Energy Matters

Compounds and Bonding

Covalent Network, Ionic, Molecular, Polar Covalent, Polar-Polar attractions, Hydrogen bonding, and Water

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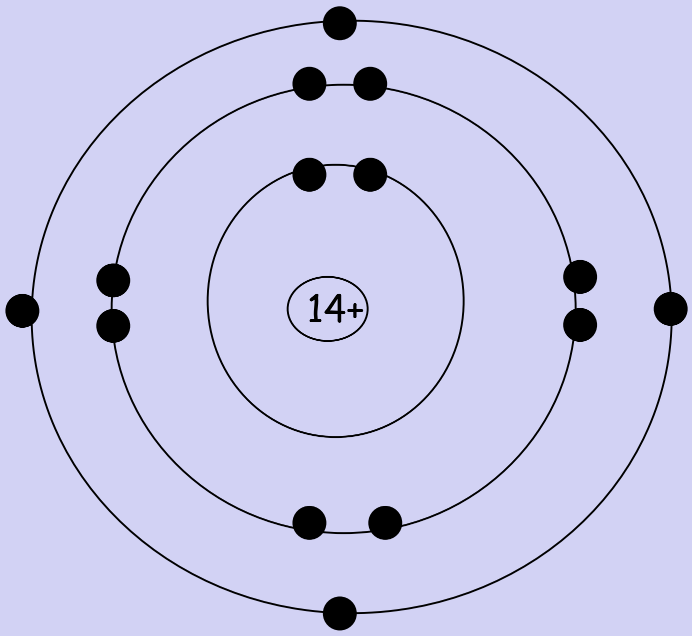
Covalent Network Compounds

Silicon, like carbon, can form giant covalent networks. Silicon and silicon carbide exist in a similar structure to diamond.

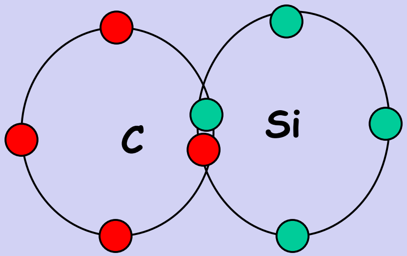
C $_{2,4}$ **Si** $_{2,8,4}$



Silicon, like carbon needs
4 more electrons to achieve
a stable electron arrangement

