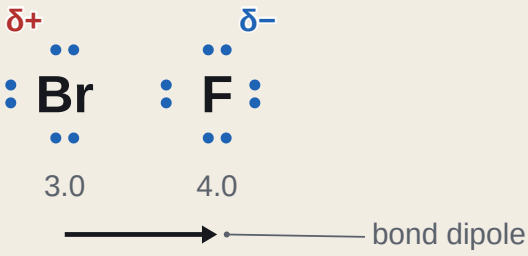
A10 · Polar and non-polar molecules · Completed notes

Goals: Explain what makes a molecule polar or non-polar. Use the shape of a molecule to decide whether its bond dipoles cancel. Decide whether a molecule is polar, and give the reason.

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

Slide 1 of 7 · From polar bonds to polar molecules

In lesson A7, a bond could be polar. In lesson A9, a molecule got a shape. Today you put the two together and ask if a whole molecule is polar.



a polar bond has a δ− end and a δ+ end

Key ideas

A **polar molecule** has a slightly negative side and a slightly positive side.

A **non-polar molecule** has no negative side and no positive side.

The bond dipole arrow points to the **δ− end**.

Example

What is the difference between a polar bond and a polar molecule?

1. A polar bond has a δ− end and a δ+ end.
2. A polar molecule has a slightly negative side and a slightly positive side.

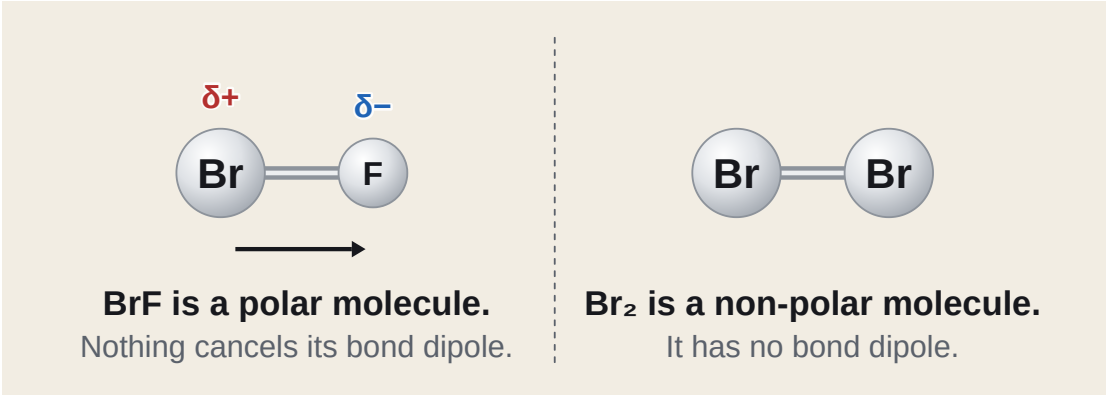
Try it

A molecule has no negative side and no positive side. What kind of molecule is it?

1. No side is slightly negative or slightly positive.
2. So it is a non-polar molecule.

Slide 2 of 7 · A molecule with one bond

Start with the simplest case, a molecule with two atoms. It has only one bond, so that bond decides everything.



BrF is a polar molecule.
Nothing cancels its bond dipole.

Br_2 is a non-polar molecule.
It has no bond dipole.

Key ideas

A molecule with two different atoms has one **polar bond**.

Nothing can **cancel** it, so the molecule is polar.

Two atoms of the same element make a **non-polar** molecule.

Example

Is hydrogen chloride, HCl, a polar molecule? Say why.

1. HCl has two different atoms, so its one bond is polar.
2. Nothing can cancel it, so HCl is polar.

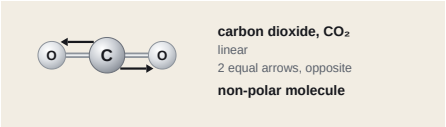
Try it

Is nitrogen gas, N_2, a polar molecule? Say why.

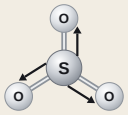
1. N_2 has two atoms of the same element.
2. Its bond is non-polar, so N_2 is non-polar.

Slide 3 of 7 · Bond dipoles that cancel

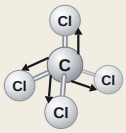
On the last slide, one polar bond made a polar molecule. With several polar bonds, the shape matters. The bonds can pull against each other.



carbon dioxide, CO_2
linear
2 equal arrows, opposite
non-polar molecule



sulfur trioxide, SO_3
trigonal planar
3 equal arrows, evenly spread
non-polar molecule



carbon tetrachloride, CCl_4
tetrahedral
4 equal arrows, evenly spread
non-polar molecule

Key ideas

Equal arrows that point in opposite directions **cancel**.

CO_2 is linear, so it is a **non-polar molecule**.

Linear, trigonal planar and **tetrahedral** shapes can cancel.

They cancel when all the outer atoms are **the same**.

Example

Carbon tetrafluoride, CF_4, is tetrahedral. All 4 outer atoms are fluorine. Is CF_4 polar? Say why.

1. Each arrow points from carbon to fluorine.
2. The 4 arrows are equal and evenly spread.
3. They cancel, so CF_4 is non-polar.

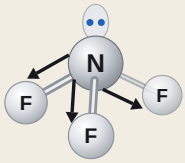
Try it

Silicon tetrachloride, $SiCl_4$, is tetrahedral. All 4 outer atoms are chlorine. Is $SiCl_4$ polar? Say why.

