Covalent bonding

4.2.1.4 · Bonding, structure and the properties of matter · revision notes

How non-metal atoms share pairs of electrons to form covalent bonds, the three kinds of covalent substance (small molecules, very large molecules and giant structures), and the different ways of drawing them. You must be able to draw dot and cross diagrams for eight small molecules and work out formulae from diagrams.

Key facts

- Covalent bond = a shared pair of electrons between two non-metal atoms (strong)
- O_2: double bond, O=O. N_2: triple bond, N≡N
- Covalent substances: small molecules, very large molecules (polymers), giant covalent structures
- Molecular formula = the actual numbers of atoms in one molecule (do not simplify)
- Bonds usually formed: H 1, Cl 1, O 2, N 3, C 4
- Non-bonding pairs: each Cl in Cl_2 3; O in H_2O 2; N in NH_3 1; C in CH_4 0
- Displayed formula: one line = one covalent bond

Notes

Sharing pairs of electrons

- When non-metal atoms bond, they **share pairs of electrons**. Each shared pair is one **covalent bond**. Covalent bonds are **strong**.
- Atoms share electrons until each has a full outer shell. The number of bonds an atom usually forms is the number of electrons it needs: H and Cl form 1, O forms 2, N forms 3, C forms 4.
- Two shared pairs make a **double bond** (O=O); three shared pairs make a **triple bond** (N≡N).

The eight dot and cross diagrams to learn

- Hydrogen, H_2: one shared pair. Chlorine, Cl_2: one shared pair, plus three non-bonding pairs (lone pairs) on each Cl.
- Hydrogen chloride, HCl: one shared pair, plus three non-bonding pairs on the Cl.
- Water, H_2O: two shared pairs (one to each H), plus two non-bonding pairs on the O.
- Ammonia, NH_3: three shared pairs, plus one non-bonding pair on the N. Methane, CH_4: four shared pairs and no non-bonding pairs.



water, H_2O **methane, CH_4**

× from O or C, • from H

Outer shells only. Each shared pair (one dot, one cross) is one covalent bond.

- Oxygen, O_2: two shared pairs, plus two non-bonding pairs on each O. Nitrogen, N_2: three shared pairs, plus one non-bonding pair on each N.



oxygen, O_2: double bond nitrogen, N_2: triple bond

Two shared pairs make a double bond; three make a triple bond.

- Check: every atom except hydrogen ends with 8 outer electrons; each hydrogen has 2.

Three kinds of covalent substance

- **Small molecules**: a few atoms joined by covalent bonds, e.g. the eight above and CO_2.
- **Very large molecules**, such as **polymers**: long chains of atoms. A polymer is drawn as its repeating unit in brackets, with the bonds passing through the brackets and *n* after them, where n is a large number.
- **Giant covalent structures**: huge networks in which every atom is covalently bonded, e.g. diamond and silicon dioxide. A diagram of one shows bonds running off its edges: the network continues in all directions.

Ways of drawing covalent substances

- **Dot and cross**: shows the shared pairs and which atom each electron came from, but not the 3D shape.
- **Displayed formula**: each covalent bond is a line, e.g. H–O–H. It shows which atoms are bonded, but not the non-bonding electrons or the 3D shape. Lines are also used for polymer repeating units and giant structures.
- **Ball and stick (3D)**: shows the shape, but bonds are not really sticks, and the atoms are really much closer together and not to scale.
- A **molecular formula** gives the actual number of each type of atom in one molecule. Count them from the diagram and do not cancel down: ethane is C_2H_6, not CH_3.

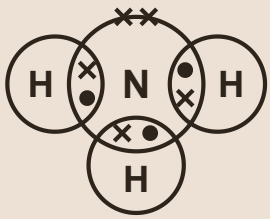
How to answer each type of question

Draw a dot and cross diagram for a molecule 2 marks **Grade 5**

1. Work out how many bonds each atom needs to fill its outer shell.
2. For each bond, put one shared pair (a dot and a cross) where the atoms overlap.
3. Add non-bonding pairs so that every atom except hydrogen has 8 outer electrons.
4. Check that each atom still has its own original number of outer electrons.

Example. Draw a dot and cross diagram for a molecule of ammonia, NH_3. Show the outer shell electrons only.

Model answer.



