

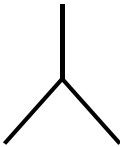

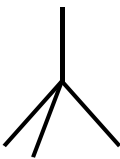


Small Molecules

Small molecules are formed either of non-metallic elements or of compounds of non-metallic elements. The shapes of small molecules can be predicted by VSEPR (valence shell electron pair repulsion) theory.

| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| linear | V-shaped | trigonal planar | trigonal pyramidal | tetrahedral |

Method for drawing molecules which have one central atom:

1. Draw an electron-dot diagram first
 - A. Write the central atom (the element there is only one atom of in the molecule)
 - B. Write the other atoms around it.
 - C. The central atom will share enough electrons to make all the other atoms stable. Draw these electrons around the central atom.
In a negative ion, the central atom may share more than it originally had in its valence shell.
 - D. Each outer atom will share the same amount as is being shared with it. Draw these electrons between the central atom and each other atom.
 - E. Draw any remaining electrons (non-bonding electrons) so all the atoms are stable.
For most atoms this will mean 8 electrons (except hydrogen which needs 2). Sometimes the central atom will have a total of more than 8, this is called 'expanding the octet' and is not a problem.
2. Draw the stick-bond diagram
 - A. Arrange the shape so that regions of negative charge are far away from each other.
Electron pairs within double and triple bonds do not repel one another and can be treated as a single 'cloud'.
 - B. If the molecule is a polyatomic ion, draw positive charge on the central atom or negative charge evenly spread around the outer atoms.
 - C. The number of sticks between any two atoms is half the electrons drawn between them (since they are electron pairs), *unless* the outer atom has a negative charge, in which case only a single bond is drawn.
 - D. Draw any central-atom non-bonding electrons.

Note: Draw electrons in pairs, where possible.

Polar and Non-polar Bonding

The polarity of a covalent bond is related to the difference in electronegativity between the two atoms involved in the bond.

Non-polar covalent: There is little or no difference between the electronegativity of bonding atoms

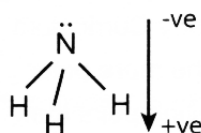
Polar covalent: Significant difference between the electronegativities of bonding atoms

Note: if the difference is significant enough that the valence electron(s) move from one atom to the other and are no longer shared, the bond is *ionic*.

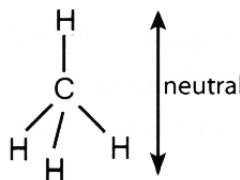
In a polar covalent bond the electron density is greater around the more electronegative atom so that end of the bond will have a partial negative charge (δ^-) and the other will have a partial positive charge (δ^+). This is known as a *dipole* (arrangement with two poles).

Molecular Polarity

For a molecule to be polar, it must contain polar covalent bonds and the molecular shape must be arranged in such a way that overall there is a positive and a negative end (net molecular dipole).



NH₃ has a net molecular dipole.



CH₄ has polar covalent bonds but the symmetrical spatial arrangement cancels out the polarity.

Intermolecular (secondary) forces

The covalent bonding in molecules (intramolecular) is **primary** bonding, holding the atoms together within the molecule. These are **strong** bonds requiring a large amount of energy to break.

Secondary (intermolecular) forces describe the interaction between molecules, and are much weaker than primary bonding.

Types of secondary interactions (forces):

- Dispersion forces (between non-polar molecules)
 - Random movement of electrons can cause a temporary dipole to form in a molecule. This can induce a dipole in a neighbouring molecule and result in attractive force.
- Dipole-dipole interactions (between polar molecules)
 - One section of the molecule is more negative than the other and will attract to a positive section of a neighbouring molecule.
 - Stronger than dispersion forces
- Hydrogen bonding (a special, strong case of dipole-dipole interaction)
 - Involves hydrogen and usually fluorine, nitrogen or oxygen
 - Since the hydrogen atom has only one electron it can be left unshielded while in a polar bond and form a strongly positive dipole
 - Stronger than ordinary dipole-dipole forces

Melting and boiling points

The melting and boiling points of molecular substances are determined by the strength of the secondary forces (stronger secondary forces means higher melting and boiling points).

- The strengths of secondary interactions between non-polar molecules depend on their molar mass, because there are more electrons in larger molecules and hence stronger dispersion forces between the molecules.
- The strengths of secondary interactions between molecules of similar molar mass depend on the polarity of the molecules.
- The polarity of a molecule depends on the polarity of the bonds (which depends on the difference in electronegativity between atoms), and the arrangement of the dipoles. For molecules with multiple polar groups, polarity increases with the number of polar groups.