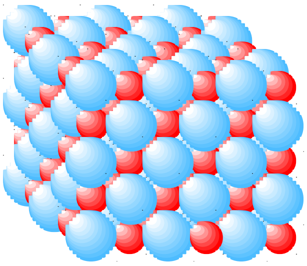
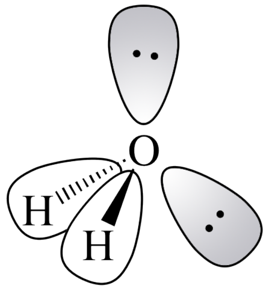
National 5 Chemistry



Unit 1:



Chemical Changes & Structure

Student:

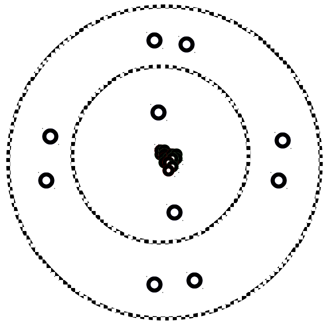
Topic 3

Bonding & Bonding Structures

Topics		Sections	Score	Done	Checked
3.1 *Bonding*	1.	Ionic Bonding			
	2.	Covalent Bonding			
	3.	Molecular Shapes			
	4.	Metallic Bonding			
		Self -Check Questions 1 - 8	Score: /		
3.2 *Bonding Structures*	1.	Single Atoms			
	2.	Covalent Molecules			
	3.	Covalent Networks			
	4.	Ionic Networks			
	5.	Metallic Networks			
		Self -Check Questions 1 - 8	Score: /		
3.3 *Melting Points*	1.	Single Atoms			
	2.	Covalent Molecular			
	3.	Networks			
		Self -Check Questions 1 - 8	Score: /		
3.4 *Conductivity*	1.	Single Atoms			
	2.	Covalent Molecular			
	3.	Networks			
	4.	Summary			
		Self -Check Questions 1 - 8	Score: /		
3.5 *Polarity & Solubility*	1.	Unequal Sharing			
	2.	Water Molecules			
	2.	Solubility			
		Self -Check Questions 1 - 8	Score: /		
Consolidation Work		Consolidation A	Score: /		
		Consolidation B	Score: /		
		Consolidation C	Score: /		
		Consolidation D	Score: /		

End-of-Topic Assessment	Score: %	Grade:

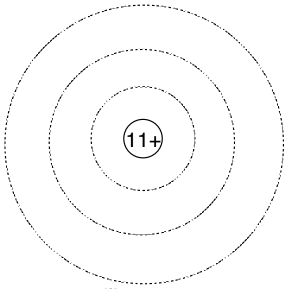
3.1 Bonding



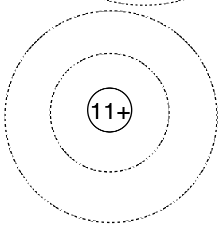
No ***gases*** like ***ne*** are unusual because they do ***not*** seem to need to form bonds. They do ***not*** react. Their ***val*** are zero.

The noble gases also have a ***full ou*** ***shell*** and this seems to be a ***very stable elec*** ***arrangement***.

Ionic Bonding



Na
atom



Na^{+}
ion

Sod is element and very close to ***ne*** in the *Periodic Table*.

Sod atoms cannot change the ***number of pro*** in their nuclei, but they can ***lose one electron*** to have the same ***stable electron arrangement*** as a ***ne*** atom.

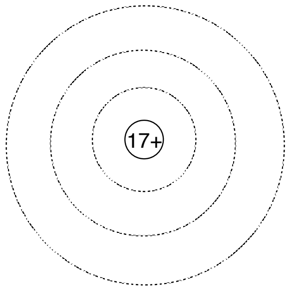
The ***sod*** ***ion*** formed has the *same nucleus* as the sodium atom, but has the ***same elec*** ***arrangement*** as ***ne*** ; the nearest noble gas.

Chl is element and very close to ***ar*** in the *Periodic Table*.

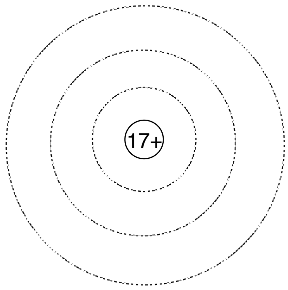
Chl atoms also cannot change the ***number of pro*** in their nuclei, but they can ***gain 1 electron*** to have the same ***stable elec*** ***arrangement*** as an ***ar*** atom.

The ***chl*** ***ion*** formed has the ***same nucleus*** as the chlorine atom, but has the ***same electron arrangement*** as ***ar*** ; the nearest noble gas.

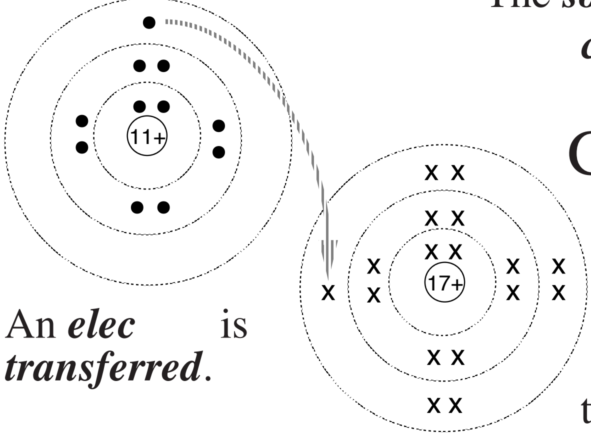
Cl
atom



Cl^{-}
ion



Na

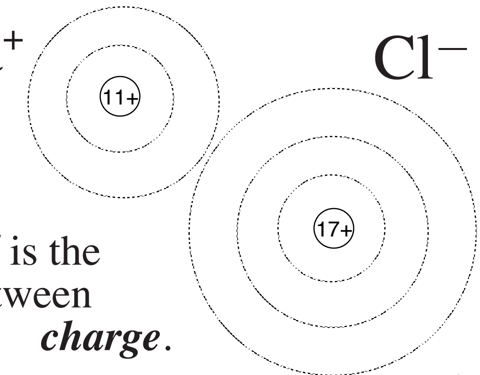


Cl

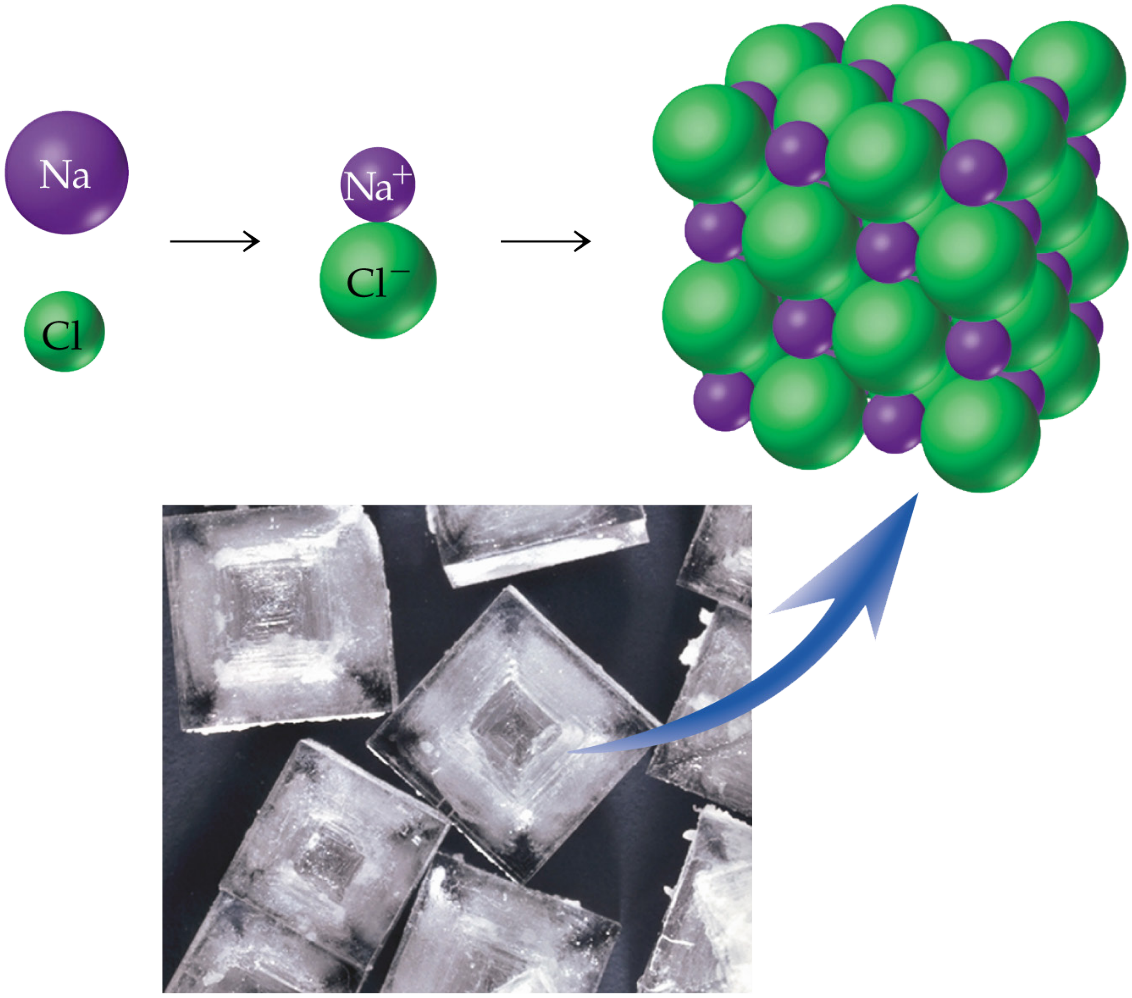
The ***sod*** can only ***lose*** *an electron* because the ***chlorine*** is willing to ***gain*** *the electron*.

An ***elec*** is ***transferred***.

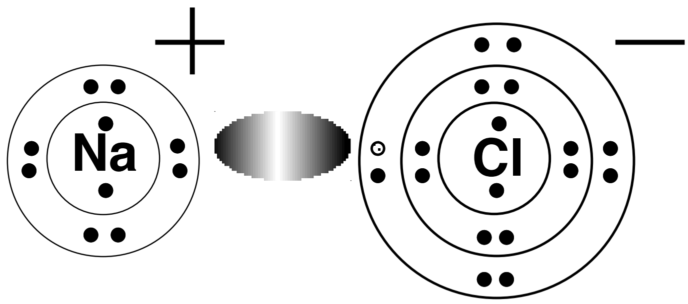
Na^{+} Cl^{-}

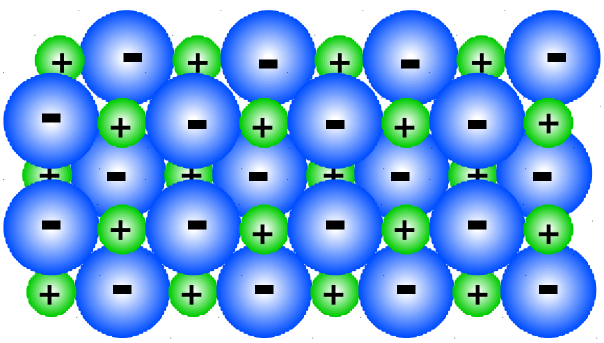


The ***io*** ***bond*** is the ***attr*** between the ions of ***opp*** ***charge***.



