BONDING

VISUAL CHEM CARDS

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Ionic Bonding

Electron transfer/acceptance

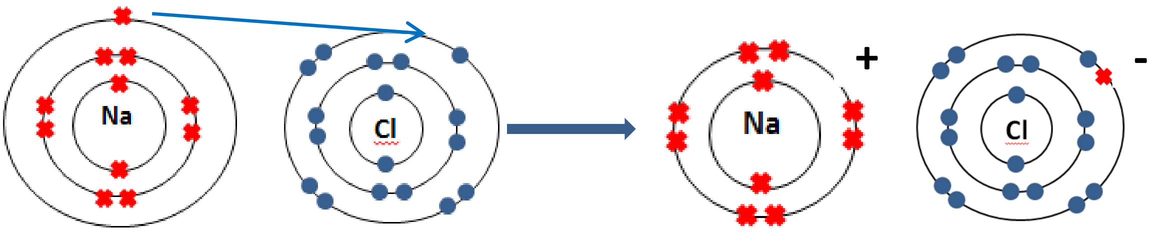
SODIUM CHLORIDE (NaCl)

one electron is transferred from Na to Cl

ionic bond between Na and Cl

Na	Cl		Na$^+$	Cl$^-$
sodium atom	**chlorine atom**		**sodium cation**	**chloride anion**
$1s^22s^22p^63s^1$	$1s^22s^22p^63s^23p^5$	→	$1s^22s^22p^6$	$1s^22s^22p^63s^23p^6$

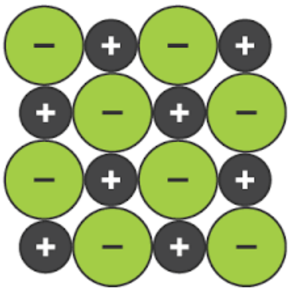
Sodium Chloride, NaCl



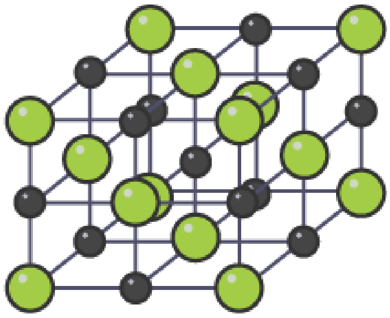
sodium loses an electron, leaving it with a complete valence shell

chlorine gains an electron, leaving it with a complete valence shell

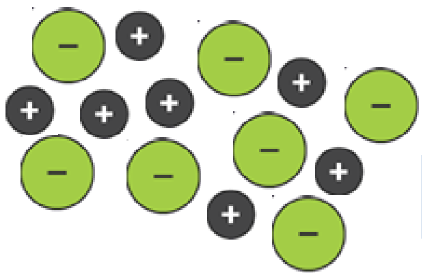
Ionic Bonding



Ionic compounds do not exist as isolated molecules, but as a part of a crystal lattice.



Ions are fixed in lattice and cannot move: insulator



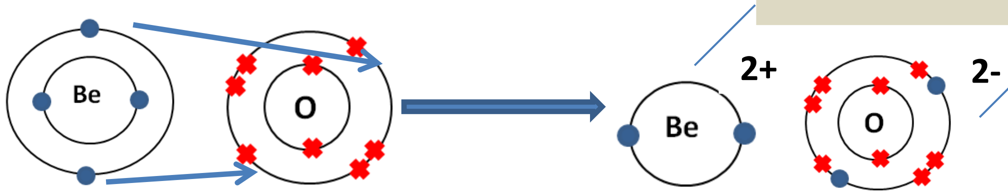
Molten ionic salts - ions are free to move: conductor

Example: Beryllium Oxide, BeO

Be O → Be^{2+} O^{2-}

$1s^2 2s^2$ $1s^2 2s^2 2p^4$ $1s^2$ $1s^2 2s^2 2p^6$

complete valence shells



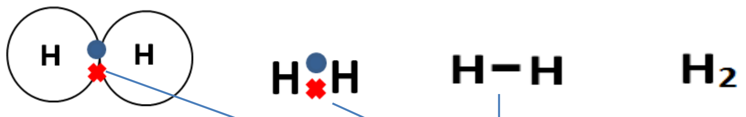
beryllium loses two electrons, leaving it with a complete valence shell

