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Electronegativity

Suitable for Senior Cycle Chemistry

NARRATOR: Tara Ryan, EPI•STEM, University of Limerick
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Syllabus

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2. CHEMICAL BONDING (CONTINUED)			
Content	Depth of Treatment	Activities	Social and Applied Aspects
2.4 Electronegativity (Time needed: 2 class periods)	Electronegativity. Periodic variation of electronegativity – explanation for general trends in values: (i) down a group (ii) across a period. Electronegativity differences and polarity of bonds.	Prediction of bond type using electronegativity differences.	

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Overview of Topics

- What is Electronegativity?
- Pauling Scale (Trends & Values)
- What are Polar Covalent Bonds?
- Uses of Electronegativity
- Electronegativity Simulation

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Types of Bonding

Intramolecular Bonding	Intermolecular Forces
Bonding that takes place <u>within</u> a molecule, holding atoms together.	**The forces of attraction that exist <u>between</u> molecules.**
• Ionic Bonds	• Van Der Waals Forces
• Covalent Bonds	• Dipole-Dipole Forces
• Metallic Bonds	• Hydrogen Bonding

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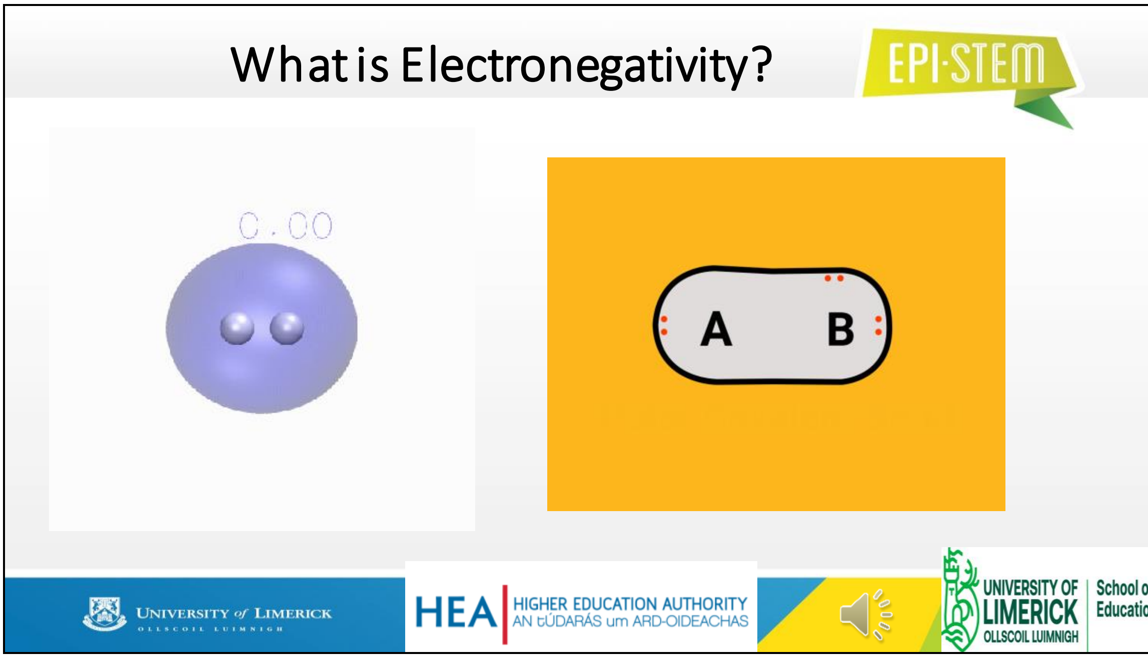
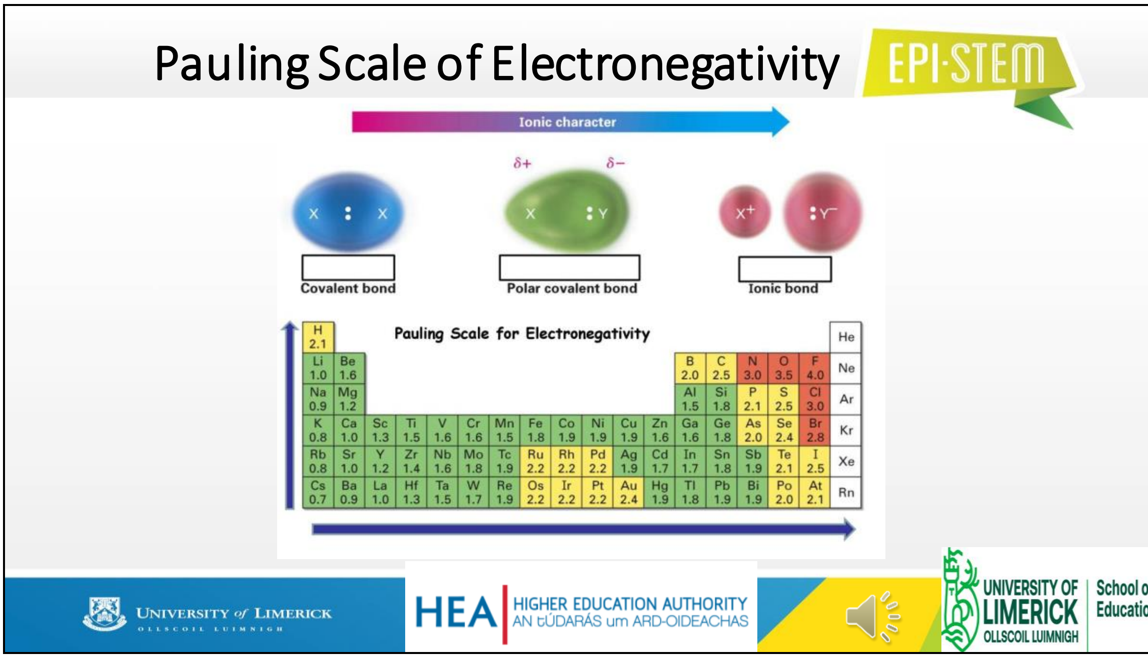
When referring to bonding in chemistry, it's important to make clear distinctions. Intramolecular bonding refers to bonding that takes places within a molecule, holding different atoms together. Intermolecular forces, are the forces of attraction that exist between molecules.