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





Sodium ***ion***		
protons	=	+
electrons	=	-
overall	=	

Chlorine ***ion***		
protons	=	+
electrons	=	-
overall	=	

$$Na^{+} Cl^{-}$$

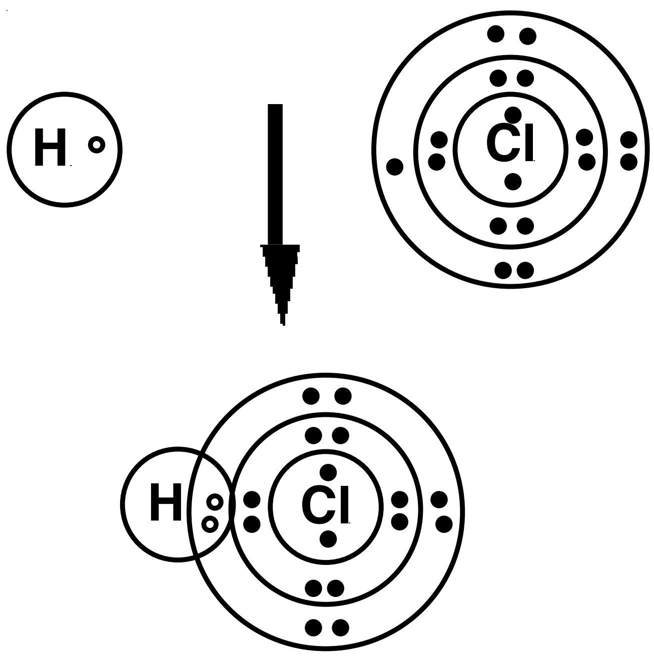
Though ***1 sodium*** atom will give ***1 electron*** to ***1 chlorine*** atom and the formula for sodium chloride will be NaCl, each Na^+ ion will attract several Cl^- ions and vice versa, hence a ***net*** structure.

Covalent Bonding

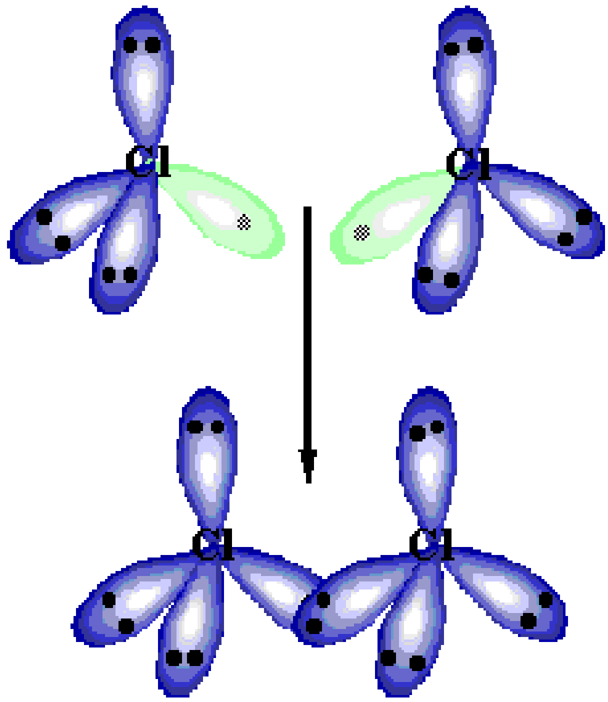
In ***cov*** ***compounds***, both the ***ele*** involved are *usually* ***n*** ***-metal***.

N ***-metal*** atoms prefer to ***ga*** ***electrons***.

For ***both*** atoms to ***ga*** ***extra electrons***, the atoms have to ***share electrons***.



H—Cl



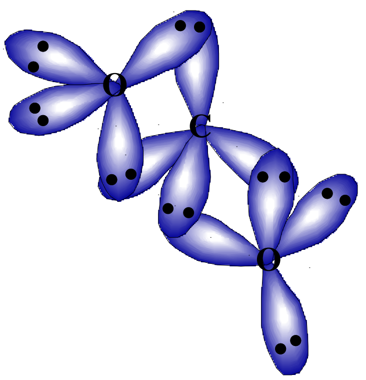
Cl—Cl

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

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

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

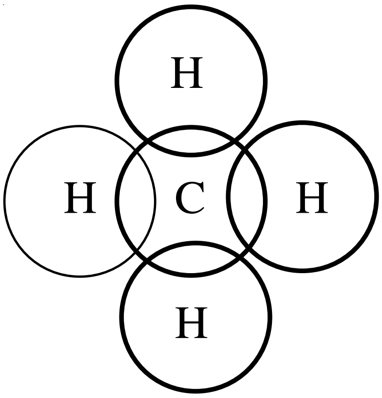
The Covalent Bond is the force of attraction between the two positive nuclei and the shared pair of electrons.



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.

O=C=O

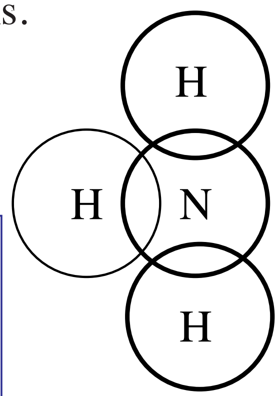
H—C≡N



A ***mol*** of *methane* has ***fo*** ***hydrogen*** atoms joined to ***one car*** atom.

'Dots and crosses' can be used to stand for the ***outer-most elec*** in both types of atoms.

All the electrons are now ***paired*** up.



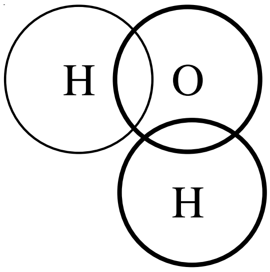
In ***cov*** ***compounds*** atoms join together by ***sha*** ***electrons***.

Only the ***ou*** ***electrons*** are involved.

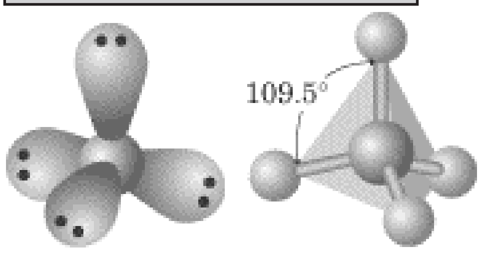
Sha allows odd electrons from different atoms to ***pair up***.

Cov ***compounds*** usually only involves ***n*** ***-metal*** atoms.

The ***sha*** ***pair of electrons*** hold the atoms together.



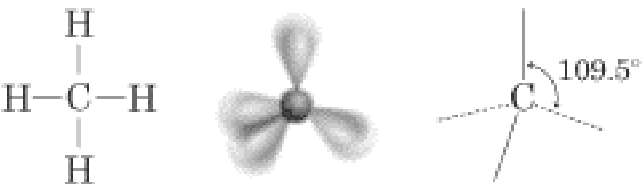
Molecular Shapes

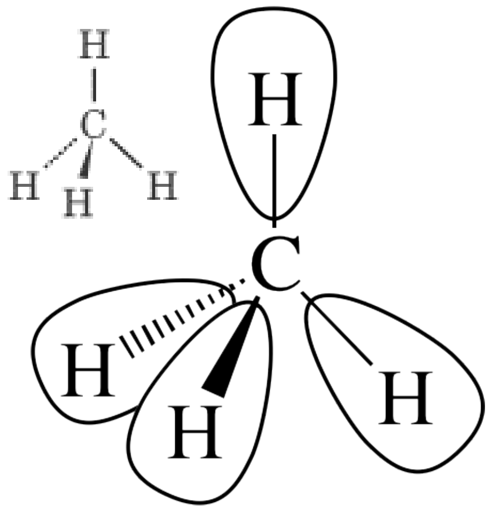


tetrahedral tetrahedral

The ***sh*** of some simple ***mol*** need to be known and understood. Their shapes are all based on the need for the 4 ***orb*** , found in the outer shell of many atoms, to remain *as far apart as possible* to *minimise* ***rep*** . This 3-dimensional arrangement is ***tet*** .

Methane, CH_4

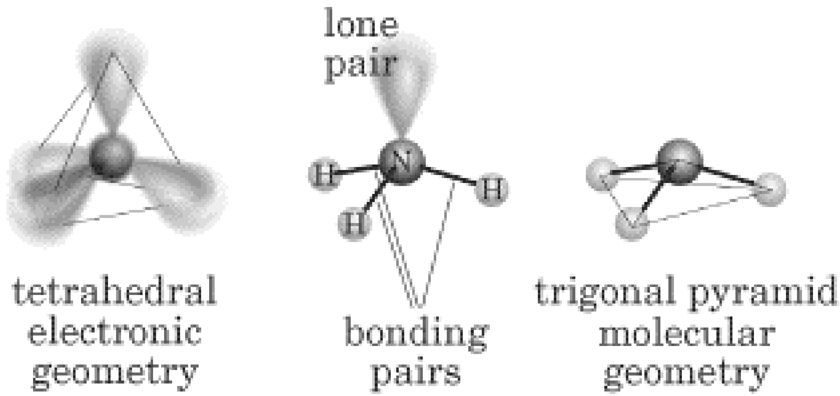


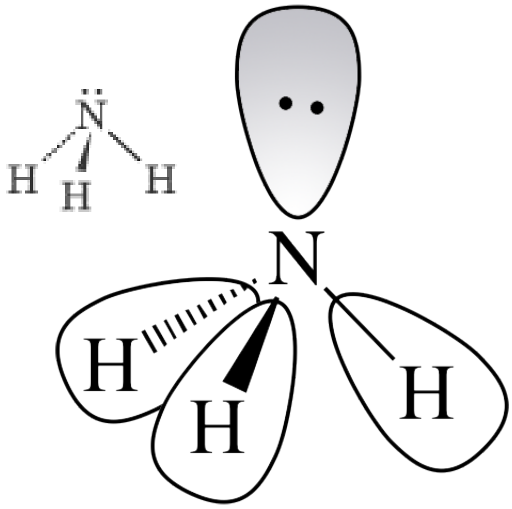


Carbon atoms have ***sin*** ***ele*** in all 4 ***orb*** available to form ***bonding pairs***.

The 4 ***orb*** will be arranged ***tet*** and with 4 hydrogen atoms overlapping with each orbital, the *molecular shape* is also described as ***tet***

Ammonia, NH_3

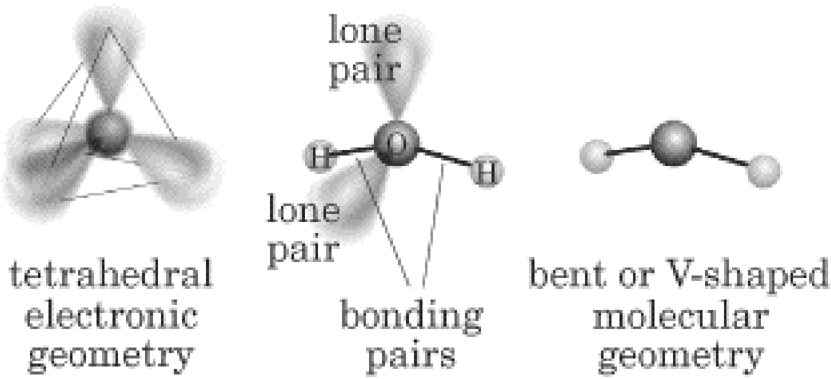


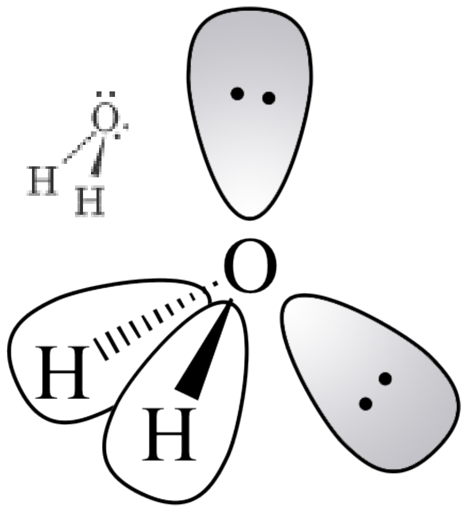


Nitrogen atoms have ***sin*** ***ele*** in 3 of the 4 ***orb*** available to form ***bonding pairs***. The 4th orbital is full - these form a ***lone pair*** or ***non-bonding pair***.