oxygen gains two electrons, leaving it with a complete valence shell

Covalent Bonding

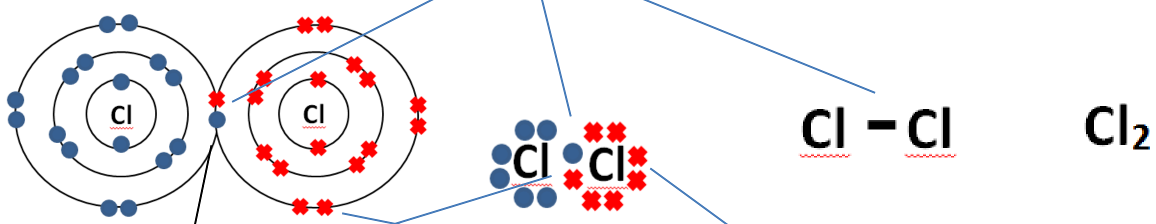
Electron sharing

Hydrogen, H_2



covalent bond - shared pair of electrons

Chlorine, Cl_2



covalent bond - shared pair of electrons

By sharing electrons both atoms can achieve complete valence shells

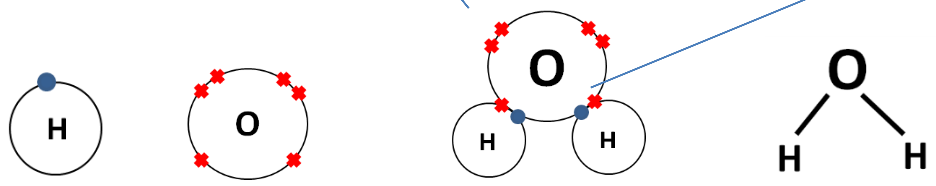
Water, H_2O

Electron arrangements
H 1
O 2:6

non-bonding electron

non-bonding electron

bonding electron pair



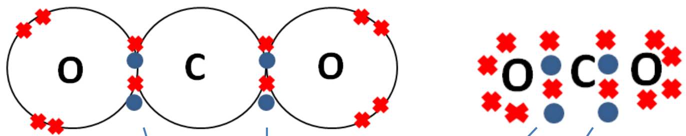
Hydrogen atom **Oxygen atom** **Water molecule**

By sharing electrons both O and H attain complete valence shells

Covalent Bonding

Carbon Dioxide, CO_2

Electron arrangements
C 2:4
O 2:6

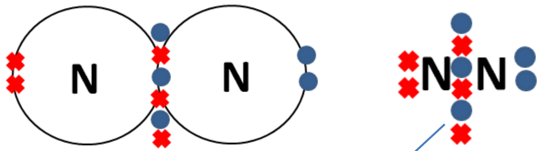


Double bond – two shared pairs of electrons

O = C = O CO_2

Nitrogen, N_2

Electron arrangement
N 2:5



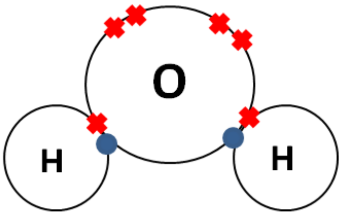
Triple bond – three shared pairs of electrons

N≡N N_2

Shapes of Simple Covalent Molecules

Valence Shell Electron Pair Repulsion Theory

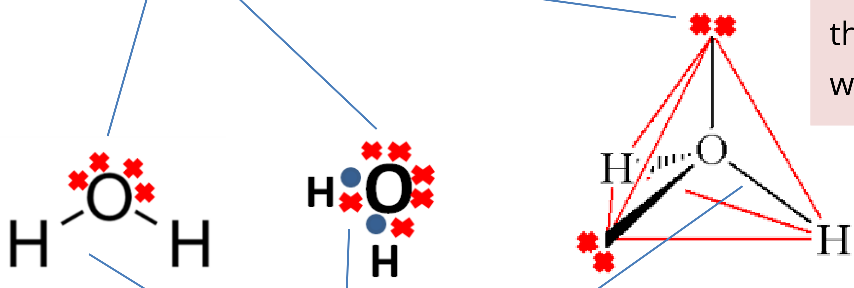
The structure and bonding present in water can be represented in several ways



Water, H_2O

Lone pairs of electrons

Tetrahedral arrangement of electron pairs around the central oxygen atom in water



H_2O

Water adopts a bent or V-shape since we can only 'see' the bonding electron pairs.