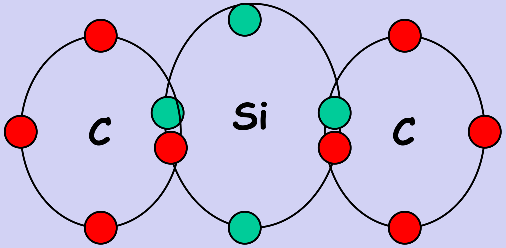
Silicon Carbide SiC

Considering the outer shells only

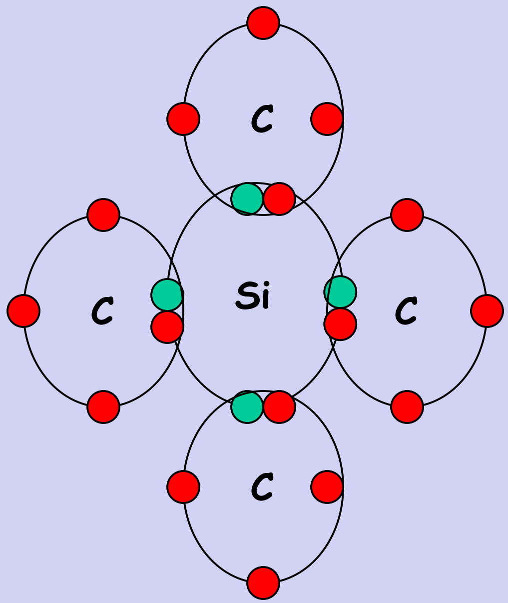


Silicon Carbide SiC

Considering the outer shells only

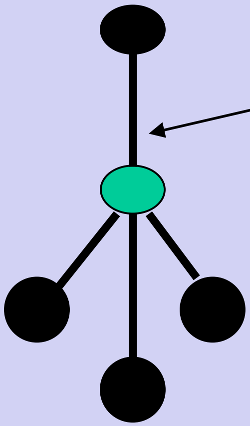


Silicon Carbide SiC

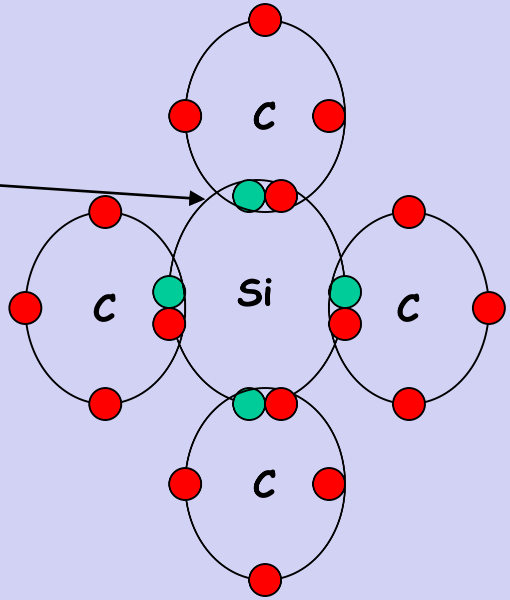


Silicon Carbide SiC

Tetrahedral shape



Covalent Bond

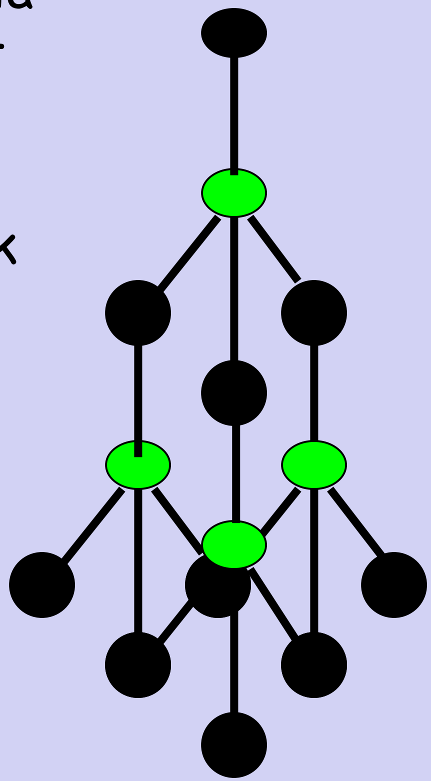


The 4 carbon atoms are available to bond with another 4 silicon atoms.

This results in a COVALENT NETWORK COMPOUND

Silicon Carbide SiC

Silicon carbide (carborundum) has a chemical formula is SiC. As this compound is linked by strong covalent bonding, it has a high m.p. (2700°C).



It is a hard substance as it is very difficult to break the covalent lattice.

SiC is used as an abrasive for smoothing very hard materials.

Each Si is bonded to 4 C's and each C is bonded to 4 Si's.

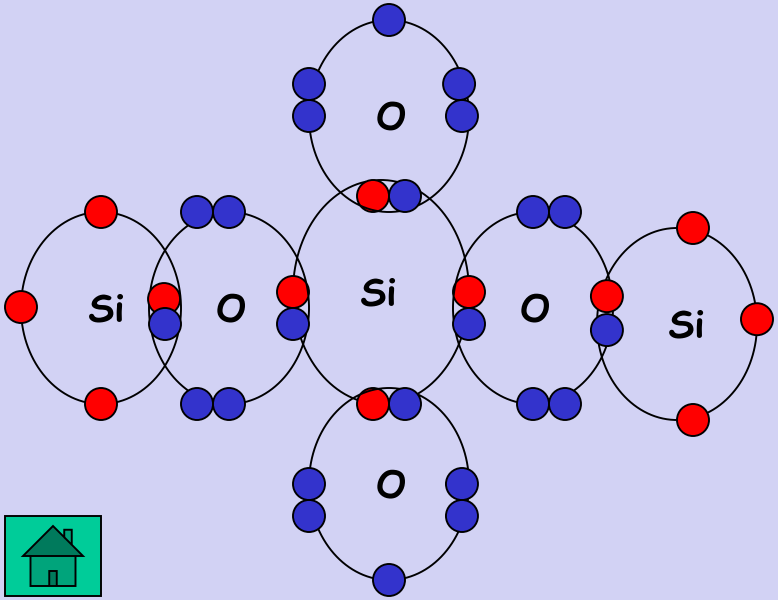
Hence the chemical formula, SiC

Silicon Dioxide SiO_2

Silicon and oxygen make up nearly 75% of the Earth's crust.
They are therefore the most common elements in the Earth's crust.

They combine together to make a covalent network compound called silicon dioxide. This is usually found in the form of sand or quartz.

Each Si atom is bonded to 4 O atoms, and each O atom is bonded to 2 Si atoms. Hence the chemical formula, SiO_2 .

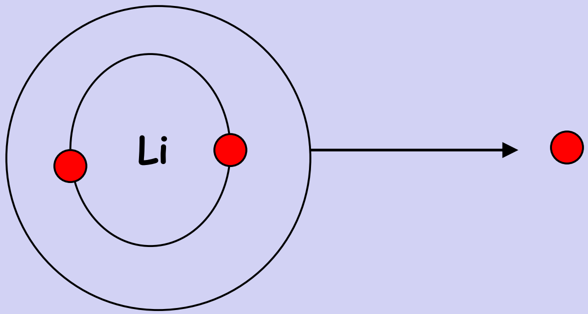


Silicon dioxide (silica) also has a high m.p. (1610 °C) and like SiC, it is very hard and used as an abrasive.
It is relatively un-reactive.

Ionic Compounds

Neutral atoms which have the most stable electron arrangement are the noble gases.

Other atoms can achieve this arrangement by either losing or gaining electrons and so forming positive or negative ions.



Lithium can donate the electron from its outer shell.

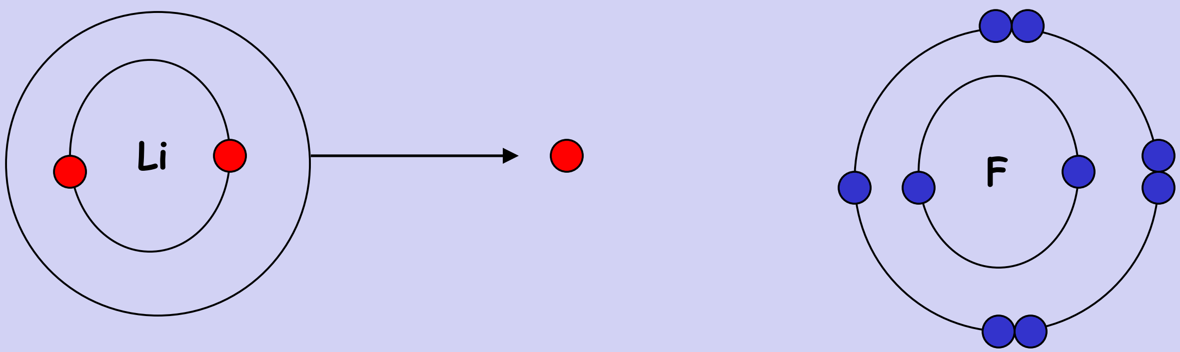
A Li^+ ion is produced

All metal atoms donate electrons. They are said to be reducing agents.