The ***4 orbitals*** will be *arranged* ***tet*** but with *only 3* ***hy*** atoms overlapping with *3 orbitals*, the *molecular shape* will be different and is described as ***trigonal pyramidal***.

Water, H_2O





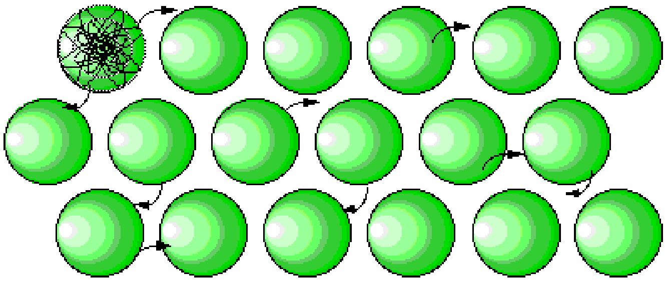
Oxygen atoms have ***sin*** ***ele*** in *2 of the 4 orbitals* available to form ***bonding pairs***. The other 2 orbitals are full - these form ***lone pairs*** or ***non-bonding pairs***.

The *4 orbitals will be arranged* ***tet*** and with *only 2* ***hy*** *atoms* overlapping with 2 orbitals, the *molecular shape* will be different and is described as ***bent*** or ***v-shaped***.

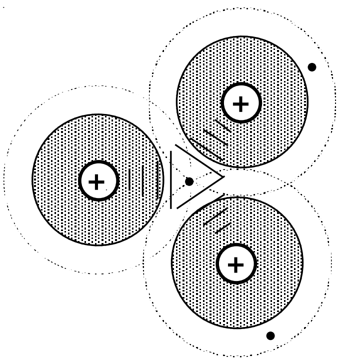
Metallic Bonding

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

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



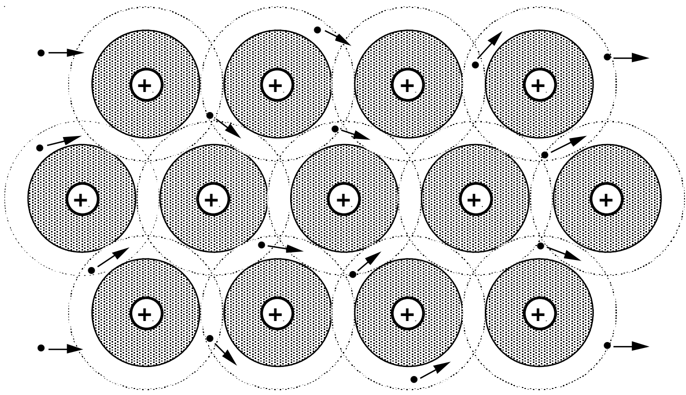
This results in *temporary metal 'ions'* forming which ***immediately*** attract an electron back to *reform the atom*.

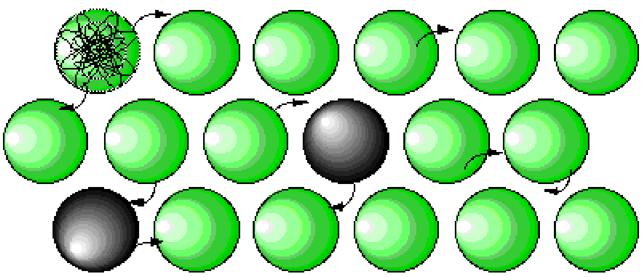


The outer electrons end up *'belonging'* to more than one atom;

the metal 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 ***mix*** of metals (***all***) are usually very stable and would be very difficult to separate again.

Q1. Int2

Which of the following pairs of elements combine to form an ionic compound?

A Lead and fluorine
B Sulphur and oxygen
C Carbon and nitrogen
D Phosphorus and chlorine

Q2. SG

Identify the covalent compound

A zinc chloride
B magnesium sulphate
C lead carbonate
D hydrogen sulphide

Q3. Int2

Metallic bonds are due to

A pairs of electrons being shared equally between atoms
B pairs of electrons being shared unequally between atoms
C the attraction of oppositely charged ions for each other
D the attraction of positively charged ions for delocalised electrons.

Q4. Int2

Atoms of an element form ions with a single positive charge and an electron arrangement of 2,8.

The element is

A fluorine
B lithium
C sodium
D neon

Q5. Int2

The table shows information about an ***ion***.

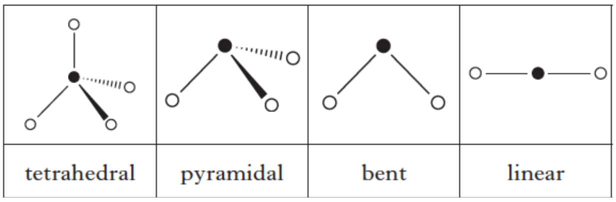
Particle	Number
protons	19
neutrons	20
electrons	18

The charge on the ion is

A 1+
B 1–
C 2+
D 2–

Q6. SC

The shapes and names of some molecules are shown below.



Phosphine is a compound of phosphorus and hydrogen. The formula is PH_3. The shape of a molecule of phosphine is likely to be

A tetrahedral
B pyramidal
C bent
D linear

Q7. Int2

Carbon forms many compounds with other elements such as hydrogen.

a) Draw a diagram to show how the outer electrons are arranged in a molecule of methane, CH_4.

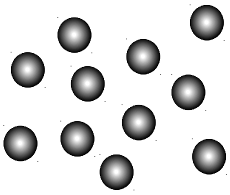
b) Draw a diagram to show the ***shape*** of a molecule of methane, CH_4.

c) Identify the ***two*** elements which react together to form a molecule with the same shape as a methane molecule.

A H
B N
C Si
D Al
E Mg
F O

3.2 Bonding Structures

Single Atoms



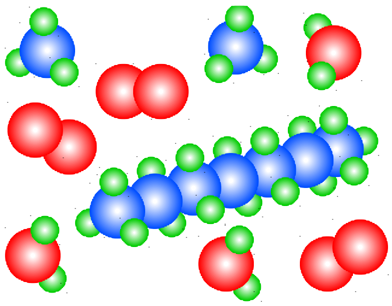
At ***room tem*** , about °C, there are only really substances that we consider as having ***sin at*** structure - sometimes referred to as ***mon*** .

These are the ***No Gases***; He , , , and Xe

They have *extremely* ***we*** *attractions* between the atoms so have *very low* ***den*** - used in ***ba*** and would *distort your* ***vo*** *box*. However, as the *atoms get* ***bi*** , the ***att inc*** so, by the time we reach Xenon, it is dense enough to 'pour' and allow an ***al*** foil boat to float.

If *electrically 'excited'*, these atoms *release* ***li*** with characteristic ***co*** making them suitable for *strip lights* and ***ad*** *signs*.

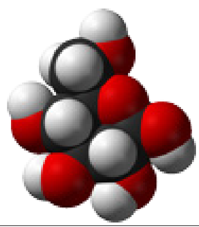
Covalent Molecular



This is undoubtedly the ***largest*** and most *diverse* grouping.

Though they can have *extremely* ***we att between*** the molecules and form very *low density gases* - they can also have ***st*** *enough attractions* to form *liquids* and *solids* as well.

Whilst most are ***com*** , there are a reasonable number of ***ele*** with a ***cov mol*** structure. *For example*;

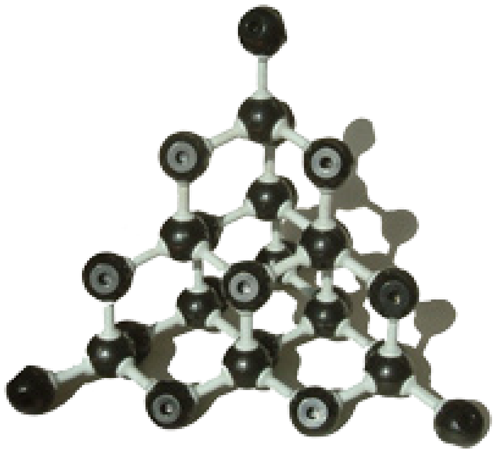
Covalent Molecular Elements	***Covalent Molecular Compounds***
	

Covalent Network

By contrast, this is a much smaller group and you are only likely to meet 6 examples.

Diamond

In this form each ***ca*** atom uses ***all*** of its ***el*** to form ***4 bo*** to different ***ca*** atoms.



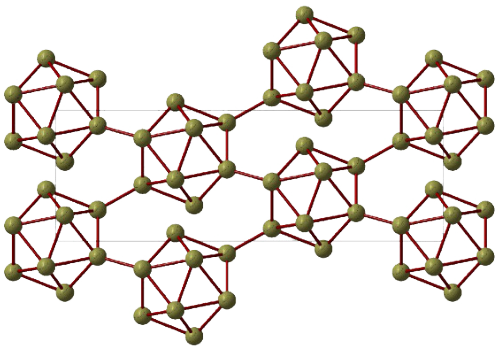
The ***pat*** can be described in two ways: it is called ***tetrahedral*** because the ***ca*** atoms lie at the ***cor*** of a ***pyr*** or ***tetetrahedron***, but you could also call it ***hexagonal*** as there are ***ri*** of carbons.

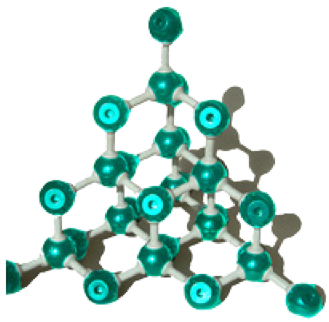
Graphite

In this form each ***ca*** atom uses ***only*** of its ***el*** to form ***3 bo*** to different ***ca*** atoms.

This produces ***fl*** ***sheets*** of ***ca*** atoms joined in ***ri*** of ***6***, ***hex***. The ***fou*** electrons are ***free to mo*** *within* the ***sh*** and produce very weak ***att*** *between* the sheets.

