Higher Chemistry: Unit 1 - Chemical Changes and Structure

Part A – Periodicity and Bonding

Lesson 6 – Polarity and the Bonding Continuum

Learning Outcomes

By the end of this lesson you should know:

1. It is the difference in electronegativity that influences whether a bond is covalent or ionic.

2. Covalent and ionic bonds can be thought of as different ends of the same scale.

3. Covalent bonds can be one of two types; polar or non-polar, depending on the difference in electronegativity.

4. Polar bonds can be written using a δ+ or δ- symbol.

Success Criteria

You will have been successful in this lesson if you:

1. Read and learn the material given

2. Watch the links provided

3. Complete Exercise 1.6 and check your answers.

There is also a further reading section to help you gain more depth of understanding for this section.

MS Teams will be monitored throughout the week by a chemistry teacher. If you need help or clarification with either the task or the content of the lesson, just ask.

Links to Prior Knowledge

You may wish to revise the following to help you understand this lesson:

- Higher chemistry – electronegativity

- Data booklet https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf

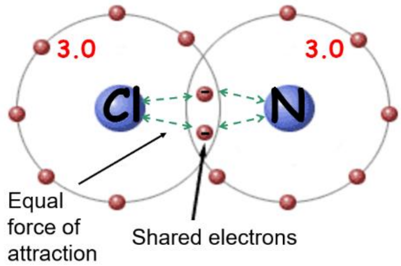
Introduction - You don't need to write this part down, just read it, or watch this clip – Lesson 5 – Polarity and the Bonding Continuum

Covalent and Ionic Bonding

In National 5 you learned that covalent and ionic bonds were two very different kinds of bond… that wasn't exactly correct (our bad - sorry). In fact, whether atoms make covalent or ionic bonds with each other, is all to do with their pull for the bonding electrons, in other words, their difference in electronegativity.

(Remember electronegativities are listed on page 11 of the data booklet.)

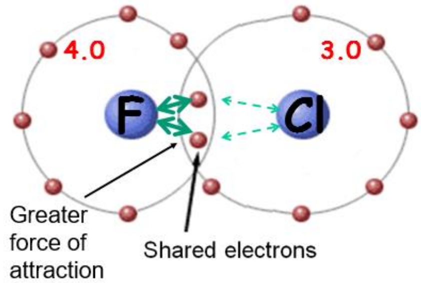
Let's say that chlorine and nitrogen want to bond together. Chlorine and nitrogen both have the **same electronegativity**, 3.0. So when they bond together, they both have an equal pull on their bonding electrons, so they share those electrons equally.



(Difference in electronegativity, ΔEN = 3.0 - 3.0 = 0)

This is called a **pure covalent bond** or a **non-polar covalent bond.**

Let's now look at what would happen if chlorine bonded to fluorine. Chlorine and fluorine have **slightly different electronegativities**, chlorine is 3.0 and fluorine is 4.0. This means that fluorine has a greater pull for bonding electrons. When fluorine and chlorine bond, the electrons are not equally shared. This time, the electrons are pulled closer to the fluorine atom, resulting in an uneven covalent bond.



(Difference in electronegativity, ΔEN = 4.0 - 3.0 = 1.0)

This is called a **polar covalent bond.**

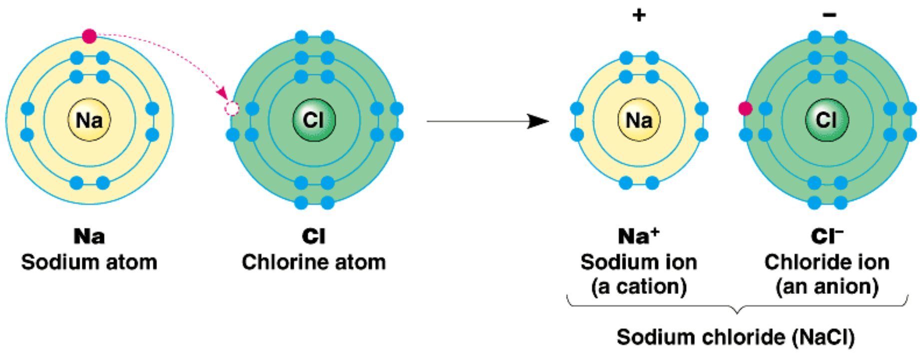
This unequal sharing means that the fluorine end of the bond becomes **slightly more negative** (because negative electrons are closer to that side) and the chlorine end of the bond becomes slightly more positive, (because electrons are further from that side.)

$$^{\delta-}F — Cl^{\delta+}$$

The symbol δ– or δ+ (delta negative or delta positive) is given to describe the slight change in charge.