Ionic Compounds

The donated electron is usually accepted by a non-metal.

Is this case a fluorine atom needs just one electron to achieve the Noble gas electron arrangement.

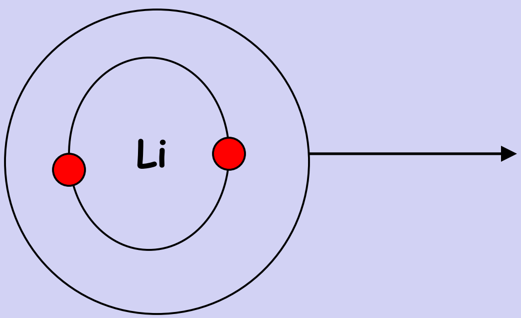


Li^{1+}

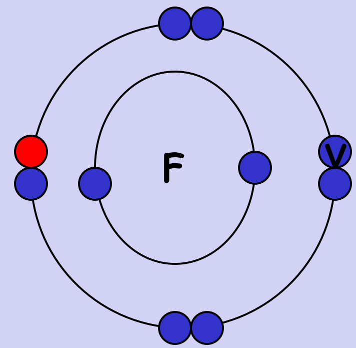
Ionic Compounds

The donated electron is usually accepted by a non-metal.

Is this case a fluorine atom needs just one electron to achieve the noble gas electron arrangement.



Li^{+}

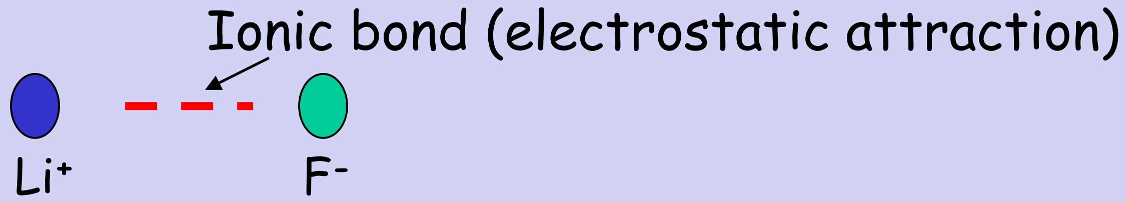


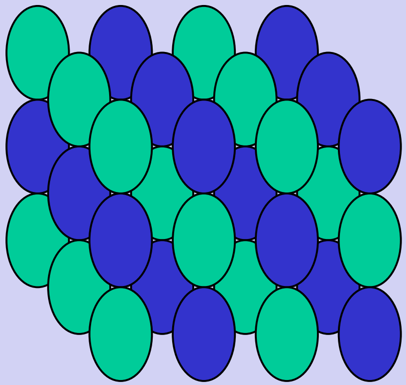
The fluoride ion
F^{-} 2,8

Metal atoms usually donate electrons.
Non-metal atoms can accept electrons.

Ionic Compounds

The positive and negative ions are attracted (electrostatic bond) to each other.





A giant lattice structure is formed.
Each Li^+ ion is surrounded by 6 F^- ions.
While each F^- is surrounded by 6 Li^+ ions.

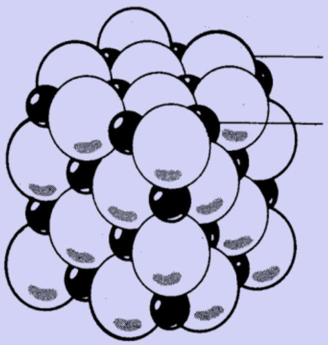
Ionic bonding is the electrostatic force of attraction between positively and negatively charged ions.

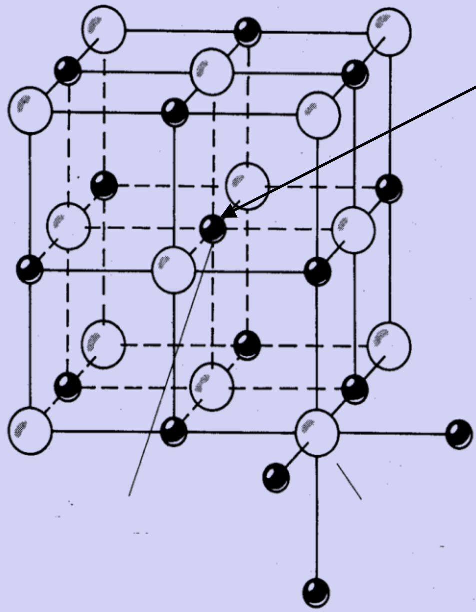
This ionic network compound has many ionic bonds so ionic compounds have high m.p.s

Ionic Compounds

A giant lattice structure is formed when each Na^+ ion is surrounded by 6 Cl^- ions and each Cl^- ion is surrounded by 6 Na^+ ions.