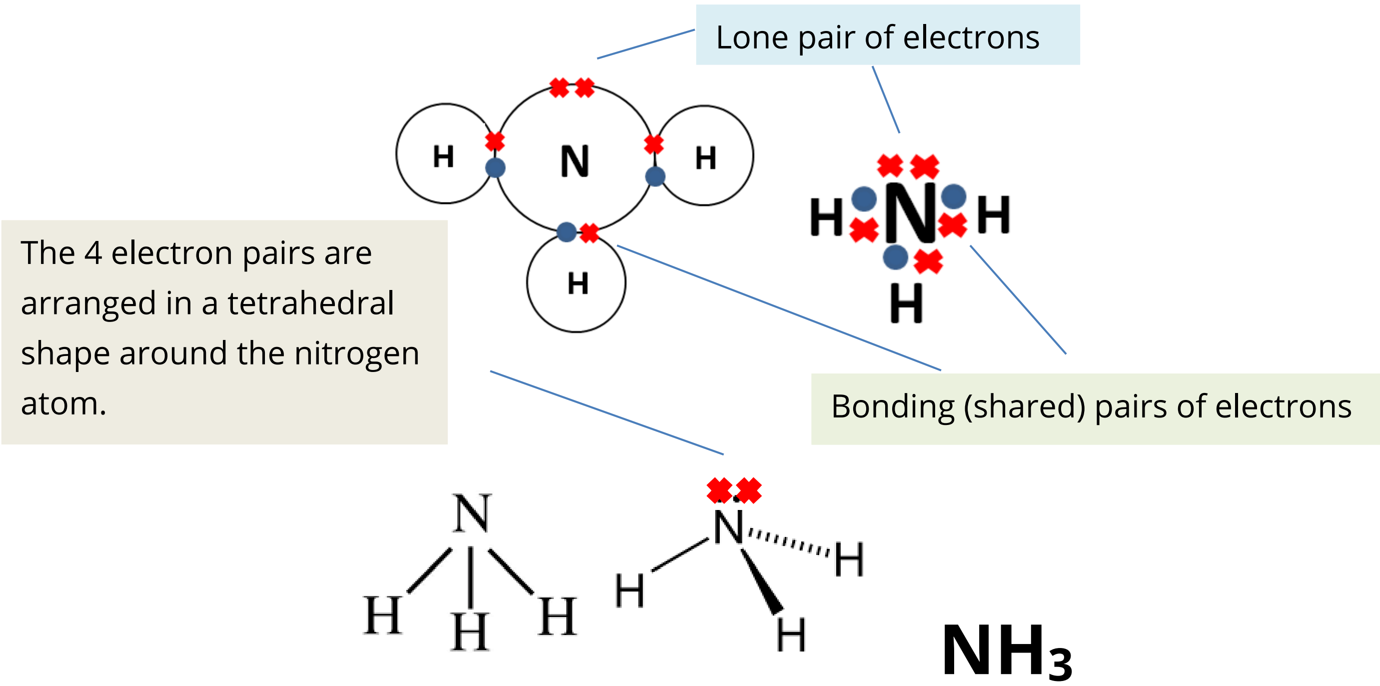
Bonding electron pairs

The V- or bent structure of water accounts for many of the unique properties of water that make life on Earth possible.

Shapes of Simple Covalent Molecules

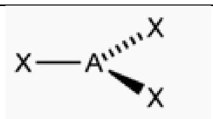
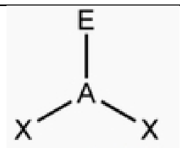
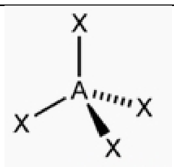
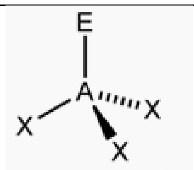
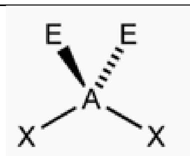
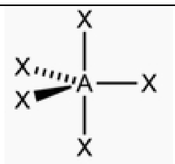
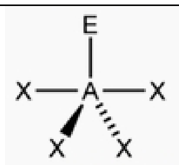
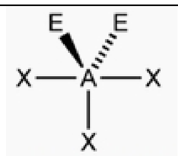
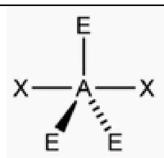
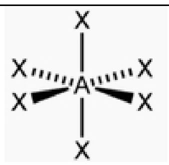
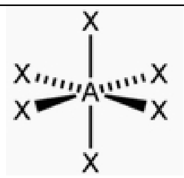
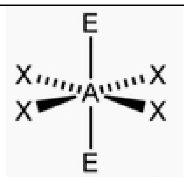
Valence Shell Electron Pair Repulsion Theory