In relation to electronegativity, the leaving certificate chemistry course focuses on the interactions of ionic and covalent bonding.



Electronegativity is the relative attraction that an atom in a molecule has for the shared paired of electrons in a covalent bond.

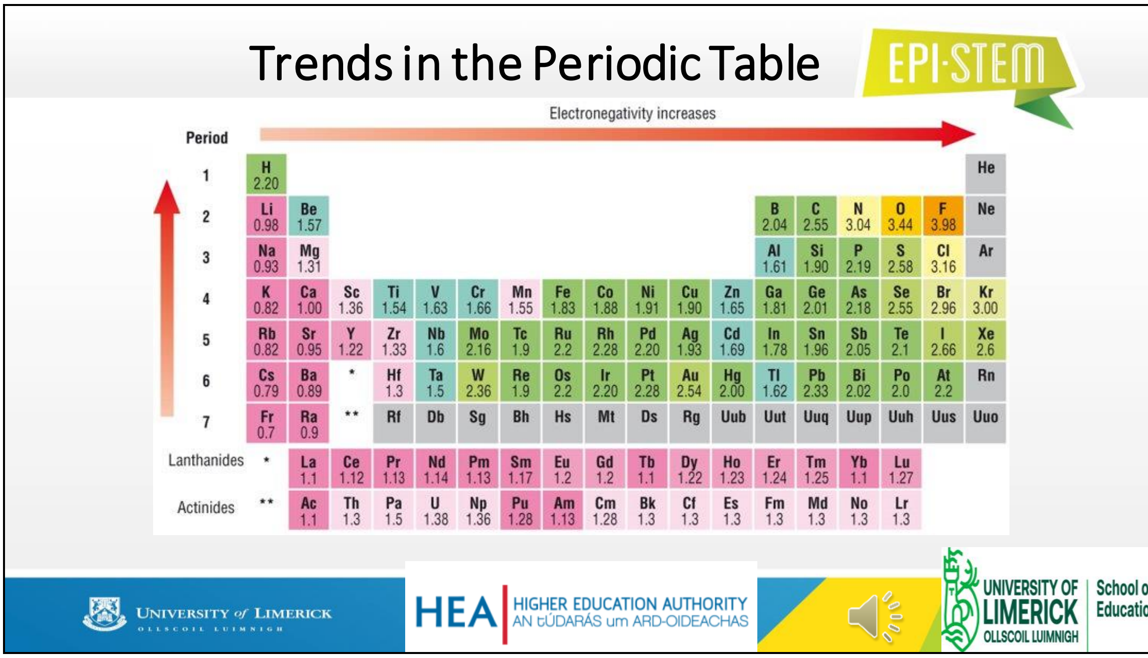


H 2.1																	He
Li 1.0	Be 1.6											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe
Cs 0.7	Ba 0.9	La 1.0	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.1	Rn

Pauling scale of electronegativity is a numerical scale of electronegativities based on bond-energy calculations for different elements joined by covalent bonds.

Pauling based his scale on thermochemical data, particularly bond energies, which allowed him to calculate differences in electronegativity between atoms in a covalent bond. He assigned a value of 4.0 to fluorine, the most electronegative element, and calculated other values with respect to that.

The scale ranges from zero to four. The higher the value, the better the atom is at attracting an electron towards itself. This is also referred to the pulling power, or the energy needed to break the chemical bonds.



Electronegativity values tend to follow a trend in the periodic table.

The values increase across the rows and decrease down the groups.

<u>Across a Period:</u>
•Number of protons increases
•Nuclear charge increases
•Atomic radius decreases
•Electronegativity increases.

<u>Down a Group:</u>
•Adding an extra level of e-
Shieling outer e- from nucleus
•Even though nuclear charge increases
The e- not attracted as strongly.
•Increasing atomic radius decreases electronegativity.

Electronegativity Trends

More Electronegative	Less Electronegative
•Very reactive non-metals •E.g. fluorine/ chlorine	•Very reactive metals •E.g. Potassium/ Sodium **Electropositive:** Elements with low electronegativity

Elements with higher electronegative values, are usually very reactive non-mentals, like fluorine and chlorine.

Elements with lower electronegativity values, are referred to electropositive. These are usually very reactive metals, like potassium and sodium.

