at which it changes from ***liq*** ⇔ ***gas***.

Both these changes in state will probably involve a change in ***stru*** but may also involve the breaking of ***bo*** .

Single Atoms

Element	*Mass*	*Mpt (°C)*	*Bpt (°C)*
He			
Ne			
		-189	-186
Kr			
		-112	-107

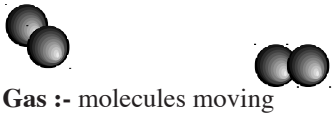


Conclusion: The ***no*** ***gases*** have *extremely low melting and boiling points* :- are ***all*** gases at room temperature.

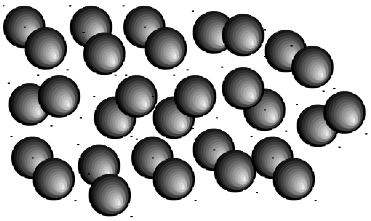
Explanation: Since there are ***no*** bonds *between* atoms at all, it requires very little ***en*** to move them ***fa*** and ***fur*** apart; depends mainly on their ***ma*** .

Covalent Molecular

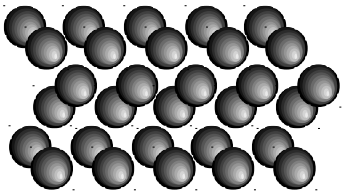
Use your Data Book to complete the tables, using 3 colours to shade solid, liquid and gas ranges.



Gas :- molecules moving extremely fast, total freedom to travel anywhere



Liquid :- molecules moving faster, free to change position within body of liquid

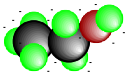


Solid :-molecules vibrate slowly in fixed position

Elements

Name	Bromine	Hydrogen	Iodine	Oxygen
Formula	Br_2			
Molecule				
Melting Pt (°C)	-7			
Boiling Pt (°C)	59			
State at room T	liquid			

Compounds

Name	Ammonia	Ethanol	Methane	Water
Formula	NH_3	C_2H_5OH		
Molecule				
Melting Pt (°C)	-78			
Boiling Pt (°C)	-33			
State at room T	gas			

Conclusion: ***Cov*** ***mol*** , depending on ***ma*** , are ***ga*** or ***liq*** mostly. Any ***sol*** are usually *easily melted* (***Low Mp***t)

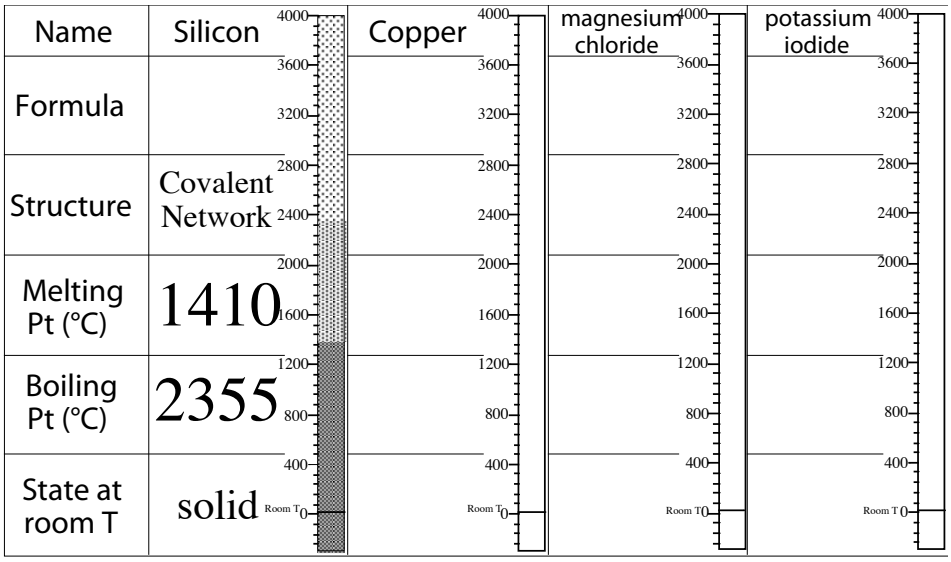
Explanation: Since there is no need to actually break the strong bonds *within* the molecule and forces *between* molecules are usually *weak*, it requires very little ***en*** to move them ***fas*** and ***fur*** apart.