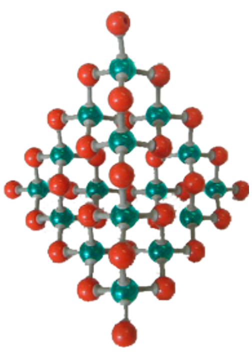
As well as ***carbon***, there are two other ***ele*** that have a ***cov*** ***net*** structure -

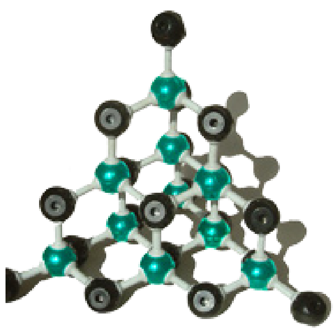




Boron and Silicon

There are two main ***com*** that have a ***cov*** ***net*** structure -



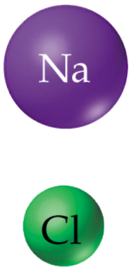


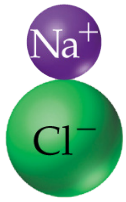
Silicon Dioxide and Silicon Carbide

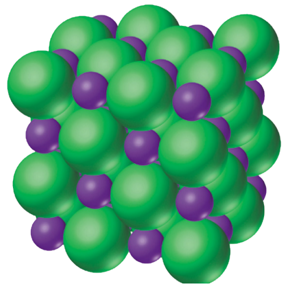
Ionic Network

Ionic Networks are quite straightforward, if we stick to the normal '*rule of thumb*';

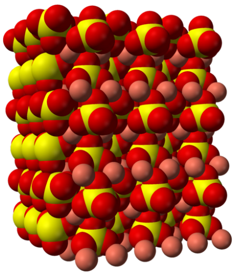
metal / non-metal ➠ ***Ionic Compound*** ➠ ***Ionic Network***

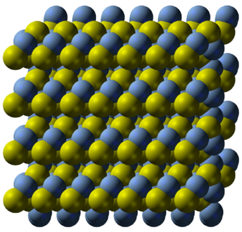


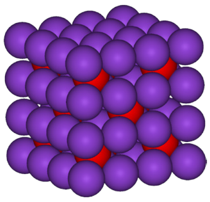


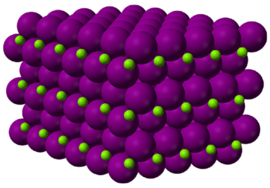


Examples include:-









However, there are ***io net*** which *do not contain any metal ions*

and ***io com*** that *only exist in solutions* so ***don't*** *form networks*

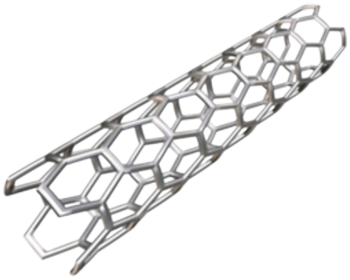
Formula	*Name*
$Cu^{2+}\ SO_4^{2-}{}_{(s)}$	***co (II) sul***
$(K^+)_2\ CO_3^{2-}{}_{(s)}$	***pot car***
$Ni^{2+}\ (I^-)_{2\,(s)}$	***ni (II) io***
$Na^+\ Cl^-{}_{(s)}$	***so ch***
$(K^+)_2\ O^{2-}{}_{(s)}$	***pot ox***
$Mg^{2+}\ (I^-)_{2\,(s)}$	***mag io***
$NH_4^+\ NO_3^-{}_{(s)}$	***amm ni***
$H^+\ Cl^-{}_{(aq)}$	***hy acid***

Subtle differences in the *arrangements of ions* with different ***Io Net*** need not concern us.

Our '*rule of thumb*' works best with ***me*** well over to the ***le*** (in *Periodic Table*) and with ***n -me*** well over to the ***ri*** .

In the end, it is the properties that will confirm structure, not a 'rule of thumb'.

Metallic Network



Met ***Net*** are also quite straightforward, with little difference between ***metal ele*** and ***mix*** ***of metals*** called ***all*** .

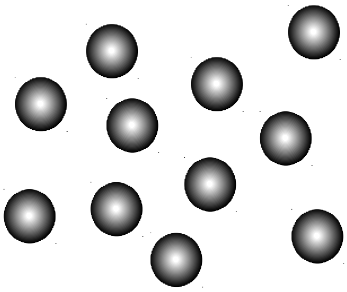
Though they have many ***pro*** in common there are enough ***diff*** to ensure that metals have a *wide variety of uses*.

Name	*Elements*	*Properties*	*Uses*
Mer	Hg	*liquid (low Mpt)* *very dense* *poisonous*	ther bar smoothing felt (hats)
Gold		*melts (low MPt)* *easily shaped (soft)* *corrosion resistant*	co je etc
Tu	W	*hard* *heavy* *very high BPt*	fil in light bulbs
Steel (alloy)	Fe , , ,	*corrosion resistant* *unreactive* *strong*	various types of st steel
Alkali Metals	, Na ,	*very reactive* *low MPt* *low density*	having fun at school!
Nitinol (alloy)	,	*shape memory* *superelasticity*	arterial st artificial ten self-ad clothing

SUMMARY

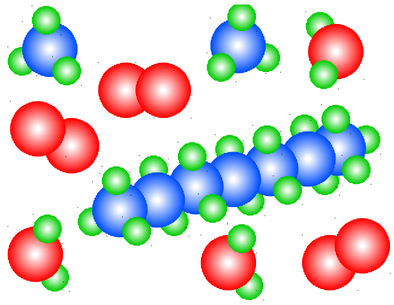
Single Atoms
(monatomic elements)

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

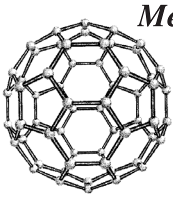


He Ne Ar Kr Xe

Covalent Molecular
(non-metal elements & compounds)



Small - H_2 O_2 N_2 etc
HCl H_2O NH_3 CH_4

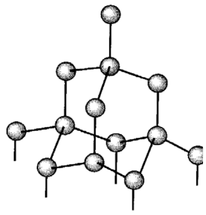


Medium - $C_6H_{12}O_6$
C_6H_{14} C_{60}

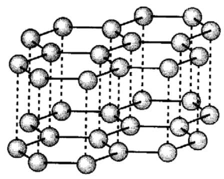
Large - starch
polythene etc

Covalent Network
(non-metal elements & compounds)

Only a few examples

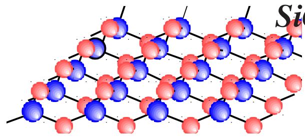


the ***element carbon*** (diamond)



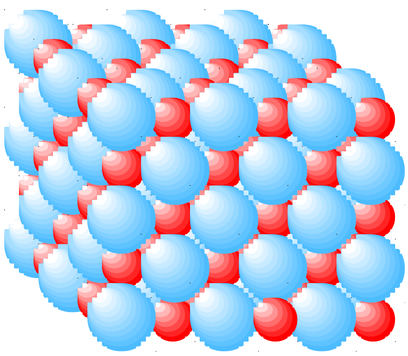
the ***element carbon*** (graphite)

the ***compound*** SiO_2



Ionic Network
(metal/non-metal compound)

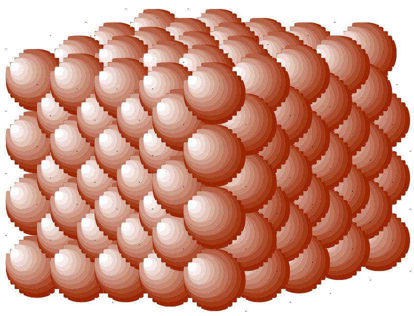
Almost all metal/non-metal ***compounds***



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

Q1. Int 2

An element, **X**, has the following properties.

- It is a gas.
- It is not made up of molecules.
- It does not react with other elements.

Element, **X**, is likely to be in group

A 0

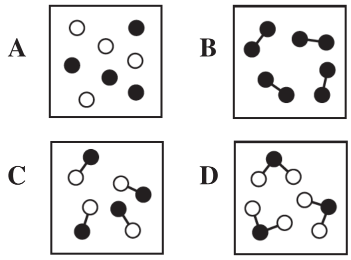
B 1

C 2

D 7

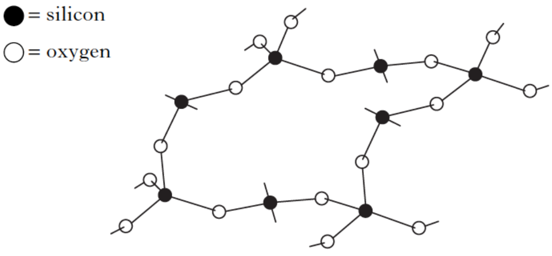
Q2. Int2

Which of the following diagrams represents a ***compound*** made up of ***diatomic*** molecules?



Q3. Int 2

A section of a covalent network is shown below



Write the formula for this covalent network compound ______________

Q4. Int 2

a) To which ***family*** of metals does copper belong?

(You may wish to use page 8 of the data booklet to help you)

____

b) Copper can be used to make other metals such as *brass* and *bronze*.

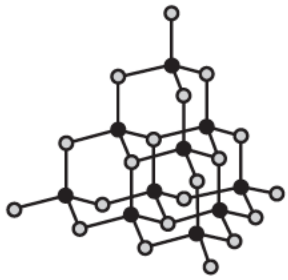
What term is used to describe metals such as *brass* and *bronze*?

____

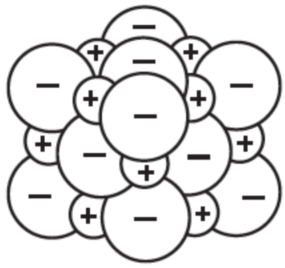
Q5. Int 2

Which of the following diagrams could be used to represent the structure of sodium chloride?

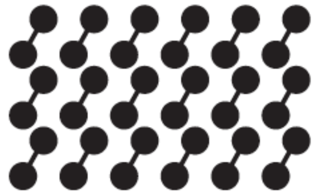
A



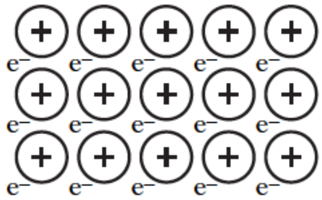
B



C

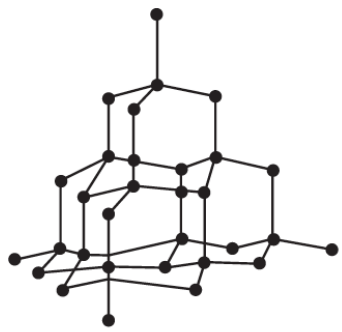


D



Q6. Int 2

The element carbon can exist in the form of diamond. The structure of diamond is shown in the diagram.



a) Name the type of ***bonding*** and ***structure*** present in diamond.

____

3.3 Melting Points

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

Mel ***Point*** tells us the ***temp*** at which a substance changes state from

so ⇔ ***liq*** and

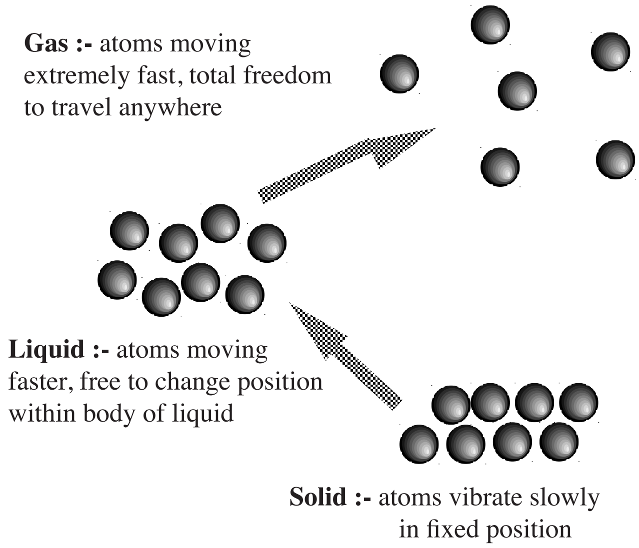
Boi ***Point*** the ***temp*** at which it changes from

liq ⇔ ***gas***.