Sodium Chloride





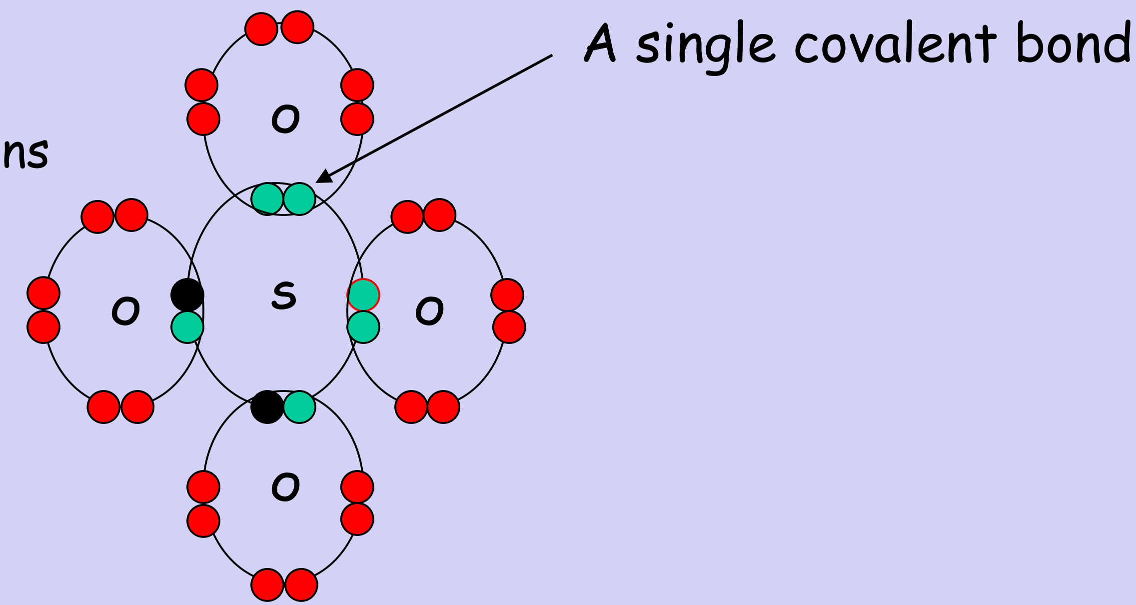
The formula of sodium chloride is NaCl, showing that the ratio of Na^+ to Cl^- ions is 1 to 1.

The m.p. of NaCl is 801 ^0C

The size of the ions will effect the strength of the ionic bond and how the ions pack together. e.g. NaF m.p. 1000^oC, NaI 660^oC

Molecular Ions, e.g. SO_4

- Oxygen
- Sulphur
- 2 additional electrons



e.g. Copper can donate the extra 2 electrons needed.

$Cu \rightarrow Cu^{2+} + $ **2e**

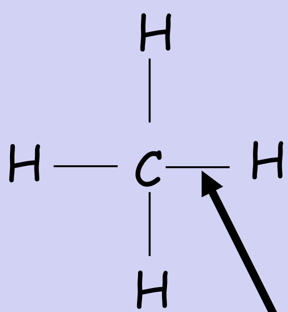
Copper sulphate contains the Cu^{2+} and the SO_4^{2-} **ions.** There is, therefore, covalent bonding and ionic bonding in copper sulphate

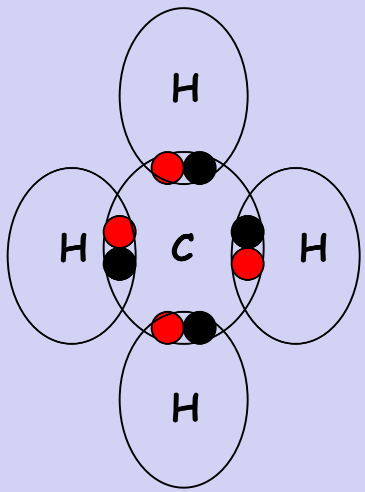
A solution of copper sulphate can conduct electricity.
Molten ionic compounds can also conduct electricity.

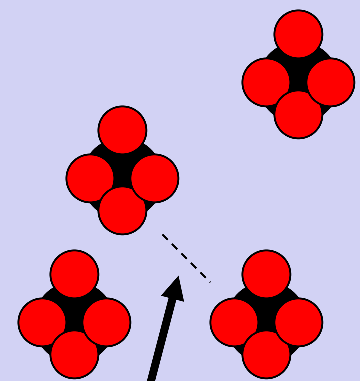
Covalent Molecular Compounds

Discrete molecules are formed when two or more atoms share electrons. The atoms are non-metal elements. An example is methane.

Methane: CH_4





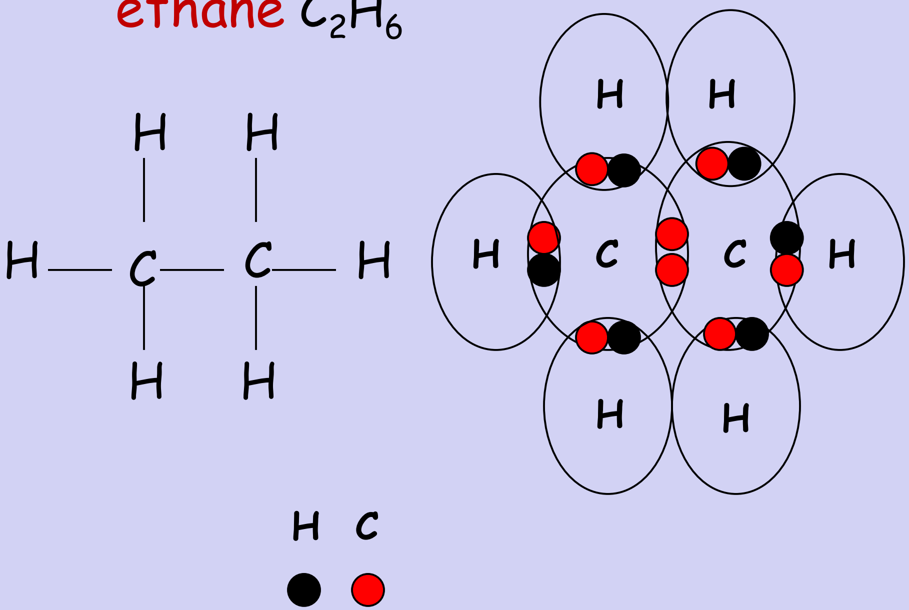


Methane has **strong intra-molecular** and **weak inter-molecular**.
It's b.p. is -183°C

