A5 · Covalent bonds: bonding capacity, dot diagrams and structural formulas · Completed notes

Goals: Explain a covalent bond as a pair of electrons shared by two non-metal atoms. Use bonding capacity to decide how many bonds an atom forms and which atom goes in the middle. Draw the electron dot diagram and the structural formula of a molecule with single bonds.

These are the completed notes. The blanks are filled in and each question is worked.

Slide 1 of 8 · Non-metal atoms share electrons

In lesson A3, a metal atom gave electrons to a non-metal atom. Today both atoms are non-metals. Both need electrons, so neither can take them from the other.



two bromine atoms

Each has 7 valence electrons, with 1 single dot.

Key ideas

Two non-metal atoms **share** electrons.

A shared pair of electrons is a **covalent bond**.

A **molecule** is a separate group of atoms.

Br_2 means **2** bromine atoms.

Example

Two chlorine atoms each have 7 valence electrons. How do both atoms get 8?

1. Each atom needs 1 more electron.
2. The two atoms share one pair of electrons.
3. Both atoms count the shared pair, so each has 8.

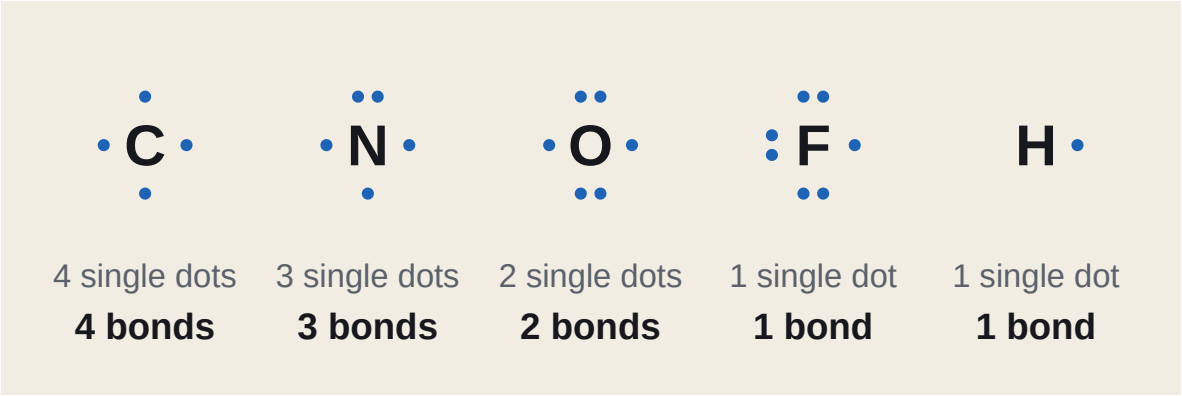
Try it

What does the molecular formula Cl_2 tell you?

1. One molecule has 2 chlorine atoms.
2. A covalent bond joins the two atoms.

Slide 2 of 8 · Bonding capacity

On the last slide, each bromine atom formed one bond. Other atoms form more. The dot diagram tells you how many.



Key ideas

A single dot is a **bonding electron**.

The number of bonds an atom forms is its **bonding capacity**.

Carbon has 4 single dots, so it forms **4** bonds.

Group 16 forms **2** bonds.

Example

Sulfur is in group 16. What is its bonding capacity?

1. Group 16 forms 2 bonds.
2. So sulfur has a bonding capacity of 2.

Try it

Phosphorus is in group 15. What is its bonding capacity?

1. Group 15 forms 3 bonds.
2. So phosphorus has a bonding capacity of 3.

Slide 3 of 8 · A molecule with one bond

You can now say how many bonds an atom forms. Next you draw a molecule. Start with the simplest kind, two atoms and one bond.

1



Turn the single dots toward each other.

H has 1 dot. Cl has 7 dots.

Key ideas

Turn the single dots **toward each other**.

A shared pair is a **bonding pair**.

Pairs that are not shared are **lone pairs**.

Hydrogen has **2** electrons, which fills its outer level.

Example

Draw the electron dot diagram of hydrogen fluoride, HF. Say how many bonding pairs and lone pairs it has.

1. Hydrogen has 1 dot. Fluorine has 7 dots.
2. Pair the two single dots between the atoms.
3. HF has 1 bonding pair. Fluorine keeps 3 lone pairs.

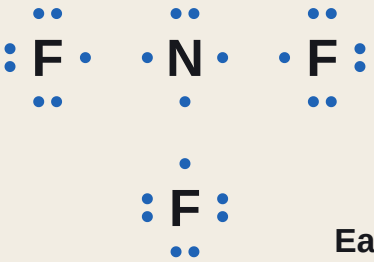
Try it

Draw the electron dot diagram of hydrogen bromide, HBr. Say how many bonding pairs and lone pairs it has.