The name **POLAR covalent bond** is given because the ends of the bond are now opposites of one another (like north and south).

Now let's look at what would happen if chlorine bonded to sodium. Chlorine and sodium **have very different electronegativities**, chlorine is 3.0 and sodium is 0.9 (ΔEN = 2.1). This means that chlorine has a much greater pull for bonding electrons. When chlorine and sodium bond, the electrons are pulled so close to the chlorine, that they leave sodium entirely, causing sodium to become a positive ion and chlorine to become a negative ion.



This has now formed an **ionic bond.**

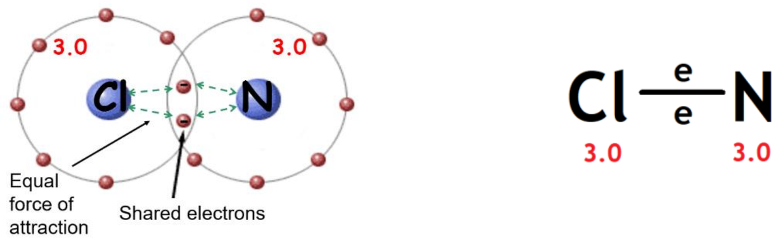
Notes - Below is the summary you should write/ save / print a stick into your notes

Electronegativity and the Bonding Continuum

Whether two atoms form a covalent or ionic bond, depends on the difference between their electronegativities.

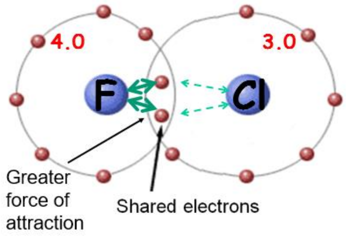
No difference in electronegativity will result in the electron pair being shared equally between the atoms.

ie. a non-polar covalent bond (also called a pure covalent bond)



A small difference in electronegativity will result in the electron pair being shared between the atoms, but shared unequally.

ie. a polar covalent bond



$$\overset{\delta-}{\mathrm{F}} \overset{e}{\underset{e}{—}} \overset{\delta+}{\mathrm{Cl}}$$

4.0 3.0

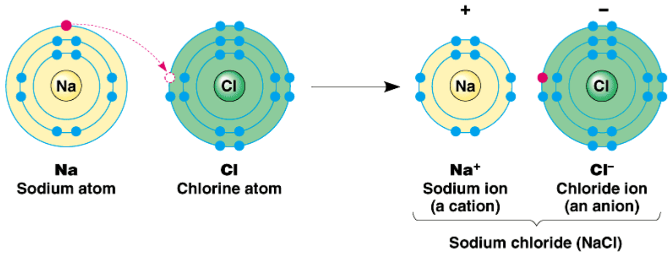
Polar bonds can be written with symbols to show the slight charge: $\overset{\delta-}{\mathrm{F}} — \overset{\delta+}{\mathrm{Cl}}$

<u>A large difference in electronegativity</u> will result in the electron pair being pulled fully to one side, resulting in the formation of a negative and positive ion.