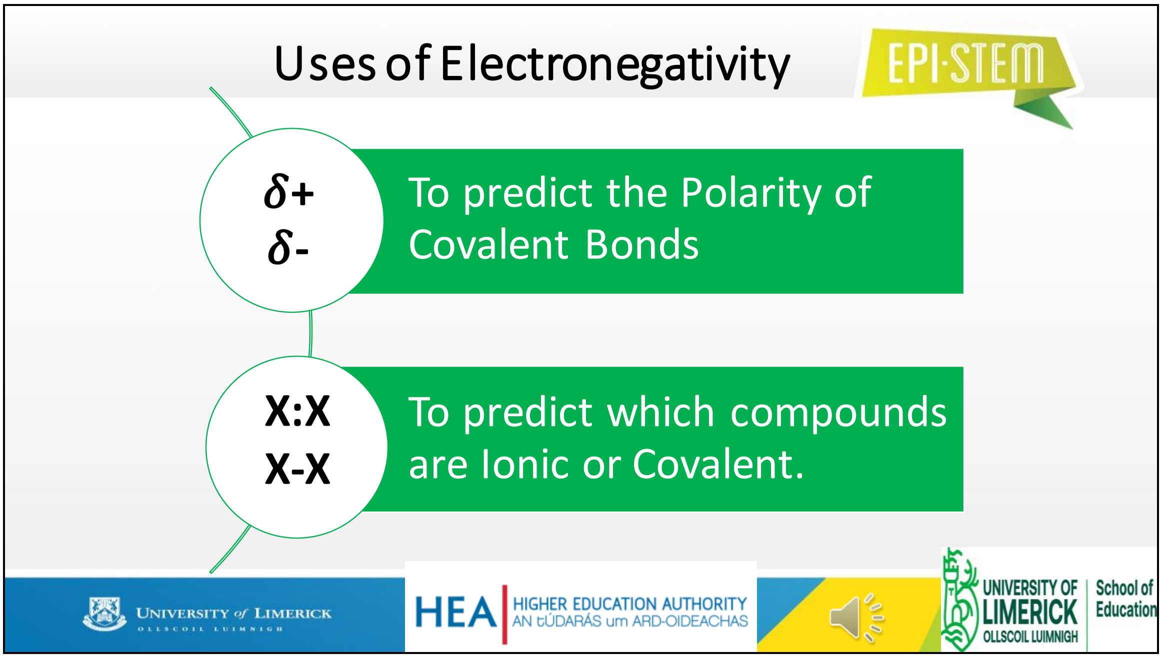
Types of Covalent Bonding

	Pure Covalent Bonding	Polar Covalent Bonding
Compound	PH_3	HCl
Electronegativity Values	P 2.19 H 2.2	Cl 3.0 δ- H 2.2 δ+
Electronegativity Difference	0.01	0.8

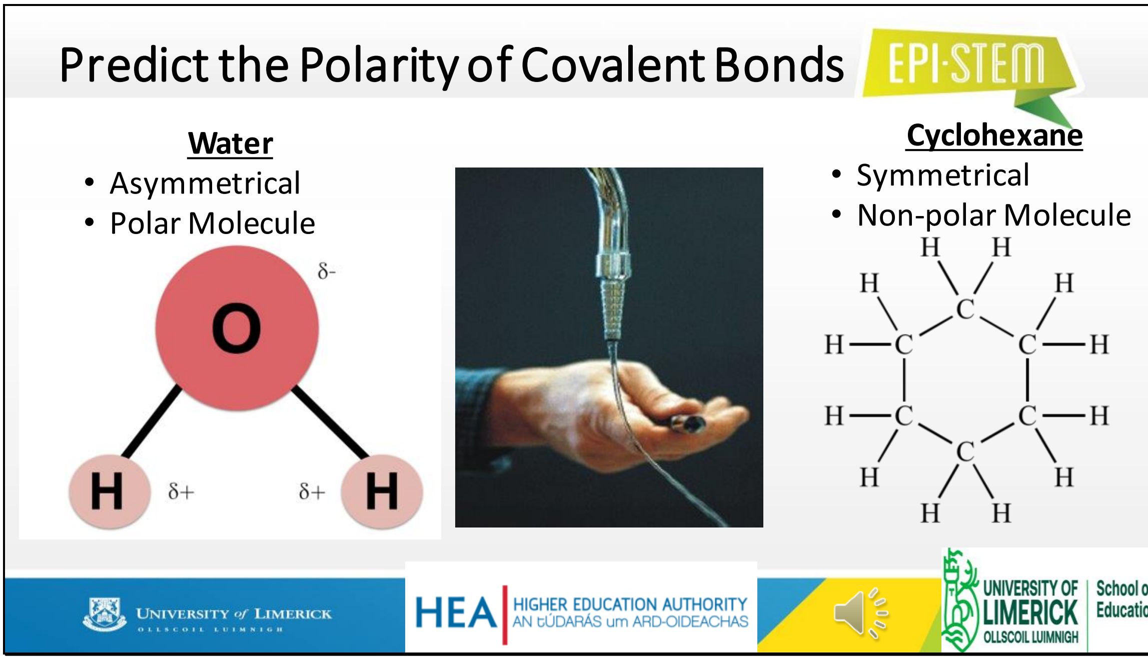
In covalent bonding, electrons are shared between atoms. Electronegativity values can give us an insight into the type of covalent bonds between atoms.

In a pure covalent bond, there is an equal sharing of electron pairs between the atoms bonded. For example, phosphine. The electronegativity values of phosphorous is 2.19 and for hydrogen is 2.2.