Some molecules, like water, have stronger forces between their molecules and, as a result, have higher Mpt and Bpts than expected.

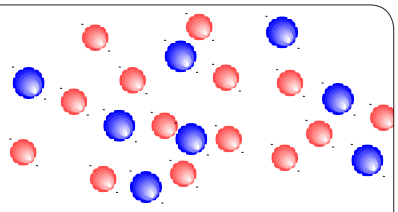
Networks

Use your Data Book to complete the table, using 3 colours to shade solid, liquid and gas ranges.

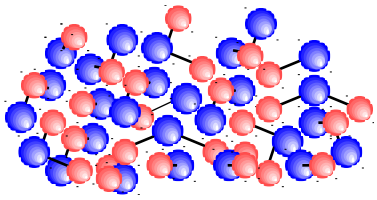
Name	Silicon	Copper	magnesium chloride	potassium iodide
Formula				
Structure	Covalent Network			
Melting Pt (°C)	1410			
Boiling Pt (°C)	2355			
State at room T	solid			



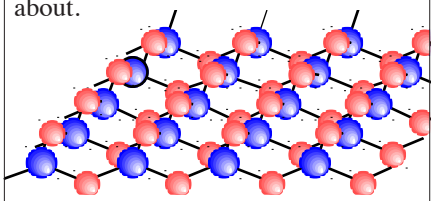
Conclusion: All ***net*** , with the exception of the metal ***mer*** , are ***sol*** at room temperature. Most have *very high* Mpt and Bpts.



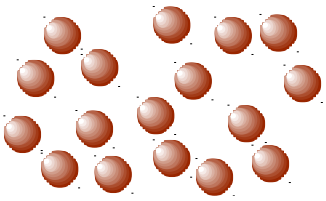
Gas :-all the remaining covalent bonds are broken resulting in individual atoms with total freedom.



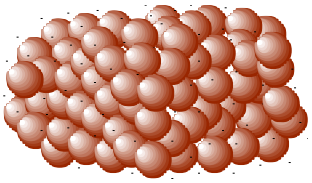
Liquid :-the network gets broken up into smaller pieces which can move about.



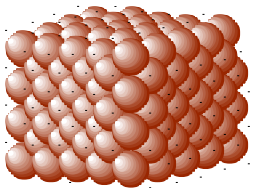
Solid :-many strong covalent bonds hold the atoms firmly in place.



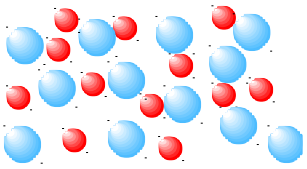
Gas :-all the remaining metallic bonds are broken resulting in individual atoms with total freedom.



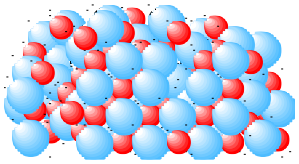
Liquid :-the network gets broken up into smaller pieces which can move about.



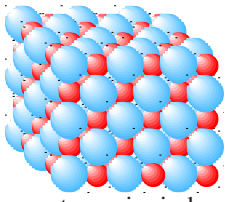
Solid :-many strong metallic bonds hold the atoms firmly in place.



Gas :-all the remaining ionic bonds are broken resulting in individual ions with total freedom.



Liquid :-the network gets broken up into smaller pieces which can move about.



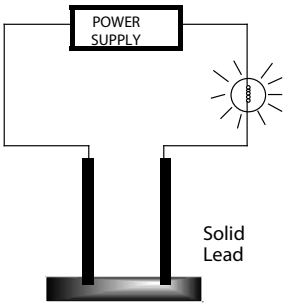
Solid :-many strong ionic bonds hold the ions firmly in place.

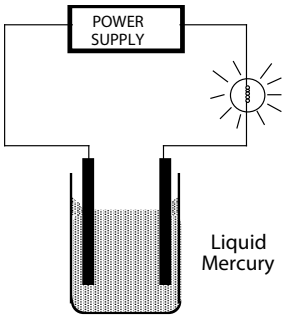
Explanation: Since there ***is*** a need to ***br*** the ***str*** ***bo*** between the particles making up the ***net*** , it requires ***lar*** amounts of ***en*** to move them ***fas*** and ***fur*** apart.

