

ELECTRONS, BONDING and STRUCTURE

ATOMIC ORBITALS

Atomic orbitals are volumes of space around the nucleus holding up to two electrons (with opposite spins)

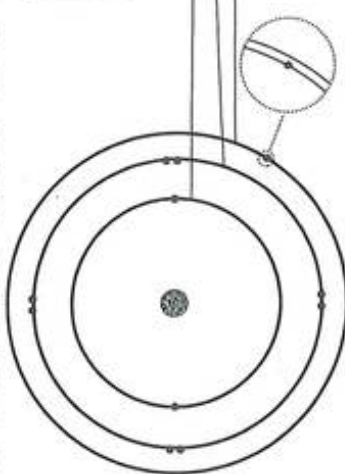
s-orbitals are spherical
p-orbitals are dumbbell shaped
d-orbitals have more complicated shapes

The Bohr model of a sodium atom shows 11 electrons in three shells (2 in the 1st, 8 in the 2nd and 1 in the 3rd).

Show which subshells electrons occupy with this notation:

Shell number subshell number of electrons

1s² 2s² 2p⁶ 3s¹



SHELLS AND SUBSHELLS

The subshells that make up a shell affect how many electrons can fit into that shell:

Shell 1 holds 2 electrons – it consists of a single s-subshell (one s-orbital)

Shell 2 holds 8 electrons – it consists of an s-subshell and a p-subshell (one s-orbital and three p-orbitals)

Shell 3 holds 18 electrons – it consists of an s-subshell, an s-subshell and a d-subshell (one s-orbital, three p-orbitals and five d-orbitals)

Electrons always fill all orbitals with the same energy singly before forming pairs

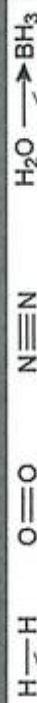


An s-subshell is just a single s-orbital
A p-subshell is three p-orbitals (at 90° to one another)
A d-subshell is five d-orbitals

Electrons exist in shells and subshells. There are different subshells, made up of s, p, or d-orbitals.

BONDING

An ionic bond is an electrostatic attraction between positive and negative ions. Ionic compounds consist of very many positive and negative ions in giant lattices.
A metallic bond is an electrostatic attraction between positive metal ions and a sea of delocalized electrons in a giant lattice.
A covalent bond is a force of attraction between the positive nuclei of two atoms and a pair of electrons shared between them. Multiple covalent bonds consist of multiple shared pairs of electrons. A coordinate (dative covalent) bond consists of a shared pair of electrons that have both come from the same atom.



A line represents a covalent bond. One line = one shared pair of electrons

Two or three lines = two or three shared pairs of electrons (double or triple bond)

An arrow represents a coordinate bond. Here, both electrons came from O

Covalent bonds can be polar – if a pair of atoms are bonded and one is more electronegative than the other, it will pull the bonding pair of electrons to itself more strongly, becoming slightly negative (shown as δ^-) and leaving the atoms that it is bonded to slightly positive (shown as δ^+)

Molecules with polar bonds may have permanent dipoles. However, if the polar bonds are arranged so that they cancel each other out, the molecule may have no overall dipole



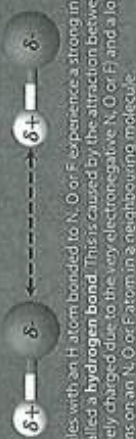
In CO_2 , the polar bonds are 180° apart and cancel each other out

H_2O molecules have permanent dipoles

INTERMOLECULAR FORCES

Molecules that are not polar have temporary dipoles because electrons move around them randomly so will sometimes be unevenly distributed. In the brief time that a dipole exists in one molecule, it will induce dipoles in nearby molecules, and so a short-lived force of attraction exists between them – called an induced dipole-dipole or London dispersion force.

If a molecule has bonds that are polar and don't cancel each other out as they do in a symmetrical linear molecule such as $\text{O}=\text{C}=\text{O}$, then the molecule will have an overall dipole. Polar molecules are attracted to one another with permanent dipole-dipole forces.



Water has some odd properties due to forming hydrogen bonds:
• When water freezes, the ice formed is less dense than liquid water – hydrogen bonds are long and force molecules apart
• Water boils at an unusually high temperature – hydrogen bonds are strong and a lot of energy is needed to overcome them

The term van der Waals force refers to both permanent dipole-dipole and induced dipole-dipole forces

Solids can be formed of a lattice of small molecules. These are just like giant lattices but with simple molecules such as I_2 or H_2O in place of ions, which are held together by intermolecular forces instead of ionic bonds. Since intermolecular forces are weaker than ionic bonds, simple molecular solids have lower melting points than ionic solids.

Non-polar simple molecular solids such as iodine will dissolve in non-polar liquids (e.g. hexane) but do not dissolve in polar solvents such as water. Ionic compounds or polar simple molecular solids dissolve in polar solvents but not in non-polar solvents. Only the solutions of ionic compounds conduct electricity.

low boiling point weakest high boiling point strongest

SHAPES OF MOLECULES

Electrons (bonding pairs and lone pairs) repel each other. Molecules form shapes where the electrons are as far from each other as possible. For example:

e pairs	Shape	Bonding pairs	Lone pairs	Shape
2		2	0	Linear, e.g. BeCl_2 , Cl_2
3		3	0	Trigonal planar, e.g. BH_3
4		4	0	Tetrahedral, e.g. CH_4
		3	1	Pyramidal, e.g. NH_3
		2	2	Non-linear, e.g. H_2O
5		5	0	Trigonal bipyramidal, e.g. PCl_5
6		6	0	Octahedral, e.g. SF_6

The bond angle gets smaller because lone pairs of electrons repel bonding pairs more strongly than bonding pairs repel other bonding pairs



The name comes from this shape (called 'octahedron' as it has eight faces)