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

Single Atoms

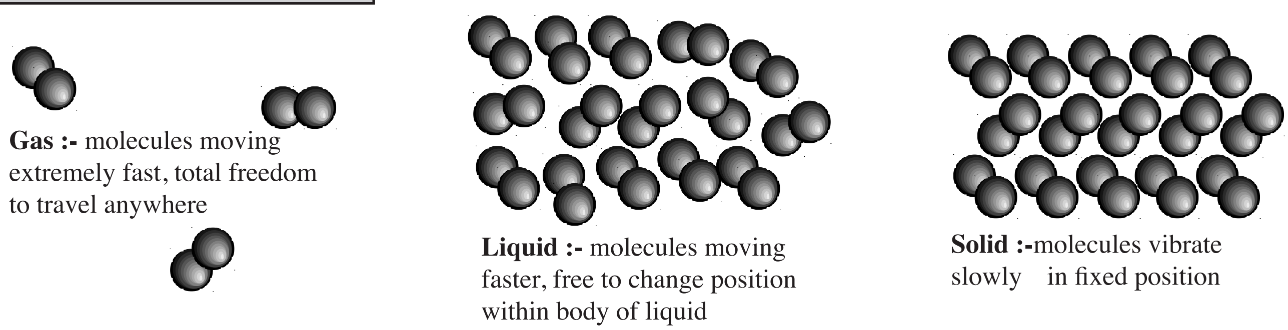
Element	*Mass*	*Mpt (°C)*	*Bpt (°C)*
He			
Ne			
		-189	-186
Kr			
		-112	-107



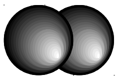
Conclusion: The ***no*** ***gases*** have *extremely low melting and boiling points* :- are ***all*** gases at room temperature.

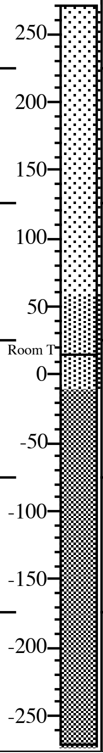
Explanation: Since there are ***no*** formal bonds *between* atoms at all, it requires very little ***en*** to move them ***fa*** and ***fur*** apart. Only very weak attractions.

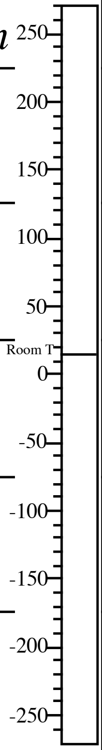
Covalent Molecular

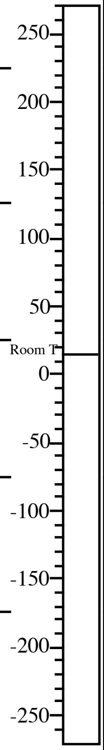


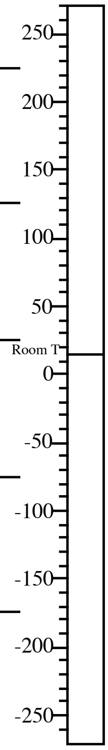
Elements

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

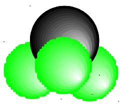
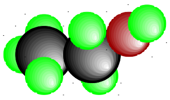


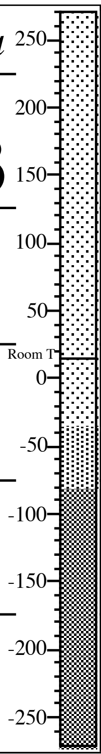


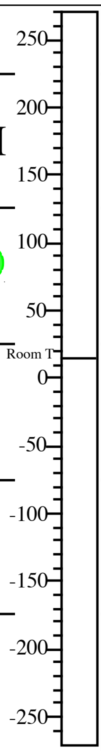


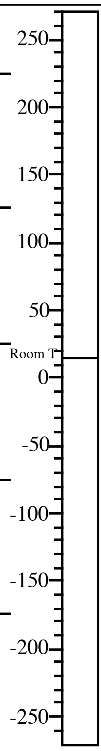


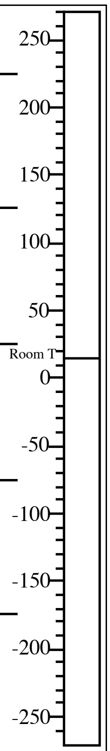
Compounds

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			







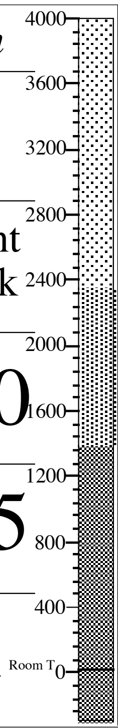


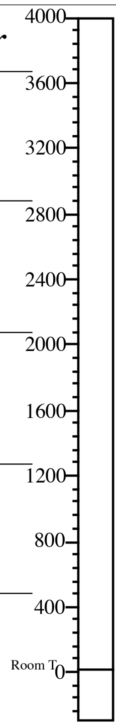
Conclusion: ***Cov*** ***mol*** , depending on ***ma*** , are ***ga*** or ***liq*** mostly. Any ***sol*** are usually *easily melted* (***Low Mp***t)

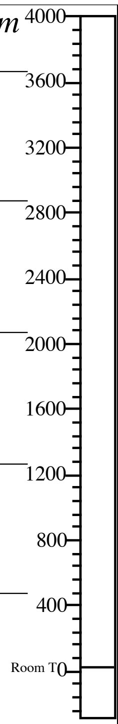
Explanation: Since there is no need to actually break the strong bonds *within* the molecule and forces *between* molecules are usually *weak*, it requires very little ***en*** to move them ***fas*** and ***fur*** apart.

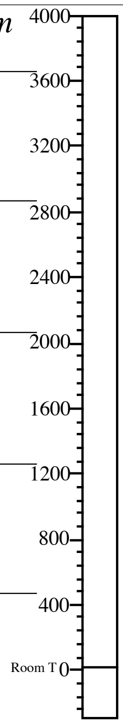
Networks

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

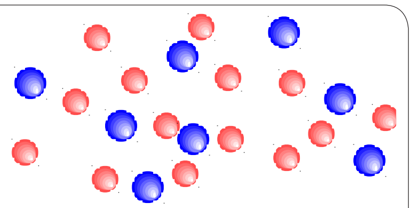




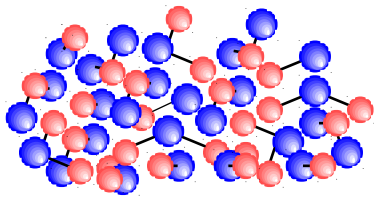




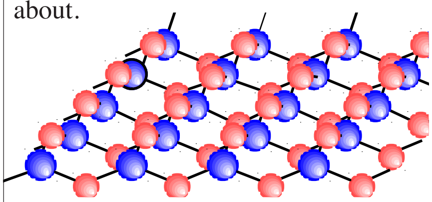
Conclusion: All ***net*** , except the metal ***mer*** , are ***sol*** at room temperature. Most have *very high* Mpt and Bpts.



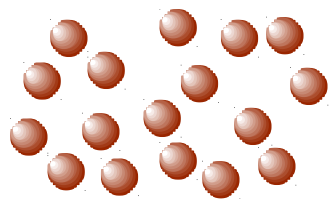
Gas :-all the remaining covalent bonds are broken resulting in individual atoms with total freedom.



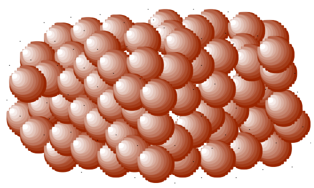
Liquid :-the network gets broken up into smaller pieces which can move about.



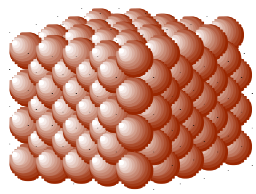
Solid :-many strong covalent bonds hold the atoms firmly in place.



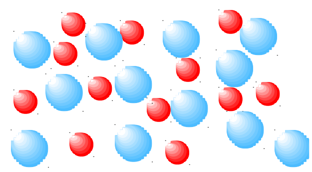
Gas :-all the remaining metallic bonds are broken resulting in individual atoms with total freedom.



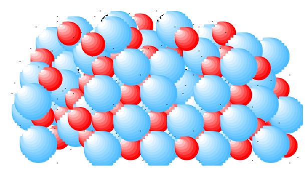
Liquid :-the network gets broken up into smaller pieces which can move about.



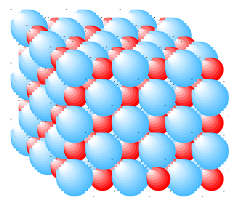
Solid :-many strong metallic bonds hold the atoms firmly in place.



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.

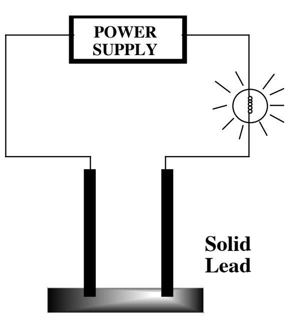
Explanation: Since there ***is*** a need to ***br*** the ***str*** ***bo*** between the particles making up the ***net*** , it requires ***lar*** amounts of ***en*** to move them ***fas*** and ***fur*** apart.

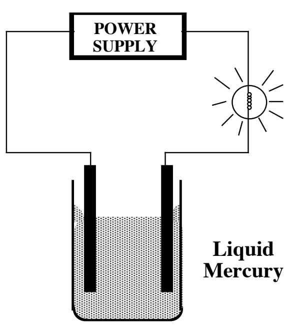
3.4 Conductivity

Metallic Network

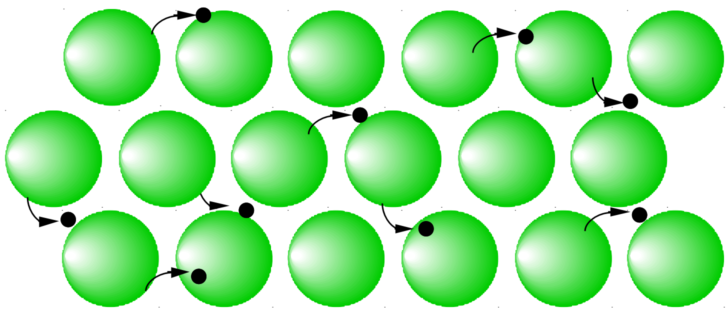
Name	*Element or Alloy*	*State*	*Appearance*	*Conducts?*
Copper				
Duraluminum				
Mercury				
Solder				
Magnesium				
Zinc				

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.*

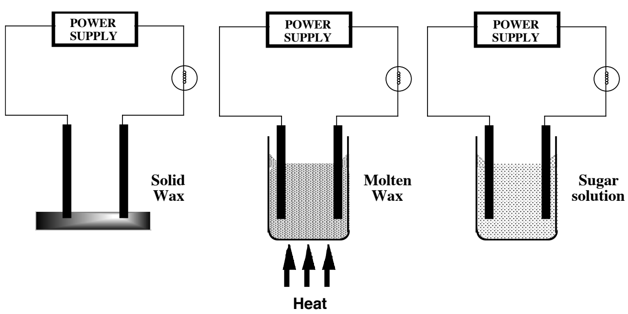
In fact, all parts of an electric circuit; bulb, leads, crocodile clips etc, will be made of ***me*** *and are just a reservoir of* ***del*** ***elec*** *which the battery forces to move in a particular direction.*

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

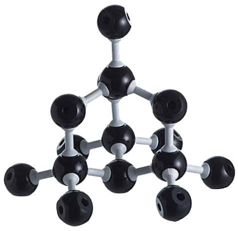
Covalent Network & Molecular

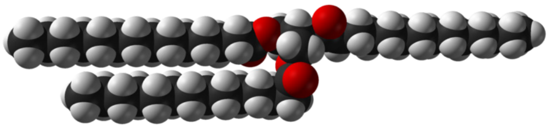
Name	*Network or Molecule*	*Element or Compound*	*State*	*Appearance*	*Conducts?*
Silicon					
Sulphur					
Wax					
Graphite					
Water					
Ethanol					
Carbon Dioxide					

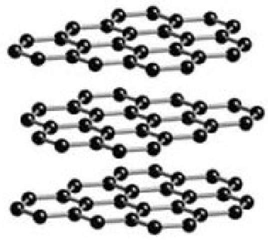
Conclusion: All ***Covalent Networks*** and ***Covalent Molecules*** are ***non - con*** when ***sol*** , ***liq*** or in ***solution***.