Conductivity

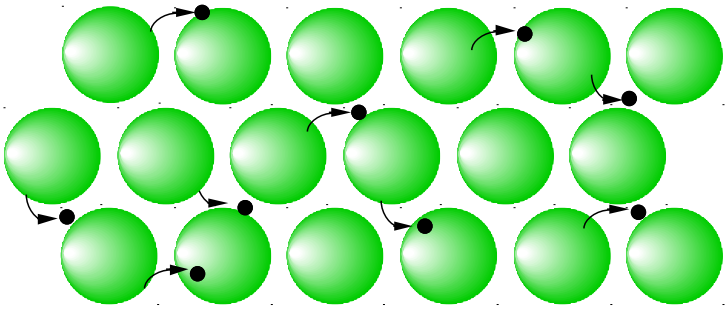
Metallic Networks

Conclusion: All metals are good ***con*** when ***sol*** and when ***liq*** .





Explanation: As previously seen, the metallic bond has ***del*** electrons making metals ideal as ***con*** ;



When a ***vol*** (push) is applied across the metal, by a ***bat*** or power supply, all the ***del*** ***ele*** move in the same direction; attracted towards the ***pos*** end of the battery.

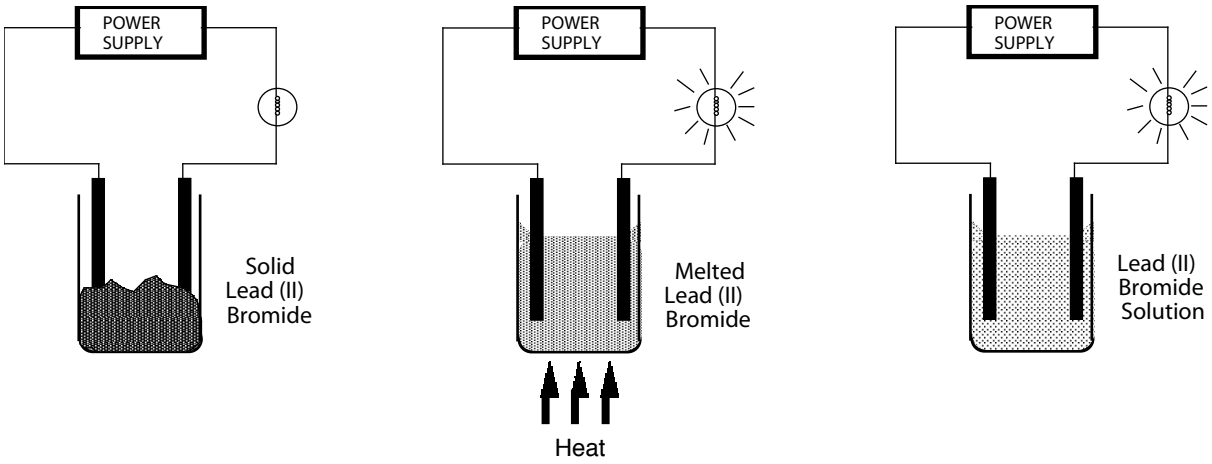
*An electric **cur** is simply a flow of **neg** charged **elec** , and metals complete the circuit by allowing a **cur** to flow easily through them. The metal is completely unchanged and when the voltage is switched off the electrons will revert to drifting freely in all directions throughout the metal.*

*In fact, <u>all</u> parts of an electric circuit; bulb, leads, crocodile clips etc, will be made of **me** and are just a reservoir of **del** **elec** which the battery forces to move in a particular direction.*

*The **bat** is like an 'electron pump', that pulls electrons in at the **pos** terminal and pumps them out at the **neg** terminal.*

Ionic Networks

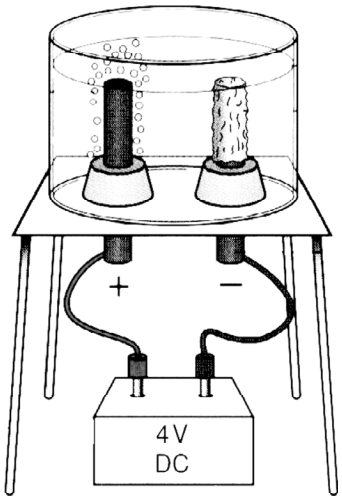
Observation: Ionic networks *cannot* act as conductors when ***sol*** , but are good ***con*** if melted to form ***liq*** or if dissolved in water to make a ***sol*** .