Cl^- Na^+

3.0 0.9

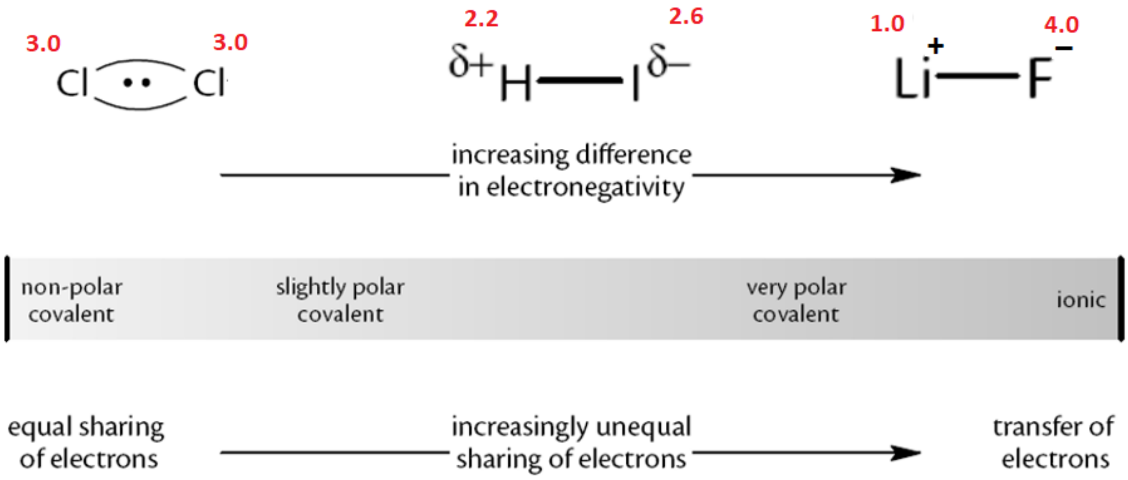
ie. an ionic bond



The difference in electronegativity is called the "ionic character", in other words, the greater the difference in electronegativity, the greater the "ionic character".

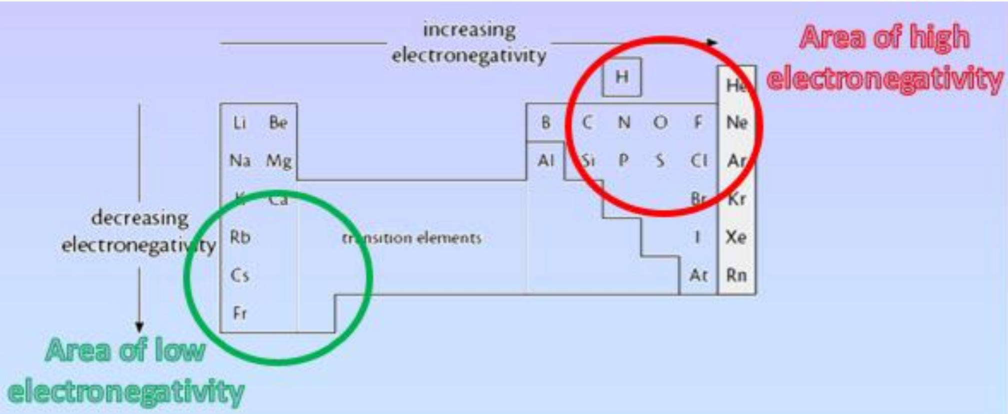
<u>The Bonding Continuum</u>

Non-polar covalent, polar covalent and ionic bonding are therefore part of the same scale. This is called the bonding continuum.



Covalent and Ionic compounds and the Periodic Table

The periodic table can be looked at in terms of areas of high electronegativity (mainly non-metals) and areas of low electronegativity (mainly metals)



Ionic compounds tend to be between metals and non-metals (because of the larger differences in electronegativity)

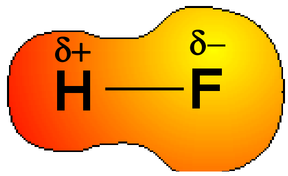
Covalent compounds tend to be between non-metals (because of the smaller differences in electronegativity)

Learning Outcomes

You should now know:

1. Non-polar covalent bonds (pure covalent) are formed between atoms with the same electronegativities.

2. Polar covalent bonds are formed between atoms with different electronegativities. The uneven pull of electrons gives rise to partial charges on the atoms within the bond. The atom with a larger electronegativity has a slightly negative (δ^-) charge and the atom with the smaller electronegativity has a slightly positive (δ^+) charge.