Ammonia, NH_3

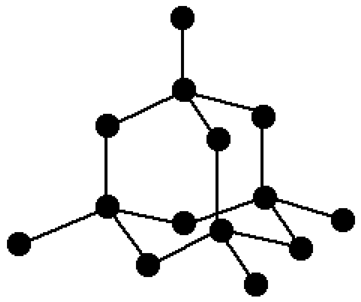


Ammonia molecule adopts a pyramidal structure

Predicting the Structure of Simple Covalent Compounds (AX_n)

	E - number of lone pairs of electrons around A			
Total number of electron pairs around A	***0 lone pair***	***1 lone pair***	***2 lone pairs***	***3 lone pairs***
2	 linear			
3	 trigonal planar	 trigonal pyramidal		
4	 tetrahedral	 pyramidal	 bent	
5	 trigonal bipyramidal	 seesaw	 T-shaped	 linear
6	 octahedral	 Square pyramidal	 square planar	

Giant Covalent Structures



Diamond

Each carbon atom is tetrahedrally covalently bonded to 4 other carbon atoms.

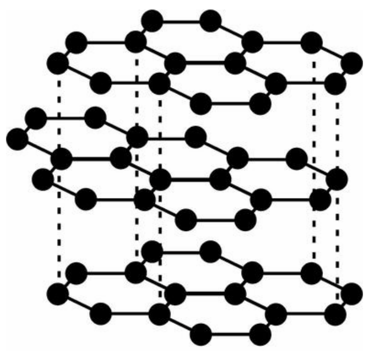
All valence electrons in carbon atom are used in bonding. Diamond is an insulator.

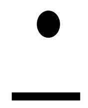
Lots of energy is required to destroy the giant lattice structure, hence diamond has very high melting point (3550°C).

Diamond is very hard as the carbon atoms cannot easily move due to the strong covalent bonds.

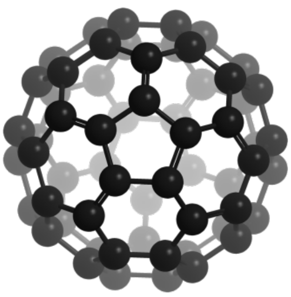
Each carbon is graphite is covalently bonded to 3 other carbon atoms in layers.

The remaining valence electron in carbon is free making graphite a conductor.



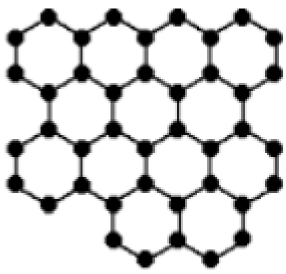


Graphite



Hollow spheres of 60 carbon atoms

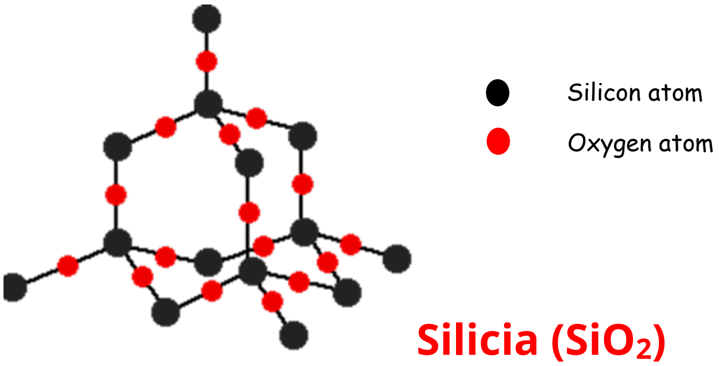
Buckminster Fullerene (C_{60})



Single layer (monolayer) of graphite

Graphene

Each silicon atom is covalently bonded to four **oxygen atoms**. Each **oxygen atom** is covalently bonded to two **silicon atoms.**



Silicia (SiO_2)

Polar Covalent Bonds

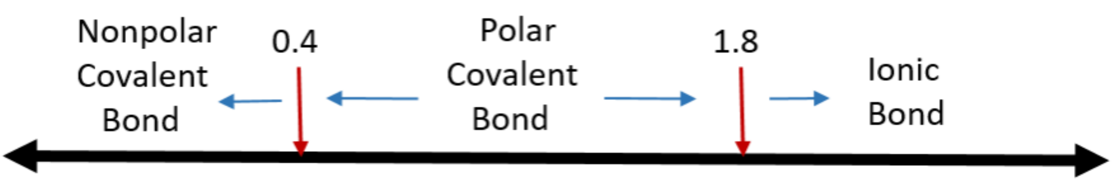
Electronegativity provides a measure of the ability of an atom to attract a bonding pair of electrons. In the Pauling scale (0 to 4), non-metals have the highest values; metals have the lowest values.