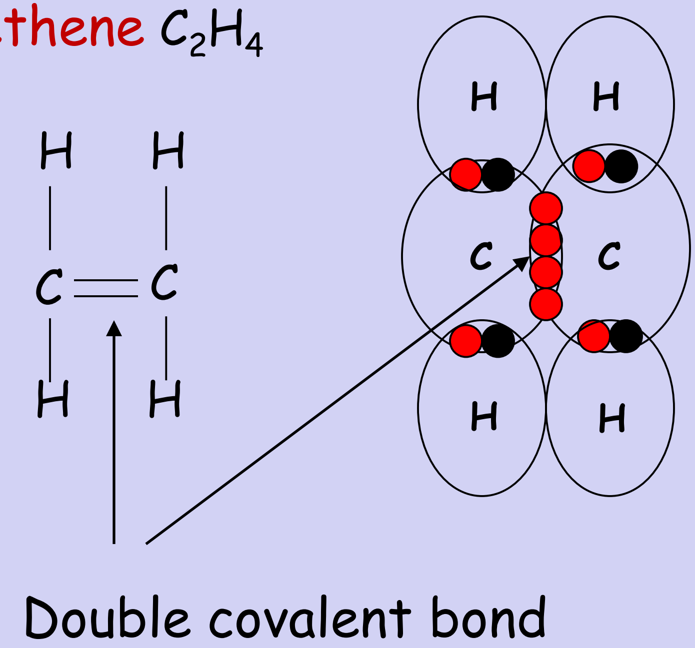
Covalent Molecular Compounds

Non- metals elements can form double and triple covalent bonds.

ethane C_2H_6



ethene C_2H_4



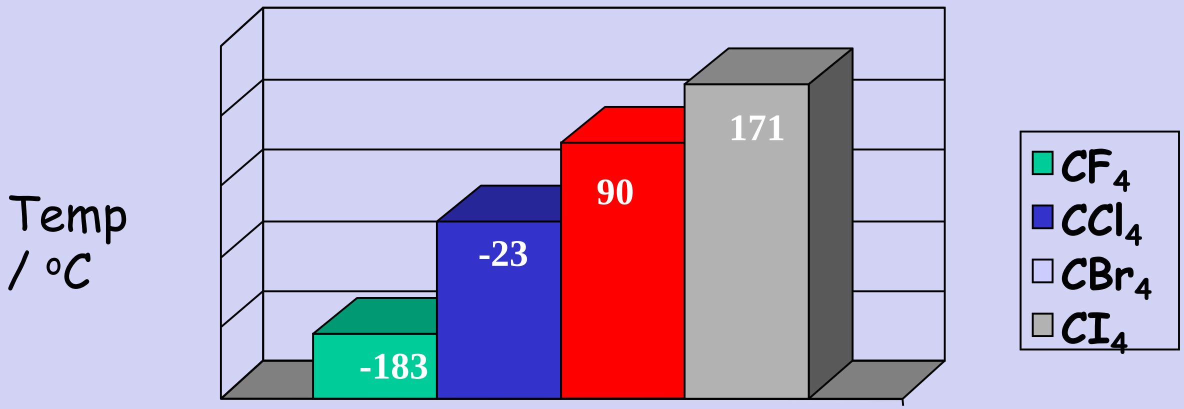
Covalent molecular compounds have low m.p.'s because the weak forces holding the molecules together require only small amounts of thermal energy to break them.

Covalent Molecular Compounds

Properties

Low m.p.'s and b.p.'s., this increases with size of the molecule and the increasing number of atoms in the molecule.

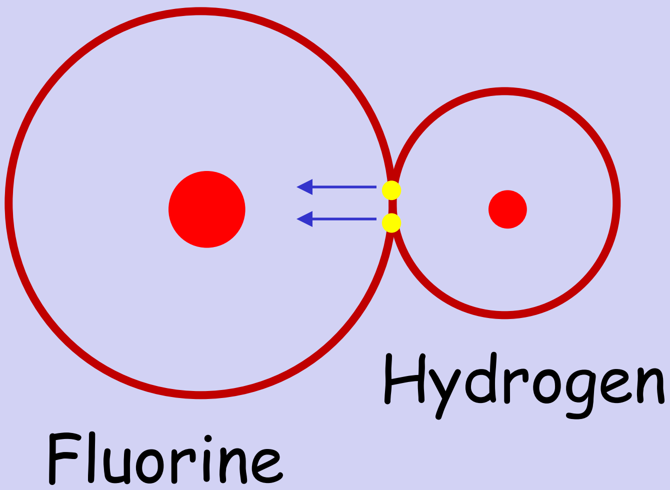
m.p.'s of the carbon halides



m.p.'s increase because the strength of the Van der Waals forces increase with the increasing size of the molecule. So more Energy is needed to separate molecules.