1. Hydrogen has 1 dot. Bromine has 7 dots.
2. Pair the two single dots between the atoms.
3. HBr has 1 bonding pair. Bromine keeps 3 lone pairs.

Slide 4 of 8 · Which atom goes in the middle

HCl had two atoms, so the bond could only go between them. With three or more atoms, one atom goes in the middle. You must decide which.



N forms 3 bonds.
It goes in the middle.

Each F forms 1 bond.
They go on the outside.

Key ideas

The atom with the highest **bonding capacity** goes in the middle.

In NF_3, **nitrogen** is the middle atom.

Hydrogen and the halogens always go on the **outside**.

Example

Which atom goes in the middle of PCl_3? Say why.

1. Phosphorus forms 3 bonds. Each chlorine forms 1.
2. Phosphorus has the highest bonding capacity, so it goes in the middle.

Try it

Which atom goes in the middle of dichloromethane, CH_2Cl_2? Say why.

1. Carbon forms 4 bonds. Hydrogen and chlorine form 1 each.
2. Carbon has the highest bonding capacity, so it goes in the middle.

Slide 5 of 8 · Method: how to draw the electron dot diagram of a molecule

You have now drawn HCl and NF_3. Each time you did the same four things. Here they are as steps.

1. **Draw** each atom's electron dot diagram.
2. **Choose** the middle atom. It forms the most bonds.
3. **Pair** single dots between atoms.
4. **Count** the electrons around each atom.



Check: every atom has 8. Hydrogen has 2.

Used again in: lessons A6 and A9

Key ideas

Step 1: draw the **atoms**.

Step 2: choose the **middle** atom.

Step 3: **share** the single dots as pairs.

Step 4: **count**. Every atom has 8, and hydrogen has 2.

Example

Use the four steps to draw the electron dot diagram of water, H_2O.

1. Step 1: oxygen has 6 dots. Each hydrogen has 1 dot.
2. Step 2: oxygen forms 2 bonds, so it is the middle atom.
3. Step 3: pair each single dot on oxygen with a hydrogen dot.
4. Step 4: oxygen has 8. Each hydrogen has 2.

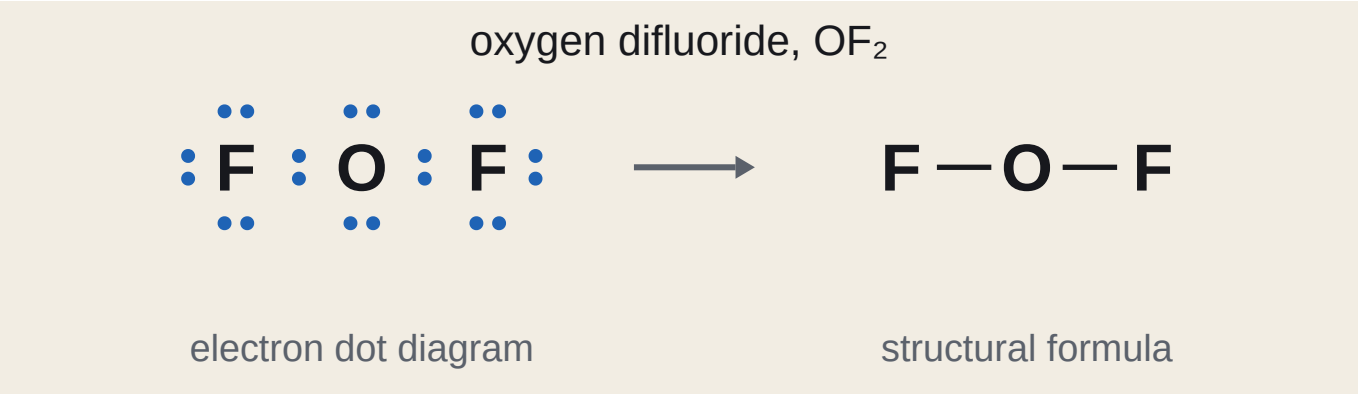
Try it

Use the four steps to draw the electron dot diagram of ammonia, NH_3.

1. Step 1: nitrogen has 5 dots. Each hydrogen has 1 dot.
2. Step 2: nitrogen forms 3 bonds, so it is the middle atom.
3. Step 3: pair each single dot on nitrogen with a hydrogen dot.
4. Step 4: nitrogen has 8. Each hydrogen has 2.