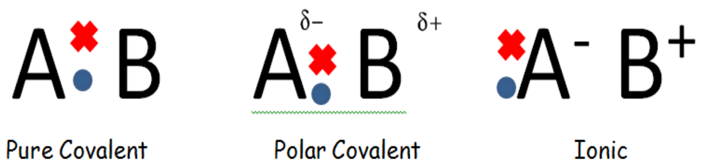
Pauling Scale of Electronegativity

H 2.1																
Li 1.0	Be 1.5											B 1.5	C 2.5	N 3.0	D 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 3.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9		Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9															

Electronegativity Difference	Type of Bond Formed
0.0 to 0.4	'Pure' Covalent
0.4 to 1.8	Polar Covalent
> 1.8	Ionic

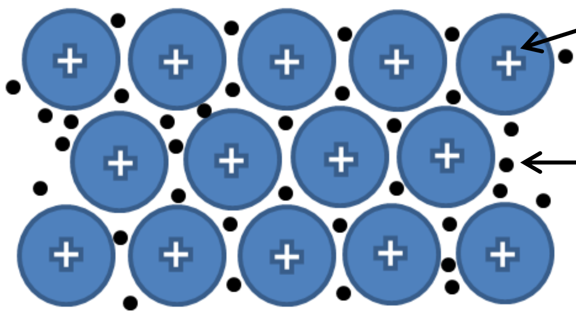
Electronegativity Difference





Metallic Bonding

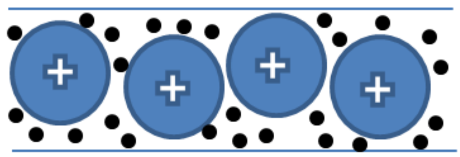
Metallic Bonding



Positively charged metal ions (cations)

'Sea gas' of negatively charged electrons

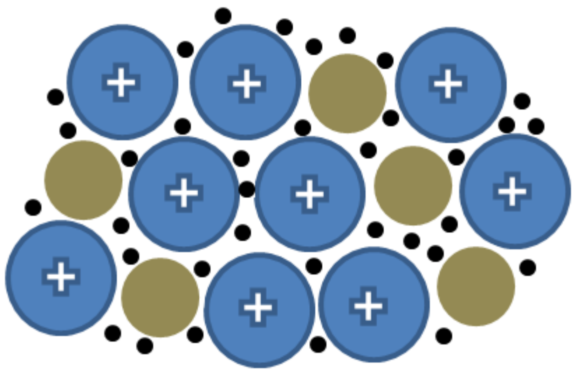
Highly ordered structure



Metal ions can roll over each other into new positions without breaking bonds. This makes metals both malleable (beaten into sheets) and ductile (pulled into wires).