3. Pure covalent bonding and ionic bonding can be considered as opposite ends of a bonding continuum, with polar covalent bonding lying between these two extremes.

4. The bonding continuum is used to understand different types of bonding by observing variations in electronegativity between atoms.

5. The difference in electronegativities between bonded atoms gives an indication of the ionic character. The larger the difference, the more polar the bond will be. If the difference is large, then the movement of bonding electrons from the element of lower electronegativity to the element of higher electronegativity is complete, resulting in the formation of ions.

Further Reading

To learn more about the bonding continuum. Follow the links below:

BBC Bitesize: https://www.bbc.co.uk/bitesize/guides/zt9887h

Read pages 1-5

Evans2 chem web: https://www.evans2chemweb.co.uk/login/index.php#

Username: snhs password: giffnock

Select any teacher → revision material → CfE Higher → Structure and Bonding

Questions

Complete Exercise 1.6 and check your answers

Exercise 1.6 – Polarity and Bonding Continuum

1. The hydrogen-oxygen bond in water is polarised as shown in the diagram below.

$$\overset{\delta+}{H} — \overset{\delta-}{O}$$

(a) Explain why the bond is polarised as shown above.

(b) Look at examples (i) to (iv) below and determine if they will contain a polar bond. If any of the bonds are polar, draw a diagram similar to the one shown for the hydrogen-oxygen bond.

(i) hydrogen to bromine
(ii) nitrogen to chlorine
(iii) hydrogen to sulfur
(iv) sulfur to chlorine
(v) phosphorus to chlorine
(vi) phosphorus to hydrogen

2. The bond between hydrogen and chloride can be described as being polar covalent.

(a) Write a diagram for hydrogen chloride showing the correct charges above each atom.
(b) With reference to your answer in part (a) explain why hydrogen chloride is described as polar covalent.
(c) The bond between the two hydrogens in a hydrogen molecule, H_2, is referred to as "pure covalent" or "non-polar covalent".
Explain what is meant by this.

3. (a) Copy and complete the table below for the following substances.

Substance	caesium oxide	chlorine	fluorine iodide	sodium bromide
Difference in electronegativity				

(b) From the table, predict which of the following substances:
(i) is likely to be non-polar covalent
(ii) has the most ionic character
(iii) is likely to be polar covalent

4. Bonding continuum is a concept used by chemists to help them predict the type of bonding present in different substances. A pupil wrongly concluded that the two compounds, aluminium phosphide and aluminium fluoride would be ionic because they both contain a metal and non-metal.
By considering the bonding continuum, explain which compound is likely to be ionic and which is likely to be polar covalent.

Exercise 1.1 – ANSWERS

1. a) Because oxygen (3.5) has a greater electronegativity than hydrogen (2.2)

b)i) $\overset{\delta+}{H}\text{-}\overset{\delta-}{Br}$ iii) $\overset{\delta+}{H}\text{-}\overset{\delta-}{S}$ iv) $\overset{\delta+}{S}\text{-}\overset{\delta-}{Cl}$ v) $\overset{\delta+}{P}\text{-}\overset{\delta-}{Cl}$

2. a) $\overset{\delta+}{H}\text{-}\overset{\delta-}{Cl}$

b) Hydrogen chloride is described as polar covalent because of the difference in electronegativity of the hydrogen and chlorine atoms. Chlorine has a greater electronegativity than hydrogen and therefore has a greater share of the bonding electrons. As a result, the chlorine atom is slightly more negative with respect to the hydrogen atom. As a result a polar covalent bond forms.

c) Hydrogen, H_2, is described as non-polar or pure covalent because both the hydrogen atoms have the same electronegativity and therefore share the bonding electrons equally.

3. a)

Substance	caesium oxide	chlorine	fluorine iodide	sodium bromide
Difference in electronegativity	2.7	0	1.4	1.9

b)i) chlorine ii) caesium oxide iii) fluorine iodide

4. Aluminium fluoride will have a greater difference in electronegativity than aluminium phosphide. Therefore, aluminium fluoride is likely to be more ionic and aluminium phosphide is likely to be more polar covalent.