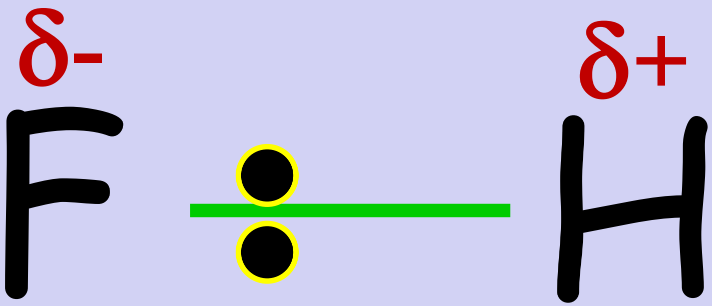
Polar Covalent Bonds

Electronegativity is a numerical measure of the relative ability of an atom in a molecule to attract the bonding electrons towards itself.



In the covalent bond between fluorine and hydrogen. The bonding electrons are not shared equally between the two atoms.

The fluorine nucleus has more protons and has a stronger pull on the electrons than the hydrogen nucleus..



Thus the fluorine atom has a greater share of the bonding electrons and acquires a slight negative charge.

The hydrogen atom is then made slightly positive.

The bond is a polar covalent bond and we use the symbols δ+ and δ- to show this.

The dipole produced is permanent.

Fluorine is the most electronegative element. It is small atom compared to others and its nucleus is massive for its atomic size.

Some other polar covalent bonds are O-H and N-H

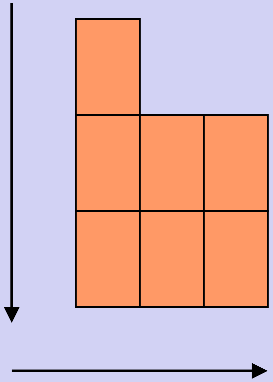
Electronegativity is useful at predicting how electrons will be shared. The Pauling scale is used for electronegativity values

The greater the difference in electronegativity the greater the polarity between two bonding atoms and the more ionic in character.

Increasing difference in electronegativity →

Non-polar	slightly polar covalent	very polar covalent	ionic
Equal sharing of electrons	Increasing unequal sharing of electrons		Transfer of electrons
4.0 F — F 4.0	3.5 O ← H 2.1		0.9 Li → F 4.0

Trends in electronegativity



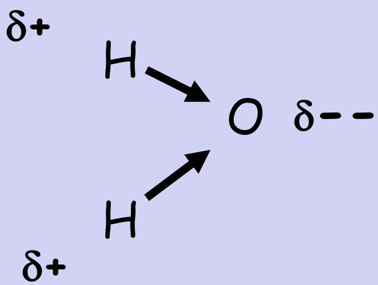
Electronegativity increases across a period.

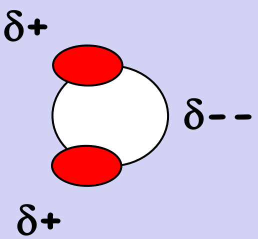
Electronegativity decreases down a group

Going across the group, the nuclear charge increases. This pulls the Electron shells closer to the nucleus. As a results, the electronegativity increases.

Going down the group, the nuclear charge increases but the number of electron shells also increases. As a result of 'shielding' and an increase distance the outer shell is from the nucleus, electronegativity decreases.

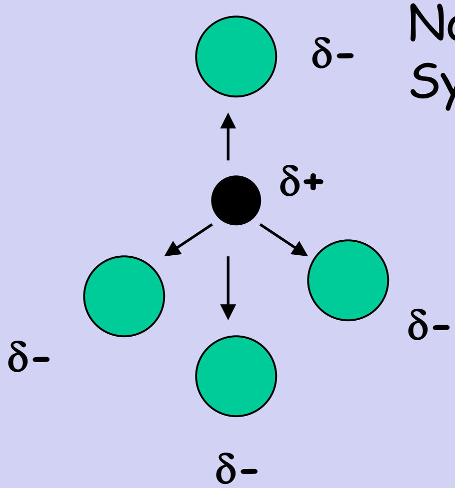
Water is a polar covalent bonding between O and H.





Polar-Polar Attractions

The differing electronegativities of different atoms in a molecule and the spatial arrangement of polar covalent bonds can cause a molecule to form a permanent dipole.