Explanation: Once formed, ***io*** hold onto their ***elec*** very strongly indeed, so there are *never* any ***del ele*** *free to move* through an ionic solid

However, when liquid or in solution, the individual ***ions are free to move*** and, being ***cha*** , will move towards the electrode of ***opp*** charge.

It appears that ***mov*** ***ion***s are able, in some way, to ***com*** ***the cir*** .



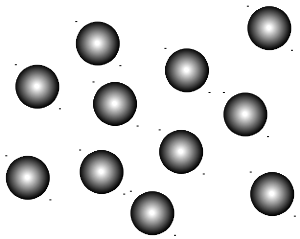
Io ***com*** are the only ***comp*** that can ***con*** ***electricity*** but they are ***chem*** ***changed*** by the process.

Me elements form ***positively charged ions*** by ***los elec*** and are always ***attr*** towards the ***neg*** ***electrode***.

N ***-metal*** elements form ***negatively charged ions*** by ***gain*** ***elec*** and are always ***attr*** towards the ***pos*** ***electrode***.

Single Atoms
(*monatomic elements*)

Very rare - only the ***Noble Gases*** exist as single atoms



He Ne Ar Kr Xe

Conductivity

Solid -	***NO***
Liquid -	***NO***
Solution -	***NO***

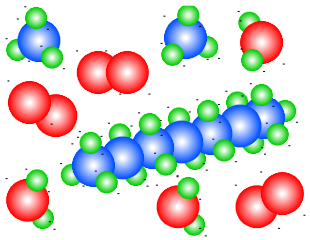
Melting / Boiling

MPt - *extremely low*

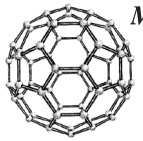
BPt - *extremely low*

All Gases

Covalent Molecular
(*non-metal elements & compounds*)



Small - H_2 O_2 N_2 etc
HCl H_2O NH_3 CH_4



Medium - $C_6H_{12}O_6$
C_6H_{14} C_{60}

Large - starch
polythene etc

Conductivity

Solid -	***NO***
Liquid -	***NO***
Solution -	***NO***

Melting / Boiling

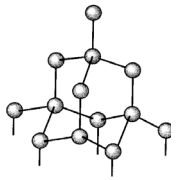
MPt - *very low*

BPt - *very low*

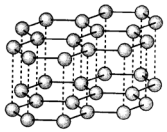
Gases, Liquids, Solids

Covalent Network
(*non-metal elements & compounds*)

Only 3 examples

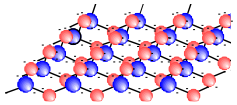


the ***element carbon*** (diamond)



the ***element carbon*** (graphite)

the ***compound*** SiO_2



Conductivity

Solid -	***NO*** *
Liquid -	***NO***
Solution -	***NO***

** except for graphite*

Melting / Boiling

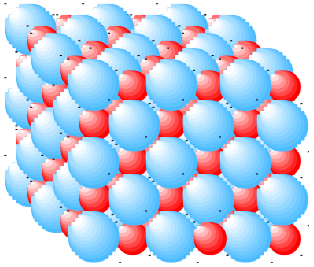
MPt - *extremely high*

BPt - *extremely high*

All Solids

Ionic Network
(*metal/non-metal compounds*)

All metal/non-metal ***compounds***



Na^+ Cl^-
Mg^{2+} O^{2-}
Cu^{2+} $(NO_3^-)_2$

Conductivity

Solid -	***NO***
Molten -	***Yes***
Solution -	***Yes*** *

** if soluble (Data Book)*

Melting / Boiling

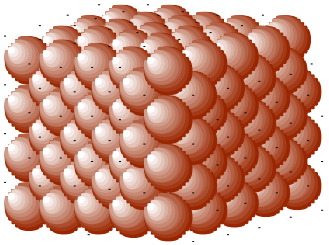
MPt - *extremely high*

BPt - *extremely high*

All Solids

Metallic Network
(*metal elements & alloys*)

All metal/non-metal ***compounds***



Cu Na
Mg Fe
brass

Conductivity

Solid -	***Yes***
Liquid -	***Yes***
Solution -	***insoluble***

Melting / Boiling

MPt - *high to very high*

BPt - *high to very high*

All Solids *(except Hg)*