Explanation: Once a ***cov*** ***bond*** forms, the ***sh*** ***ele*** are *fixed in place* and will not be available to ***move*** between electrodes to produce an ***el*** ***cur***





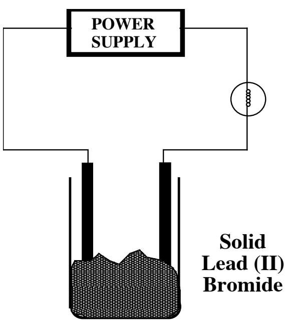


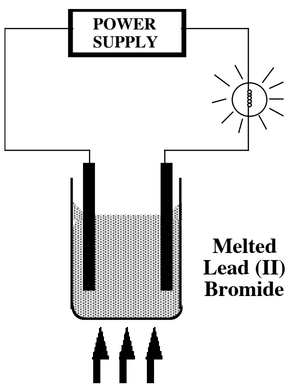
Exception: In the ***gra*** form of *carbon*, only **3** of the **4** ***ele*** are being used for the ***cov*** ***bonds***. The *4th* electron is *free to move* - it is ***del*** - and ***gra*** is similar to a metal in that it ***can con electricity***.

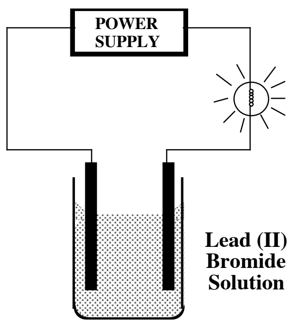
Ionic Network

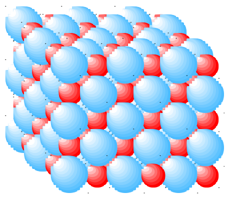
Name	*State*	*Formula*	*Conducts?*
sodium chloride	solid	$Na^+Cl^-_{(s)}$	
lead bromide	liquid	$Pb^{2+}(Br^-)_{2\,(l)}$	
copper (II) sulphate	solid	$Cu^{2+}(Cl^-)_{2\,(s)}$	
copper (II) sulphate	solution	$Cu^{2+}(Cl^-)_{2\,(aq)}$	
potassium iodide	solution	$K^+I^-_{(aq)}$	

Conclusion: 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*** .



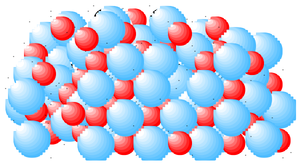






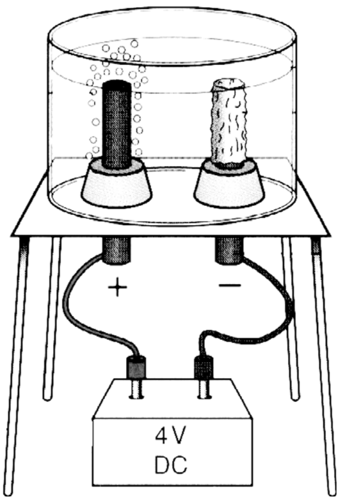
Explanation: Once formed, ***io*** hold onto their ***elec*** very strongly indeed, so there are *never* any ***del*** ***ele*** *free to move* through an ionic solid

However, when ***liq*** or in ***sol*** , 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*** .

Solution	***Formula***	***Reaction at Cathode (negative electrode)***	***Reaction at Anode (positive electrode)***
copper (II) chloride	$Cu^{2+} (Cl^{-})_{2\,(aq)}$		
zinc iodide	$Zn^{2+} (I^{-})_{2\,(aq)}$		



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***.

Ele *flow through metal wires* to the ***Cat*** (***neg*** *electrode*). These ***ele*** are *effectively removed* by ***me*** ***ions*** which are ***converted*** back into ***at*** in the process.

Meanwhile ***ele*** *appear* at the ***An*** (***pos*** *electrode*) as ***n*** ***-me*** ***ions*** *lose electrons* and are ***converted*** back into ***at*** . These ***ele*** *flow back to the battery through the wire*. It is as if electrons flow round the circuit as normal but, in reality, ***only ions move through the solution*** - not electrons.

Electrolysis - is the name given to the process of ***splitting apart*** an ***ionic compound*** using ***electricity***.

Electrolytes - are ***chemicals*** that can be used to ***complete an electrical circuit*** - effectively ***ionic solutions***.

Electrolytes:

- Conduct energy
- Regulate fluid balance
- Transport nutrients
- Support proper muscle function
- Support mental function
- Help convert calories into energy
- Regulate pH
- & much, much more

Electrolytes (ionic solutions) play a number of important roles in maintaining various processes within the body.

During sport, for example, electrolytes are lost through sweating and must be regularly topped up to prevent a deterioration in performance - particularly 'bad decision making' late in games. Sportspeople now try and 'top up' electrolytes during games.

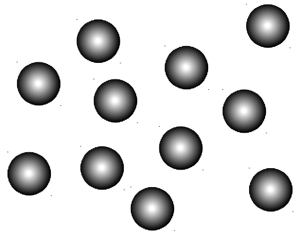
Many ***io*** ***com*** have *characteristic* ***col*** due to the presence of particular ions:

Colourless ions	*Coloured ion name*	*Coloured ion formula*	*Colour observed*
		Cu^{2+}	
		Ni^{2+}	
	dichromate		
	chromate		
	iron (II)		
		Fe^{3+}	
		MnO_4^-	
	cobalt (II)		

Compounds containing ***Tran*** ***Metal ions*** are usually coloured.

Single Atoms
(monatomic elements)

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



He Ne Ar Kr Xe

Conductivity

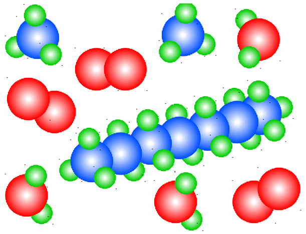
Solid - ***NO***
Liquid - ***NO***
Solution - ***NO***

Melting / Boiling

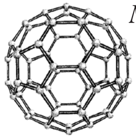
MPt - *extremely low*
BPt - *extremely low*

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***

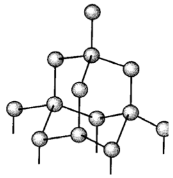
Melting / Boiling

MPt - *very low*
BPt - *very low*

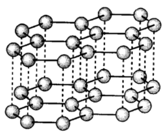
Gases, Liquids, Solids

Covalent Network
(non-metal elements & compounds)

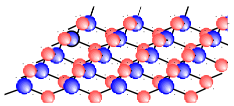
Only 3 examples



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



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



the ***compound*** SiO_2

Conductivity

Solid - ***NO*** *
Liquid - ***NO***
Solution - ***NO***
*** except for graphite***

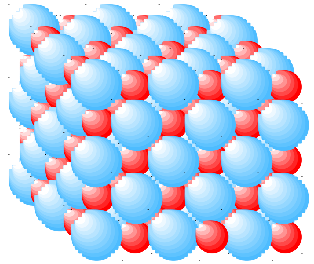
Melting / Boiling

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)***

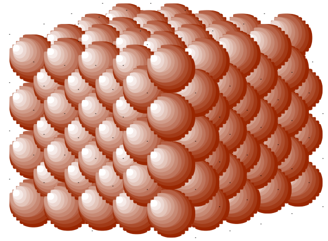
Melting / Boiling

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)***

Q1. Int2

Solid ionic compounds do not conduct electricity because

A the ions are not free to move

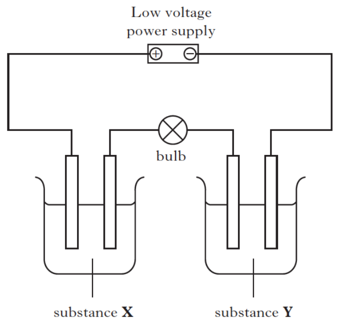
B the electrons are not free to move

C solid substances never conduct electricity

D there are no charged particles in ionic compounds

Q2. SC

Several conductivity experiments were carried out using the apparatus below.

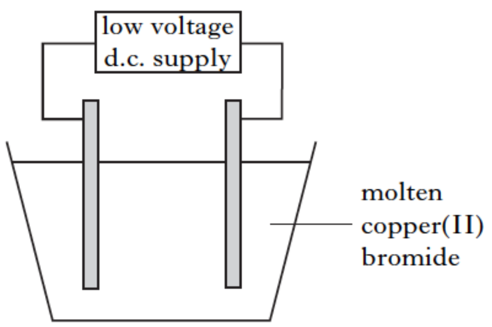


Experiment	Substance X	Substance Y
A	glucose solution	sodium chloride solution
B	copper nitrate solution	solid potassium nitrate
C	molten tin	liquid mercury
D	potassium sulphate solution	liquid hexane
E	lithium chloride solution	molten nickel bromide

Identify the two experiments in which the bulb would light.

____

Q3. Int2



During the electrolysis of molten copper (II) bromide

A copper atoms lose electrons to form copper ions

B bromine molecules gain electrons to form bromide ions

C bromide ions gain electrons to form bromine molecules

D copper ions gain electrons to form copper atoms.

Q4. SC

The table contains information about some substances.

Substance	Melting point/°C	Boiling point/°C	Conducts as a solid	Conducts as a liquid
A	−7	59	no	no
B	1492	2897	yes	yes
C	1407	2357	no	no
D	606	1305	no	yes
E	−39	357	yes	yes
F	−78	−33	no	no

a) Identify the substance which is a gas at 0 °C.

____

b) Identify the ***two*** substances which exist as molecules.

____

Q5. Int2

Glass is made from the chemical silica, SiO_2 , which is covalently bonded and has a melting point of 1700 °C

Carbon dioxide, CO_2 , is also covalently bonded but has a melting point of -78 °C.

a) What does the melting point of silica suggest about its ***structure***?

____

b) What does the melting point of carbon dioxide suggest about its ***structure***?

____

Q6. Int 2

The properties of a substance depend on its type of bonding and structure.

Here are four types of bonding and structure.

Discrete covalent molecular	**Covalent network**	**Ionic lattice**	**Metallic lattice**

a) Which type of bonding structure is missing?

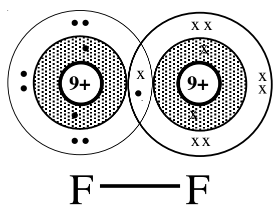
____

b) Complete the table to match up each type of bonding and structure with its properties.

Bonding and structure type	Properties
	do not conduct electricity and have high melting points
	have high melting points and conduct electricity when liquid but not when solid
	conduct electricity when solid and have a wide range of melting points
	do not conduct electricity and have low melting points

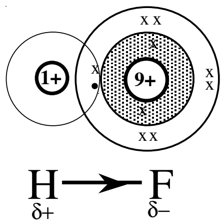
3.5 Polarity & Solubility

Unequal Sharing



In a ***mol*** like F_2, both atoms are ***exactly the sa*** . They have ***equ*** ***attraction*** for the *bonding pair* of ***elec*** .

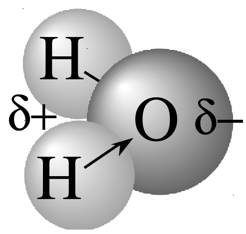
The ***elec*** are ***equ*** ***sha*** . This is a ***pure cov*** bond.