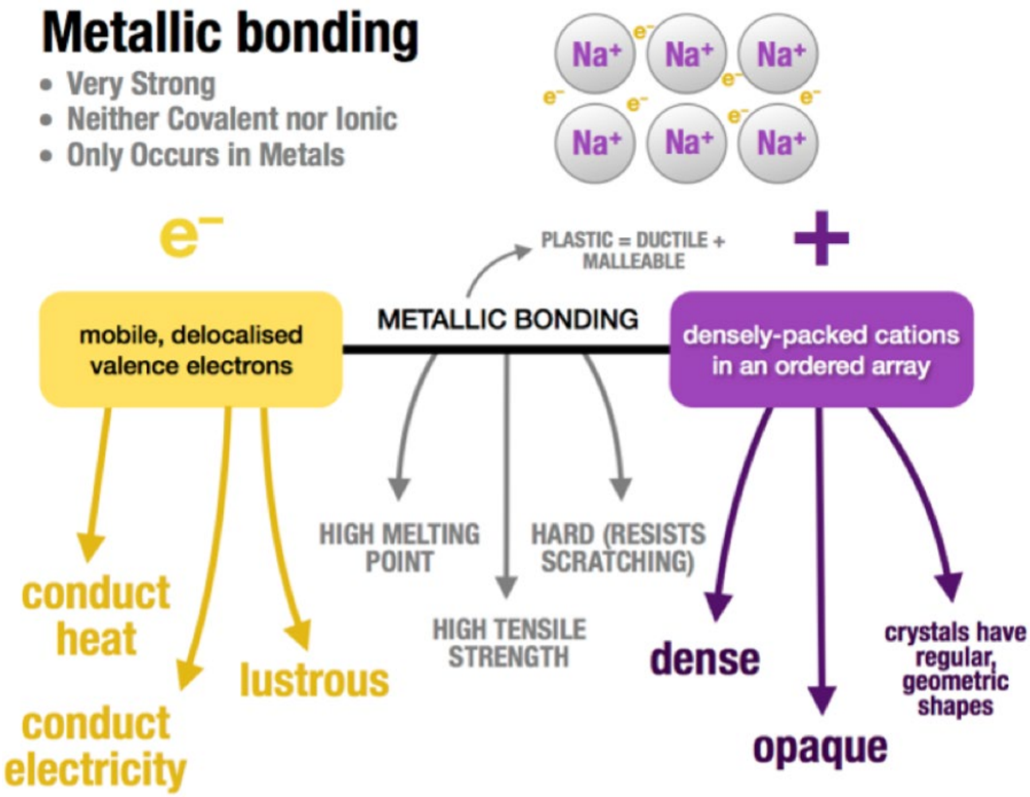
Alloys

Alloys are usually harder, less malleable and ductile since the metal ions cannot roll over each other as easily.



Disordered structure

Metallic Bonding



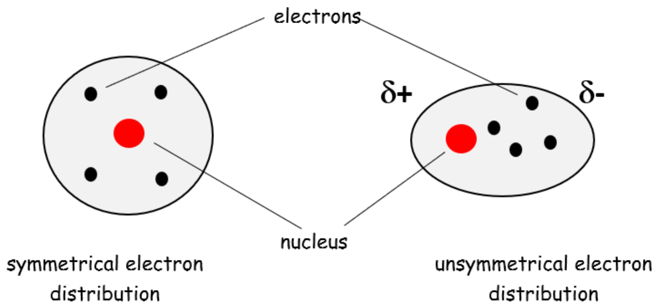
Common Alloys

Alloy	Composition (w/w)	Typical Use
Amalgam	Mercury (45–55%), plus silver, tin, copper, and zinc.	Dental fillings.
Brass	Copper (65–90%), zinc (10–35%).	Musical instruments, pipes.
Bronze	Copper (78–95%), tin (5–22%), plus manganese, phosphorus, aluminium, or silicon.	Decorative statues, musical instruments.
Cast Iron	Iron (96–98%), carbon (2–4%), plus silicon.	Metal structure, eg bridges sand heavy-duty cookware.
Gunmetal	Copper (80–90%), tin (3–10%), zinc (2–3%), and phosphorus.	Guns, decorative items.
Stainless Steel	Iron (50%+), chromium (10–30%), plus smaller amounts of carbon, nickel, manganese, molybdenum, and other metals.	Jewellery, medical tools, tableware.
Sterling Silver	Silver (92.5%), copper (7.5%).	Cutlery, jewellery, medical tools, musical instruments.

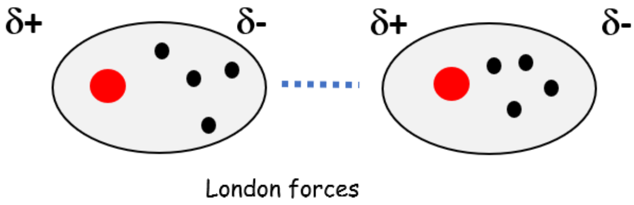
Intermolecular Forces

Intermolecular bonds are found between molecules. There are several types to consider.

London (van der Waals) Forces



nonpolar atom **polar atom**



Temporary dipoles in one atom/molecule create dipoles in nearby atoms/molecules. London forces are the weak attractions between the small (□) opposite charges on adjacent atoms/molecules.

Dipole-Dipole Intermolecular Forces

$$A^{\delta+}\text{–}X^{\delta-} \text{-------} A^{\delta+}\text{–}X^{\delta-}$$

Hydrogen Bonding in Water