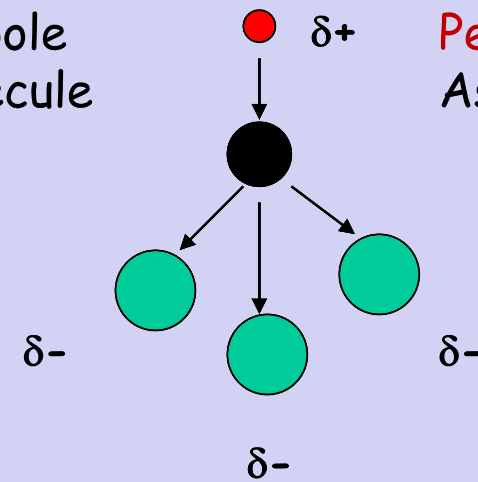


No permanent dipole
Symmetrical molecule

4 polar covalent C-Cl bonds in CCl_4 tetrahedral shape

NON-POLAR molecule

e.g. also CO_2



Permanent dipole
Asymmetrical molecule

3 polar covalent C–Cl bonds and 1 polar covalent C-H bond in $CHCl_3$

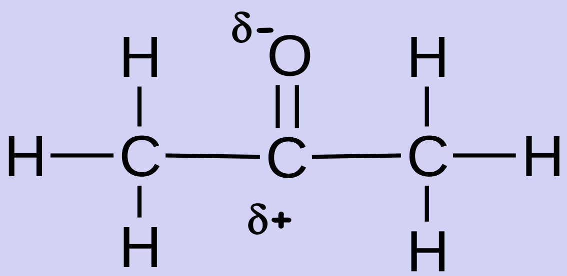
POLAR molecule

e.g. also H_2O

Polar molecules and permanent dipoles

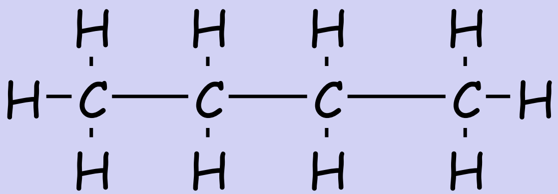
Both propanone and butane have the same formula mass of 58 however, butane boils at – 1 °C while propanone boils at 56°C

Propanone is a polar molecule as it has a permanent dipole, so has polar-polar attraction as well as Van der Waals' forces between molecules.



b.p. 56 ° C

Butane has no permanent dipoles, so only Van der Waals forces between molecules. So has a lower boiling point.



b.p. -1 ° C

Polar Molecules

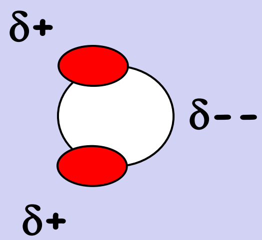
A liquid that substances dissolves in is called a **SOLVENT**.
Solvents can be either **polar** or **non-polar** molecules.

Immiscible liquids do not mix, e.g. oil and water, however, non-polar liquids are **miscible** with each other.

Polar solvents will usually dissolve polar molecules.

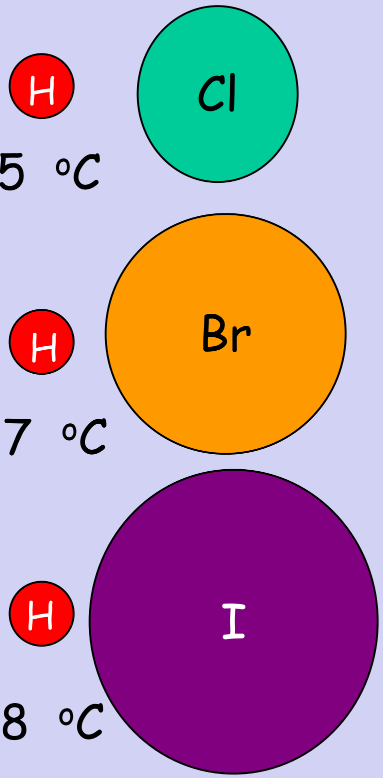
Non-polar solvents will usually dissolve non-polar molecules.

Water is a polar molecule so it is a polar solvent.



Polar Molecules

The size of the atom can affect the polarity of the molecule.



HCl -85 °C

HBr -67 °C

HI -38 °C

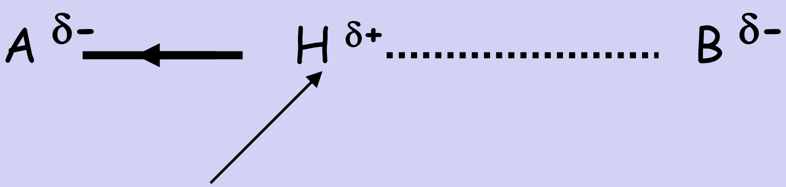
As the size of the halide increases,
so will the attraction for the hydrogen electron.

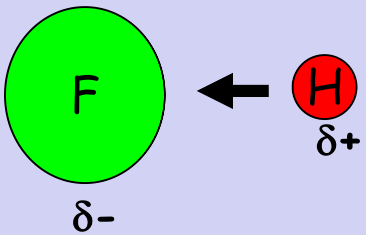
This will result in the size of the dipole increasing.

This will result in the **b.p's** increasing as the size of the halide increases, because more energy would be needed to separate molecules.

Hydrogen Bonding

Hydrogen bonding is a special type of dipole-dipole attraction in which hydrogen atom acts as a bridge between two very electronegative atoms. It is the strongest of the weak inter-molecular forces.