× nitrogen electron • hydrogen electron

The diagram should show:

three shared pairs, each one dot and one cross, one between the N and each H (1)

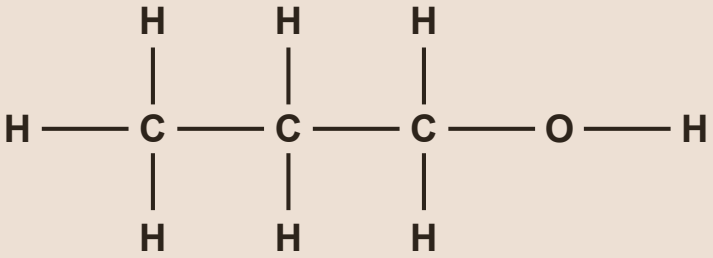
one non-bonding pair on the nitrogen, so the nitrogen has 8 outer electrons in total (1)

Deduce the molecular formula from a diagram

1 to 2 marks | **Grade 4**

1. Count the atoms of each element in the diagram, including the ones at the ends.
2. Write the formula with the numbers as subscripts (carbon first, then hydrogen, then other elements, is the usual order).
3. To count bonds, count every line: one line is one covalent bond.

Example. The displayed formula of a molecule is shown.



(a) Give the molecular formula of the molecule.

(b) How many covalent bonds are there in one molecule?

Model answer.

(a) C_3H_8O (1)

(b) 11 (1)

(7 C–H, 2 C–C, 1 C–O and 1 O–H)

Explain the bonding in a molecule with a double or triple bond

2 marks | **Grade 5**

1. Say how many electrons each atom needs to fill its outer shell.
2. Say how many pairs of electrons are shared, and name the bond.

Example. A nitrogen atom has five electrons in its outer shell.
Explain why the two atoms in a nitrogen molecule, N_2, are joined by a triple bond.

Model answer. Each nitrogen atom needs three more electrons to get a full outer shell of 8 (1). So the two atoms share three pairs of electrons, which is a triple bond (1).

Compare ways of representing a molecule 2 marks **Grade 5**

1. Say what each type of diagram shows well.
2. Say what each one leaves out (3D shape, where the electrons came from, non-bonding electrons, relative sizes).

Example. Methane can be shown as a dot and cross diagram or as a ball and stick model. Give one advantage of each way of representing methane.

Model answer.

Dot and cross: shows the shared pairs of electrons / which atom each electron in a bond came from (1).

Ball and stick: shows the 3D shape of the molecule (1).

Don't lose marks

- Drawing a shared pair with only one electron, or with both electrons from the same atom. Each covalent bond here has one electron from each atom.
- Forgetting the non-bonding pairs on O, N and Cl.
- Drawing a single bond in O_2 or N_2.
- Simplifying a molecular formula, e.g. writing CH_3 for ethane.
- Saying covalent bonds are weak. The bonds are strong; the forces between molecules are weak.
- Putting extra electrons on a hydrogen atom. Hydrogen has only its shared pair: no non-bonding electrons.

More tips

Memory tricks

- HONC 1234: hydrogen forms 1 bond, oxygen 2, nitrogen 3, carbon 4. Chlorine, like hydrogen, forms 1.
- Bonds needed = 8 − number of outer electrons (for atoms in Groups 4 to 7); hydrogen needs just 1 more to reach 2.
- Quick check on any dot and cross diagram: count the electrons around each atom. It should be 8, or 2 for hydrogen.
- Molecular formula: count, don't cancel.

Exam technique

- Draw overlapping circles for bonded atoms and put the shared pairs in the overlap. Examiners check the number of electrons in each region.
- The question usually says 'outer shell only'. Don't waste time drawing inner shells, but if you do, make sure they are correct.
- For a limitation, name the specific thing the diagram fails to show (3D shape, relative sizes, where the electrons came from), not just 'it's not realistic'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 **Describe a covalent bond as a shared pair**

A covalent bond is a pair of electrons shared between two atoms. Covalent bonds are strong.

Grade 4

Recognise small molecules from their formulae

Formulae of a few non-metal atoms, e.g. H_2, Cl_2, HCl, H_2O, NH_3, CH_4.

Grade 4

Deduce a molecular formula from a diagram

Count every atom of each element in one molecule, e.g. C_2H_6 for ethane.

Grade 5

Draw dot and cross diagrams for simple molecules

Hydrogen, chlorine, hydrogen chloride, water, ammonia and methane, which have single bonds only.

Grade 5

Draw molecules with double and triple bonds

Oxygen, O_2, has a double bond (two shared pairs); nitrogen, N_2, has a triple bond (three shared pairs).

Grade 5

Classify covalent substances as small, large or giant

Small molecules (e.g. CH_4), very large molecules (polymers) and giant covalent structures (e.g. diamond, silicon dioxide).

Grade 5

Give limitations of each type of diagram

For example, dot and cross diagrams and displayed formulae do not show the 3D shape of a molecule.

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