A ***fluo*** atom has a ***str*** ***attraction*** for ***elec*** than a ***hydr*** atom, The *bonding pair* is ***pulled clo*** to the ***fluo*** .

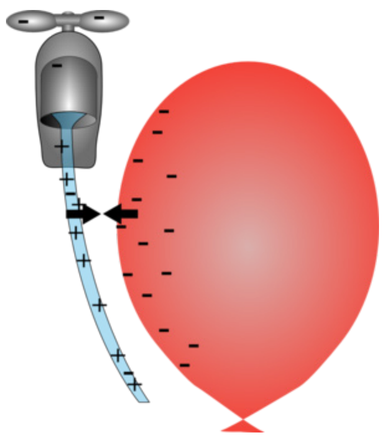
The *fluorine* becomes ***sligh*** ***neg*** (δ–), while the *hydrogen* becomes ***sligh*** ***pos*** (δ+). This is a ***polar cov*** bond.

Water Molecules

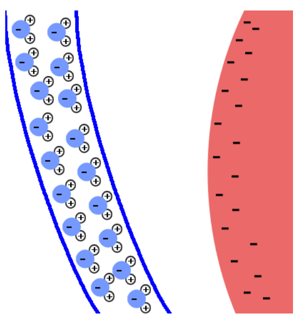


A ***wa*** molecule is a good example of a ***pol*** ***molecule***.

It is ***pol*** , because the ***ox*** atom (***8 pro***) can attract electrons more strongly than the ***hy*** atoms (***1 pro***), making the O—H bonds ***pol*** ***cov*** .



Importantly, the ***shape*** of the water molecule means that *one side* has a ***sli*** ***neg*** ***charge*** while the *other side* is ***sli*** ***pos*** . This makes water a ***polar molecule***.

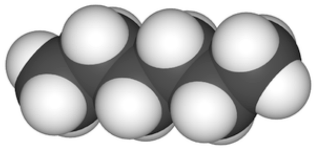


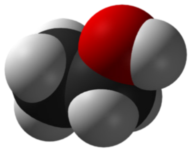
The ***wat*** ***mol*** will flip round so that their ***pos*** side is closer to the ***neg*** charged balloon. This will make the ***att*** even ***str*** , causing the stream of water to deflect ***tow*** the balloon.

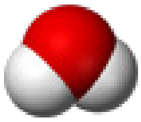
Solubility There is a '*rule of thumb*' in ***chem*** that states that '***like dissolves like***'.

In other words, *chemicals* (***sol***) will dissolve in *liquids* (***sol*** ***)*** that are *very similar* to themselves in terms of the kind of ***att*** that exist between them.

3 Solvents:

hexane  *pure covalent*

ethanol  *polar covalent*

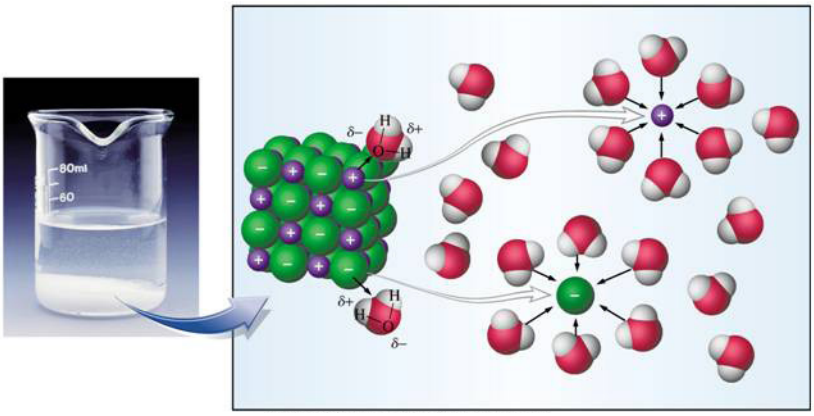
water  *strongly polar covalent*

Solute	***Hexane (pure)***	***Ethanol (polar)***	***Water (very polar)***
Wax *(pure covalent solid)*			
Glucose *(polar covalent solid)*			
Bromoethane *(polar covalent liquid)*			
White Spirit *(pure covalent liquid)*			
Copper (II) sulphate *(ionic solid)*			

Predictably, ***pure cov*** ***solutes*** tend to only *dissolve* in ***pure cov*** ***sol*** .

Polar cov ***solutes*** can *dissolve* in any of the solvents - it will ***depend on how strongly po*** they are.

The ***att*** set up by ***water molecules*** can be *strong enough* to overcome the ***io*** ***att*** in certain ***io*** ***com*** causing them to break up and ***diss*** .



Individually, the polar water attractions are not as strong as the ionic attractions ...

... but several water molecules will surround each ion and can succeed in pulling it away from the Ionic Network causing it to dissolve.

'Theoretical' Chemistry can provide us with rules which allow us to predict the properties of a substance if we know it's bonding and structure.

Bonding & Structure ⇛ ***Properties***

However, we are a Practical subject for good reason. In reality, it is the properties of a substance that often provide us with the information needed to predict it's bonding and structure

Properties ⇛ ***Bonding & Structure***

For example, if a substance

dissolves in water ⇛ we deduce ***strongly polar covalent*** or ***ionic***

dissolves in ethanol ⇛ we deduce ***polar covalent***

dissolves in bromoethane ⇛ we deduce ***weakly polar covalent*** or ***pure covalent***

dissolves in hexane ⇛ we deduce ***pure covalent*** or ***very weakly polar covalent***

*Whenever, possible we would also want to measure **Melting Points & Boiling Points** as well as **Conductivity** etc.*

Q1 Int2

The table gives information about the attraction some atoms have for bonded electrons.

Atom	Attraction for electrons
C	least
I	↓
Br	↓
Cl	↓
F	greatest

Which of the following bonds is the least polar?

A C — F

B C — Cl

C C — Br

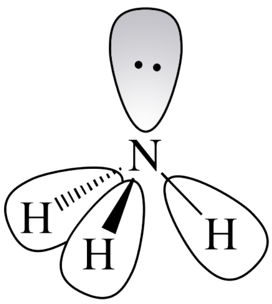
D C — I

Q2. KHS

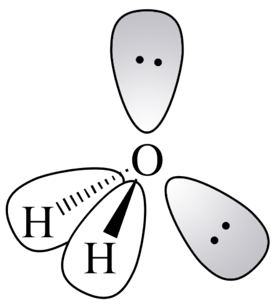
The table contains information about the attractions of some atoms for bonded electrons.

Atom	Relative attraction for bonded electrons
H	2·2
C	2·5
N	3·0
O	3·5

Ammonia and water are two covalent molecules.



ammonia



water

a) In both these molecules the electrons are not shared equally. What name is given to these types of bonds?

____

b) In both these molecules there are electrons not used for bonding. What name is given to these electrons?

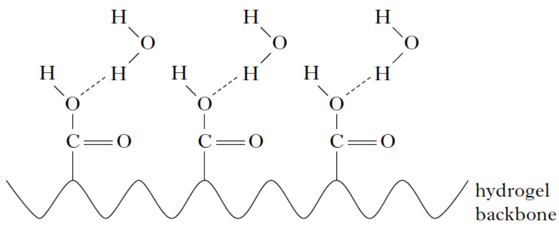
____

c) Both these molecules have partial charges. Using the symbols δ+ and δ- , mark on the molecules above the positions of these charges on each.

Q3. Int2

Synthetic nappies contain hydrogel polymers which attract and absorb water molecules.

The diagram below shows how water molecules are attracted to the hydrogel.



a) What type of bonding is present in water molecules?

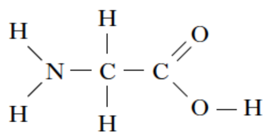
____

b) What attracts the water molecules to the hydrogel.

____

Q4. Int2

Some of the bonds in an amino acid molecule are polar covalent.



The table contains information about the attraction of some atoms for bonded electrons.

Atom	Relative attraction for bonded electrons
H	2·2
C	2·5
N	3·0
O	3·5

The most polar bond in the amino acid molecule will be

A C — H

B N — H

C O — H

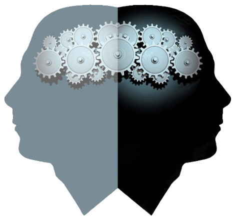
D C — O

Q5 KHS

With the help of your data book, decide which of the following ionic compounds would dissolve in water.

potassium iodide
lead(II) iodide
barium sulphate
aluminium hydroxide

Knowledge Met in this Topic



Bonding

- Only the noble gases exist as ***single atoms*** not permanently bonded to other atoms.
- In all other substances, atoms are held together by ***bonds***.
- All bonds rely on the attraction between ***positive*** and ***negative*** charge.
- Bonding usually only involves ***unpaired electrons*** in the ***outer shell***.
- All bonding involves ***orbitals*** in the ***outer shell*** coming close enough to ***overlap***
- Compounds of ***metals*** and *non-metals* usually result in ***electrons being transferred - ionic bonding***.
- Substances containing only ***non-metals*** usually result in ***electrons being shared*** - held together by ***covalent bonds***.

Ionic Bonding

- ***Metal*** atoms ***lose electrons*** to form more stable ***positively*** charged ions (***cations***),

  e.g. Na^+ , Mg^{2+} , Al^{3+} , Sn^{4+}.
- ***Non-metal*** atoms ***gain electrons*** to form more stable ***negatively*** charged ions (***anions***),

  e.g. Cl^- , O^{2-} , P^{3-}
- ***Non-metal*** atoms often form molecules which ***gain electrons*** to form more stable ***negatively*** charged ions (***anions***),

  e.g. NO_3^-. , CO_3^{2-} , PO_4^{3-}
- Very rarely, ***non-metal*** atoms form molecules which ***lose electrons*** to form more stable ***positively*** charged ions (***cations***),

  e.g. NH_4^+.
- An ***ionic bond*** is the force of ***attraction*** between ***oppositely charged ions***.
- An ion can form attractions with ***many*** (6 - 8) oppositively charged ions.

Covalent Bonding

- When atoms bond covalently, they ***share electrons*** in such a way as to obtain the same stable electron arrangement as the ***nearest noble gas***.
- A covalent bond is the result of ***two positive nuclei*** attracting the same ***shared pair of electrons*** in overlapping orbitals
- Sometimes electrons are ***not*** shared equally - resulting in ***polar covalent bonds***.