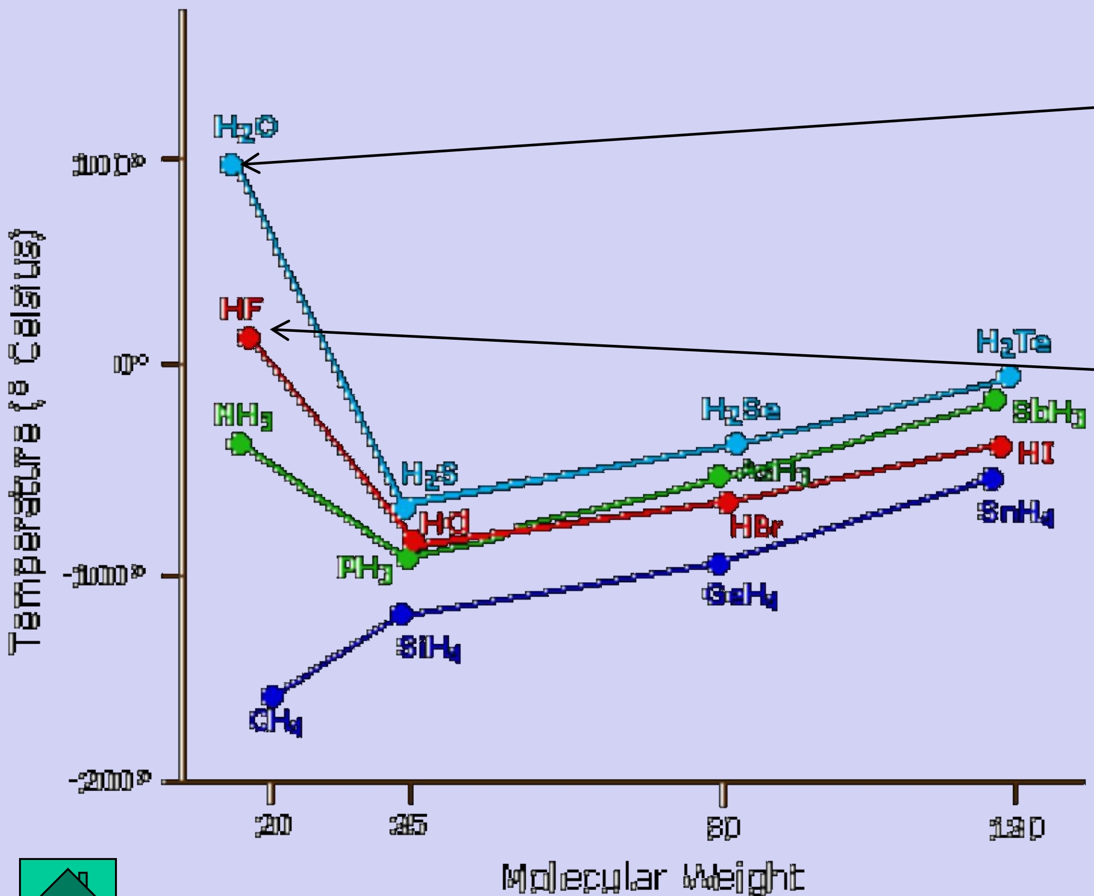
The Hydrogen atom is in a straight line between $A^{\delta-}$ and $B^{\delta-}$.
The bond strength is stronger than other forms of permanent dipole-permanent dipole interaction but weaker than a covalent bond.

A and B are electronegative atoms, such as F, O or N.
Such atoms possess one or more lone pair of electrons.

Proteins consist of long chain atoms containing polar >C=O and H-N< bonds.
Hydrogen bonds help give proteins their shape.

Physical properties of hydrides

Water has a much higher b.p. than similar compounds containing hydrogen e.g. NH_3, HF, CH_4.



Hydrogen bonding explains why water has a b.p. higher than expected. It also explains waters viscosity.

Similarly with HF b.p. 19 ^oC

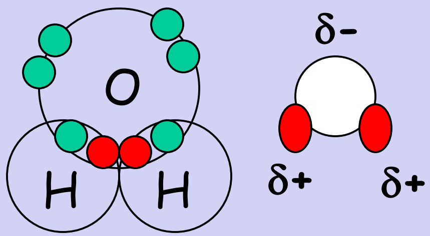
Whereas:

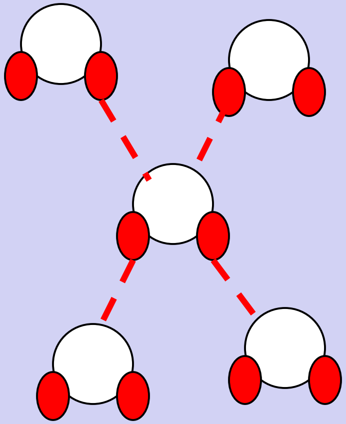
HCl –85 ^oC

HBr –68 ^oC

HI –35 ^oC

Water





Oxygen has 2 lone pairs of electrons which can form a hydrogen bonds with two hydrogen atoms.

Each water molecule, in theory, could be surrounded by 4 hydrogen bonds

Pond Skater

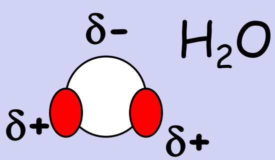
Water has a high surface tension. The molecules on the surface have in effect, hydrogen bonds. This has the effect of pulling the surface molecules closer together.

Ice Skater:

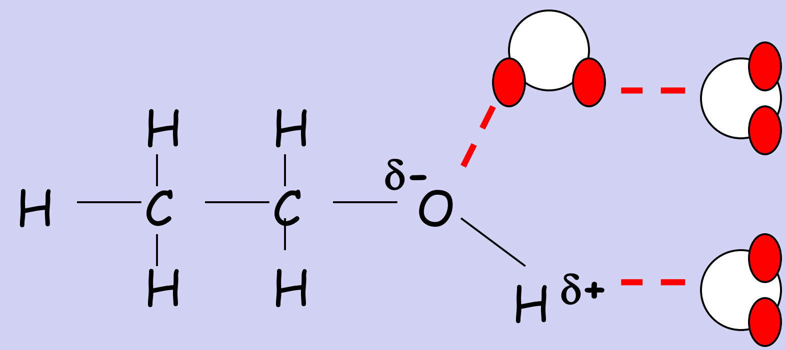
Water has a its greatest density at a temperature of 4°C. When, as water cools further, the molecules start to move further apart, due to the hydrogen bonding, until a more open structure formed at its freezing point. So ice floats!!

Dissolving in Water

Generally, covalent molecules are insoluble in water. However, small molecules like ethanol (C_2H_5OH), with a polar O-H functional group, will dissolve,



Ethanol



Ionic Compound dissolving in water