1. Each arrow points from silicon to chlorine.
2. The 4 arrows are equal and evenly spread.
3. They cancel, so $SiCl_4$ is non-polar.

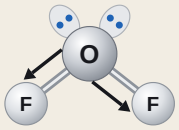
Slide 4 of 7 · Bond dipoles that never cancel

On the last slide, equal arrows pulled against each other and cancelled. A lone pair on the centre atom stops that. The molecule is lopsided.



nitrogen trifluoride, NF_3
trigonal pyramidal
the arrows all lean one way
polar molecule

The fluorine atoms are the δ− side.



oxygen difluoride, OF_2
angular
the arrows all lean one way
polar molecule

The fluorine atoms are the δ− side.

Key ideas

A **lone pair** on the centre atom makes the molecule lopsided.

In NF_3, the 3 arrows do **not cancel**.

Trigonal pyramidal and **angular** molecules with polar bonds are polar.

Example

Ammonia, NH_3, is trigonal pyramidal. Is it polar? Say why.

1. Each bond between nitrogen and hydrogen is polar.
2. The 3 arrows lean the same way, so they do not cancel.
3. So NH_3 is polar.

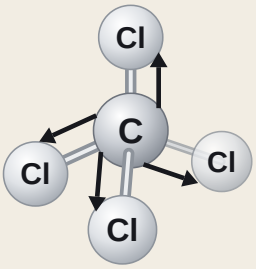
Try it

Water, H_2O, is angular. Is it polar? Say why.

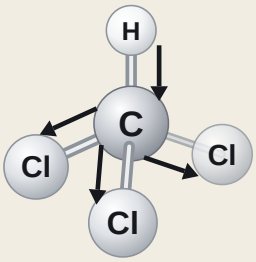
1. Each bond between oxygen and hydrogen is polar.
2. The 2 arrows are not opposite, so they do not cancel.
3. So H_2O is polar.

Slide 5 of 7 · Different outer atoms

On slide 3, three shapes cancelled because they are symmetrical. "Symmetrical" means the same on every side. But the outer atoms must match too.



CCl_4 is non-polar.
Its 4 outer atoms are the same.



$CHCl_3$ is polar.
Its outer atoms differ.

Key ideas

Symmetrical means the same on every side.

$CHCl_3$ is tetrahedral, but its arrows are **not equal**.

So the arrows do not cancel, and $CHCl_3$ is **polar**.

A molecule made of only carbon and hydrogen is **non-polar**.

Example

Chloromethane, CH_3Cl, is tetrahedral. Is it polar? Say why.

1. The outer atoms are 3 hydrogen and 1 chlorine.
2. They do not match, so the arrows are not equal.
3. They do not cancel, so CH_3Cl is polar.

Try it

Butane, C_4H_{10}, is made of only carbon and hydrogen. Is it polar? Say why.

1. A molecule made of only carbon and hydrogen is non-polar.
2. So butane is non-polar.

Slide 6 of 7 · Method: how to decide whether a molecule is polar

You have now judged nine molecules. Each time you did the same four things. Here they are as steps.

1. **Find** the shape around the centre atom.
2. **Draw** a bond dipole on each polar bond.
3. **Ask** if the arrows cancel.
4. **State** polar or non-polar, with the reason.



Check: arrows cancel with matching outer atoms and no lone pair.

Used again in: lessons A11 and A12

Key ideas

Step 1: find the **shape**.

Step 2: draw the bond dipole **arrows**.

Step 3: ask if the arrows **cancel**.

Step 4: write the **answer**: polar or non-polar.

Example

Use the four steps on phosphorus trichloride, PCl_3. It has 1 lone pair on phosphorus.

1. Step 1: PCl_3 is trigonal pyramidal.
2. Step 2: each arrow points from phosphorus to chlorine.
3. Step 3: the arrows lean the same way, so they do not cancel.
4. Step 4: PCl_3 is polar.

Try it

Use the four steps on carbon tetrabromide, CBr_4. It has no lone pairs on carbon.

1. Step 1: CBr_4 is tetrahedral.
2. Step 2: each arrow points from carbon to bromine.
3. Step 3: the 4 arrows are equal and evenly spread, so they cancel.
4. Step 4: CBr_4 is non-polar.

Slide 7 of 7 · Sort a set

Now use the four steps on six molecules. Decide each one before you look at the last column.

Molecule	Shape	Cancel?	Molecule is
SiH_4	tetrahedral	yes	non-polar
NF_3	trigonal pyramidal	no	polar
SiI_4	tetrahedral	yes	non-polar
OF_2	angular	no	polar
CH_2Cl_2	tetrahedral	no	polar
HCN	linear	no	polar

Key ideas

SiH_4 and SiI_4 are **symmetrical**, so they are non-polar.

NF_3 and OF_2 have **lone pairs** on the centre atom, so they are polar.

CH_2Cl_2 and HCN have outer atoms that **differ**, so they are polar.

Example

Nitrogen trichloride, NCl_3, has 3 bonds and 1 lone pair on nitrogen. Is it polar? Say why.

1. It has 4 groups with 1 lone pair, so it is trigonal pyramidal.
2. The arrows do not cancel, so NCl_3 is polar.

Try it

Silicon tetrafluoride, SiF_4, has 4 bonds and no lone pairs on silicon. Is it polar? Say why.

1. It is tetrahedral, and all 4 outer atoms are the same.
2. The arrows cancel, so SiF_4 is non-polar.