Slide 6 of 8 · The structural formula

The dot diagram of CCl_4 has a lot of dots. Drawing every dot takes time. Chemists use a shorter drawing.



Key ideas

A **structural formula** shows each bonding pair as one dash.

Lone pairs are not drawn.

The number of dashes at an atom equals its **bonding capacity**.

Example

Water has 2 bonding pairs and 2 lone pairs. Draw its structural formula.

1. Each bonding pair becomes one dash.
2. The formula is H–O–H, with 2 dashes.
3. The 2 lone pairs on oxygen are not drawn.

Try it

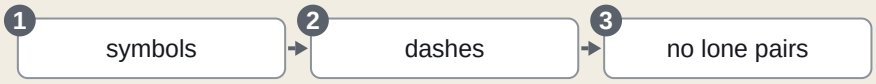
Ammonia has 3 bonding pairs and 1 lone pair. Draw its structural formula. Say how many dashes it has.

1. Each bonding pair becomes one dash.
2. Nitrogen is in the middle, with a dash to each hydrogen.
3. It has 3 dashes. The lone pair is not drawn.

Slide 7 of 8 · Method: how to turn a dot diagram into a structural formula

You just turned two dot diagrams into structural formulas. Each time you did the same three things. Here they are as steps.

1. **Copy** the symbols in the same places.
2. **Draw** one dash for each bonding pair.
3. **Leave out** the lone pairs.



Check: the dashes at each atom equal its bonding capacity.

Used again in: lessons A6 and A9

Key ideas

Step 1: copy the **symbols** in the same places.

Step 2: draw **dashes** for the bonding pairs.

Step 3: leave out the **lone pairs**.

Example

Use the three steps to draw the structural formula of hydrogen chloride, HCl.

1. Step 1: write H and Cl side by side.
2. Step 2: HCl has 1 bonding pair, so draw 1 dash.
3. Step 3: leave out the 3 lone pairs on chlorine. The formula is H–Cl.

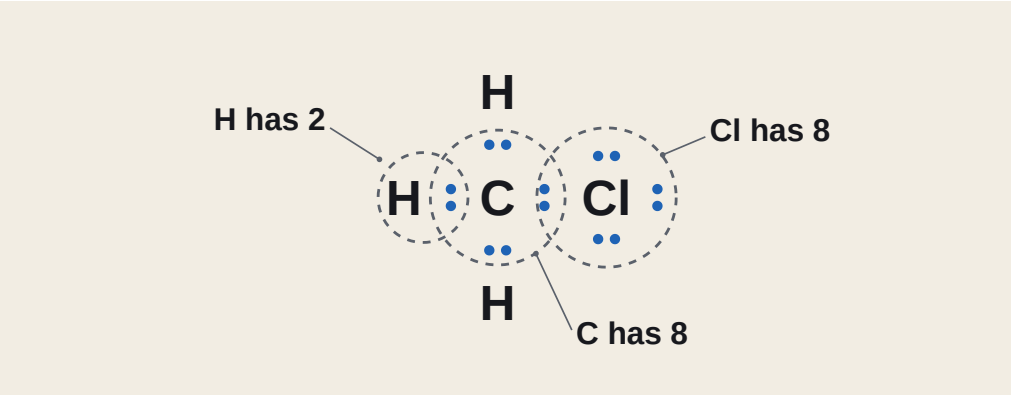
Try it

Use the three steps to draw the structural formula of carbon tetrachloride, CCl_4.

1. Step 1: write C in the middle with 4 Cl around it.
2. Step 2: CCl_4 has 4 bonding pairs, so draw 4 dashes.
3. Step 3: leave out the lone pairs on each chlorine.

Slide 8 of 8 · Check every atom

In lesson A2, the octet rule said a full outer level has 8 electrons. In a molecule, the same rule is a check. A diagram is finished only when every atom passes it.



Key ideas

Count a shared pair for **both atoms**.

In CH_3Cl, carbon has 4 bonding pairs. That is **8** electrons.

Each hydrogen has 1 bonding pair. That is **2**.

Example

In NF_3, how many electrons are around the nitrogen atom? Show your count.

1. Nitrogen has 3 bonding pairs. That is 6 electrons.
2. It has 1 lone pair. That is 2 more.
3. 6 + 2 = 8 electrons.

Try it

In OF_2, how many electrons are around the oxygen atom? Show your count.

1. Oxygen has 2 bonding pairs. That is 4 electrons.
2. It has 2 lone pairs. That is 4 more.
3. 4 + 4 = 8 electrons.