Metallic Bonding

- When metal atoms bond they overlap orbitals and ***share/lose electrons*** to become more stable
- This results in ***delocalised electrons*** *constantly moving* between the orbitals of metal atoms
- A metallic bond is the result of ***many positive nuclei*** attracting the same ***delocalised electrons*** as they move between atoms
- Metallic bonding can also be described as '*a sea of electrons drifting amongst temporary positive ions*'

Single Atoms

- Only the ***Noble Gases*** exist as single atoms at room temperature
- ***Attractions*** *between* single atoms are ***extremely weak*** resulting in ***very low Melting & Boiling Points***
- Other substances can be broken down into single atoms (*atomised*) but only at extremely high temperatures.
- Substances made up of single atoms (*monatomic*) ***cannot conduct electricity***

Covalent Molecules

- Molecules have a fixed number of atoms bonded together by shared electrons
- Molecules can be all sizes:

small - *diatomic* - H_2 , HCl , CO
triatomic - H_2O , SCl_2 , CO_2 etc

medium - *glucose* - $C_6H_{12}O_6$
fat - $C_{57}H_{110}O_9$

large - *starch*
protein

- ***Attractions*** *between* molecules are ***usually weak*** resulting in ***low Melting & Boiling Points*** but attractions increase with molecular size
- ***Attractions*** *between* molecules with ***polar covalent bonds*** can be ***stronger***
- Substances made up of molecules ***cannot conduct electricity***
- Some metals from the middle of the Periodic Table can form covalent molecules

  eg $BeCl_2$, $AlCl_3$

  as shown by their ***lower than expected Melting & Boiling Points*** and states at room temperature

Molecular Shapes

- Most central atoms in molecules have ***4 pairs of electrons*** surrounding them.
- To minimise repulsions, the electron pairs will arrange themselves ***tetrahedrally***
- The shape of a molecule will depend on how many of the electron pairs are being used to bond to other atoms.

eg *4 bonds* - CH_4 - *tetrahedral* shape
3 bonds - NH_3 - *pyramid* shape
2 bonds - OH_2 - *bent* shape
1 bond - FH - *linear* shape

Ionic Networks

- Substances made up of molecules ***cannot conduct electricity***
- A ***network*** (sometimes called a ***lattice***) is a very regular arrangement
- All ionic compounds are solids at room temperature
- Ionic compoundsdo ***not conduct*** electricity when ***solid*** because the ions are not free to move.
- Ionic compounds do ***conduct*** electricity when ***molten*** or ***dissolved*** because the ions are free to move.
- When ionic compounds conduct, ***chemical changes*** take place at the electrodes.
- ***Metals*** are produced at the ***negativ***e electrode, ***non-metals*** at the ***positive***.

Covalent Networks

- Covalent ***elements***, such as *silicon* and *carbon*, exist as giant ***networks*** of atoms.
- Covalent ***compounds***, such as *silica* (SiO_2) and *carborundum (SiC)*, exist as giant ***networks*** of atoms.
- All covalent networks are ***solids*** at room temperature
- Covalent networks, except *graphite*, do not conduct electricity in any state as they have ***no delocalised electrons*** and ***no charged particles*** are present.
- *Graphite* has some ***delocalised electrons*** which allows *graphite* to conduct electricity.

Metallic Networks

- Metallic ***elements***, such as *silver* and *copper*, exist as giant ***networks*** of atoms.
- Metallic ***alloys***, such as *bronze (Cu & Sn)* and *brass (Cu & Zn)*, exist as giant ***networks*** of atoms.

- All metallic networks, with the exception of *mercury*, are ***solids*** at room temperature
- Metallic networks ***all conduct electricity*** due to the presence of ***delocalised electrons***.

Coloured Ions

- Whilst most ionic compounds are colourless there are some which are coloured
- Most ***Transition Metals*** produce *compounds* with *characteristic* **colours**

  eg compounds containing Cu^{2+} *are always blue in colour*
- Some ***Transition Metals*** have several ions each with *characteristic* **colours**

  eg Co^{2+} *ions are pink in colour*
  Co^{3+} *ions are green in colour*

  Fe^{2+} *ions are pale blue/green in colour*
  Fe^{3+} *ions are rust in colour*

Solubility

- ***Covalent Molecule***s tend to dissolve in ***pure covalent solvents***
- ***Polar Covalent Molecule***s tend to dissolve in ***polar covalent solvents*** such as ***water***.
- Some ***Ionic Compounds*** can also dissolve in ***water***

CONSOLIDATION QUESTIONS A

Q1. SC

A nitrogen molecule is held together by three covalent bonds.

(Circle) the correct words to complete the sentence.

In a covalent bond the atoms are held together by the

attraction between the positive { ***electrons / neutrons / protons*** } *and the*

shared pair of negative { ***electrons / neutrons / protons*** } .

Q2. Int2

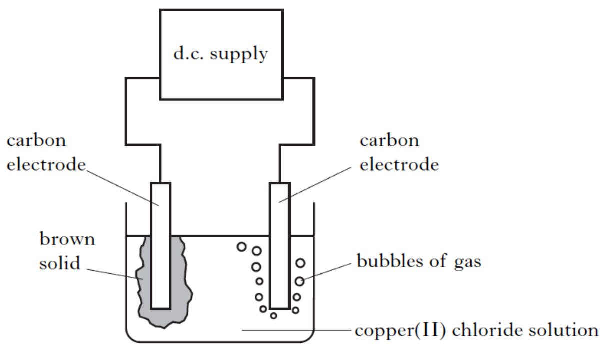
Metals can be extracted from metal compounds by heat alone, heating with carbon or by *electrolysis*.

a) What is meant by the term ***electrolysis***?

____

____

b) A solution of copper (II) chloride was electrolysed.



i) Complete the table by adding the charge for each electrode

Observation at ____________ electrode	**Observation at ____________ electrode**
bubbles of gas	brown solid formed

ii) How could the gas be identified?

____

____

Q3. Int2

Metallic bonding is a force of attraction between

- A positive ions and delocalised electrons
- B negative ions and delocalised electrons
- C negative ions and positive ions
- D a shared pair of electrons and two nuclei.

Q4. SG

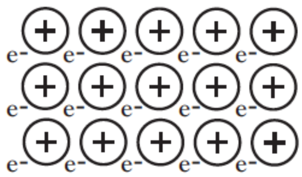
Identify the covalent compound

- **A** zinc chloride
- **B** magnesium sulphate
- **C** lead carbonate
- **D** hydrogen sulphide

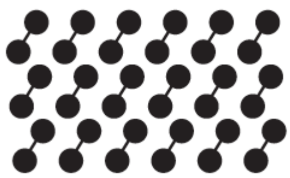
Q5. Int2

Which of the following diagrams could be used to represent the structure of a metal?

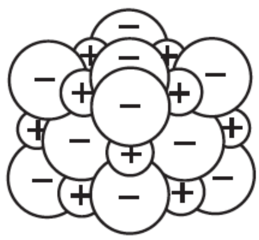
A



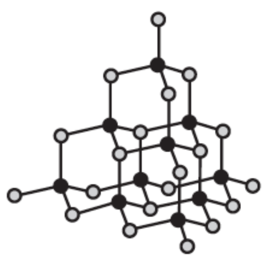
B



C



D



CONSOLIDATION QUESTIONS B

Q1. SG

Identify the covalent compound

A zinc chloride
B magnesium sulphate
C lead carbonate
D hydrogen sulphide

Q2. Int2

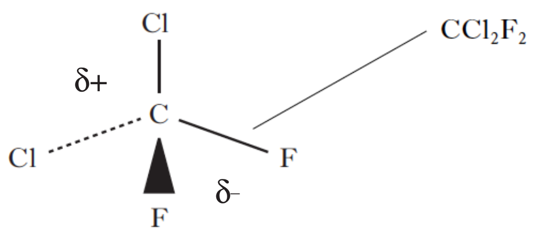
Which line in the table shows the properties of an ionic compound?

	Melting point (°C)	Boiling point (°C)	Conducts electricity?	
			Solid	Liquid
A	181	1347	yes	yes
B	–95	69	no	no
C	686	1330	no	yes
D	1700	2230	no	no

Q3. Int2

Chlorofluorocarbons (CFCs) are a family of compounds which are highly effective as refrigerants and aerosol propellants. However, they are now known to damage the ozone layer.

One example of a CFC molecule is shown.



a) What term is used to describe the ***shape*** of this molecule?

____

b) What type of bonding is found in this molecule?

____

c) What does the symbol δ+ mean?

____

d) Which atom in this molecule has the strongest attraction for electrons?

____

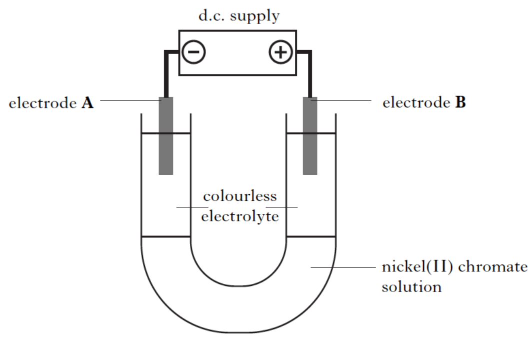
Q4. Int2

Which of the following elements has similar properties to argon?

A Fluorine
B Krypton
C Potassium
D Zinc

Q5. SC

A student set up the following experiment to investigate the colour of ions in nickel(II) chromate solution.



The results are shown.

Green colour moves towards electrode **A**
Yellow colour moves towards electrode **B**

a) What is meant by d.c. supply ?

____

b) Why ***must*** a d.c. supply be used ?

____

c) What is meant by the term *electrolyte* ?

____

d) State the colour of the nickel (II) ions ?

____

CONSOLIDATION QUESTIONS C

Q1. SG

Identify the covalent compound

A zinc chloride

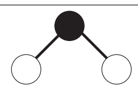
B magnesium sulphate

C lead carbonate

D hydrogen sulphide

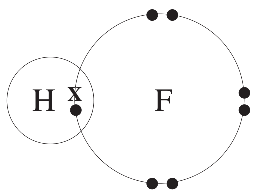
Q2. Int2

Information on some two-element molecules is shown in the table.

Name	Formula	Shape of molecule
hydrogen fluoride	HF	
water	H_2O	
ammonia	NH_3	

a) Complete the table to show the shape of a molecule of ammonia.

b) The hydrogen fluoride molecule can be represented as:



Showing all outer electrons, draw a similar diagram to represent a molecule of water, H_2O.

Q3. Int2

The table shows the colours of some ionic compounds in solution.

Compound	Colour
potassium chloride	colourless
potassium chromate	yellow
copper chromate	green
copper sulphate	blue

The colour of the chromate ion is

A colourless

B yellow

C green

D blue

Q4. Int2

Tin and its compounds have many uses.

a) Why do metals such as tin conduct electricity?

____

____

b) Tin (IV) chloride is a liquid at room temperature and is made up of discrete molecules.

What type of bonding does this suggest is present in tin (IV) chloride?

____

c) What is the most likely ***shape*** of a tin (IV) chloride molecule?

____

Q5. Int2

Which of the following substances is made up of molecules containing polar covalent bonds?

A Calcium oxide

B Chlorine

C Sodium bromide

D Water

CONSOLIDATION QUESTIONS D

Q1 Many ionic compounds are coloured.

Compound	*Colour*
nickel(II) nitrate	green
nickel(II) sulphate	green
potassium permanganate	purple
potassium sulphate	colourless

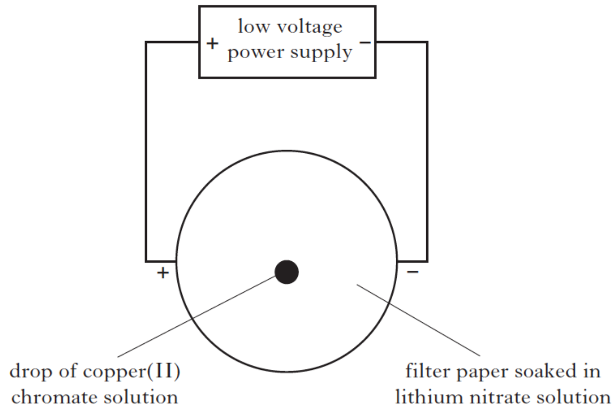
a) Give the symbol for a potassium ion.

____

b) Using the information in the table, state the colour of the potassium ion.

____

c) A student set up the following experiment to investigate the colour of the ions in copper(II) chromate.



Observation
yellow colour moves to the positive electrode
blue colour moves to the negative electrode

i) Lithium nitrate solution is used as the electrolyte. What is the purpose of an electrolyte?

____

ii) Suggest why lithium phosphate can ***not*** be used as the electrolyte in this experiment. You may wish to use the data booklet to help you.

____

d) State the colour of the chromate ion.

____