Chlorine is a more electronegative element than hydrogen, meaning that the electrons are more attracted to its atom.
The hydrochloric compound is a polar covalent molecule, meaning that the bond between hydrogen and chlorine is a polar covalent bond.
A polar covalent bond has:
1.Unequal sharing of e- pairs causing
2.One end of the bond to be slightly positive (δ+) and
3.The other end of the bond to be slightly negative (δ-)



Electronegativity values can be helpful to both predict the polarity of covalent bonds and to predict which compounds are ionic or covalent.



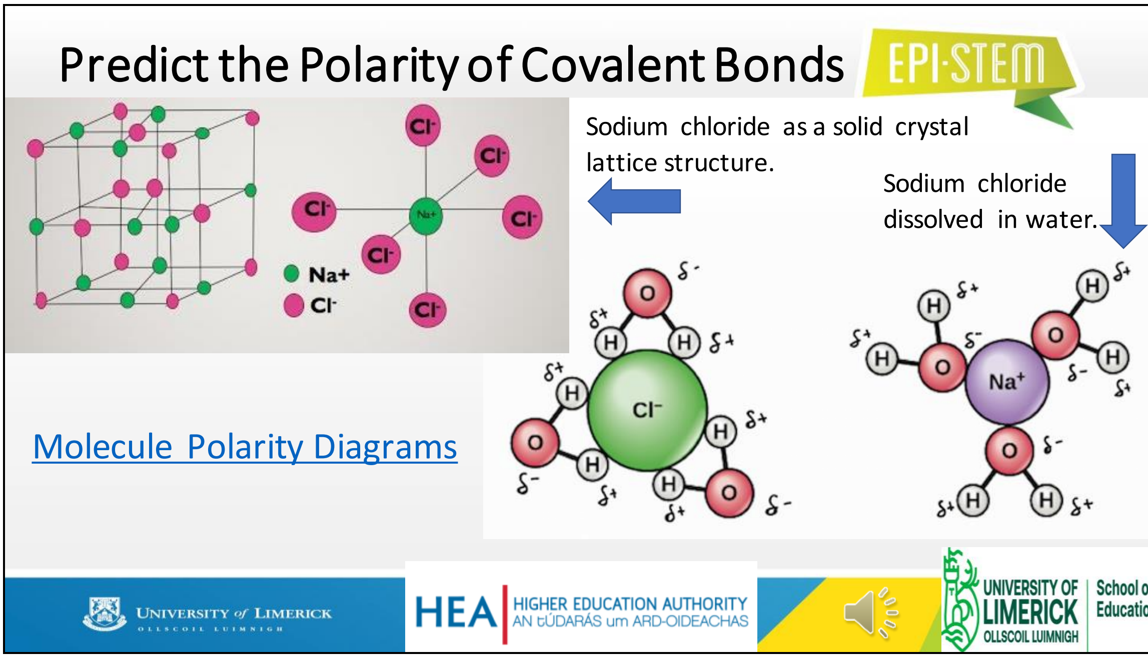
The larger the electronegativity difference, the greater the polarity of the covalent bond.

Most molecules with polar covalent bonds are polar themselves. The molecule has a partial negative and partial positive pole separated by a distance. The sum of the partial charges is zero, making the molecule overall neutral.

Some molecules with polar covalent bonds, are non-polar. These are usually symmetrical molecules. They're not polar because the centres of the partial charges coincide. The symmetry cancels out the polarities of bonds.

A demonstration to predict the polarity of a liquid can be done in the science lab.
Rub a plastic rod with a cloth to charge it by conduction. The friction causes a transfer of charge to the rod.
Place the charged rod in close proximity to a thin stream of water flowing downwards.
Repeat this experiment, this time replacing water with cyclohexane.
What happens?
The stream of water will bend when the rod is placed closed to it, this is because it is

a polar molecule and the charges between it and the rod are interaction with each other.
Cyclohexane however, is a non-polar molecule, and will not be influenced by the charged rod.



Water is an excellent solvent due to it being polar. Most ionic and polar covalent molecules will dissolve in it.
For example, sodium chloride will readily dissolve in water. This is due to the ionic bond in table salt being overcome by a strong attraction between ions and polar water molecules. The ions are dragged away from the crystal lattice, and surrounded by water molecules.

Predict if a Compound is Ionic or Covalent

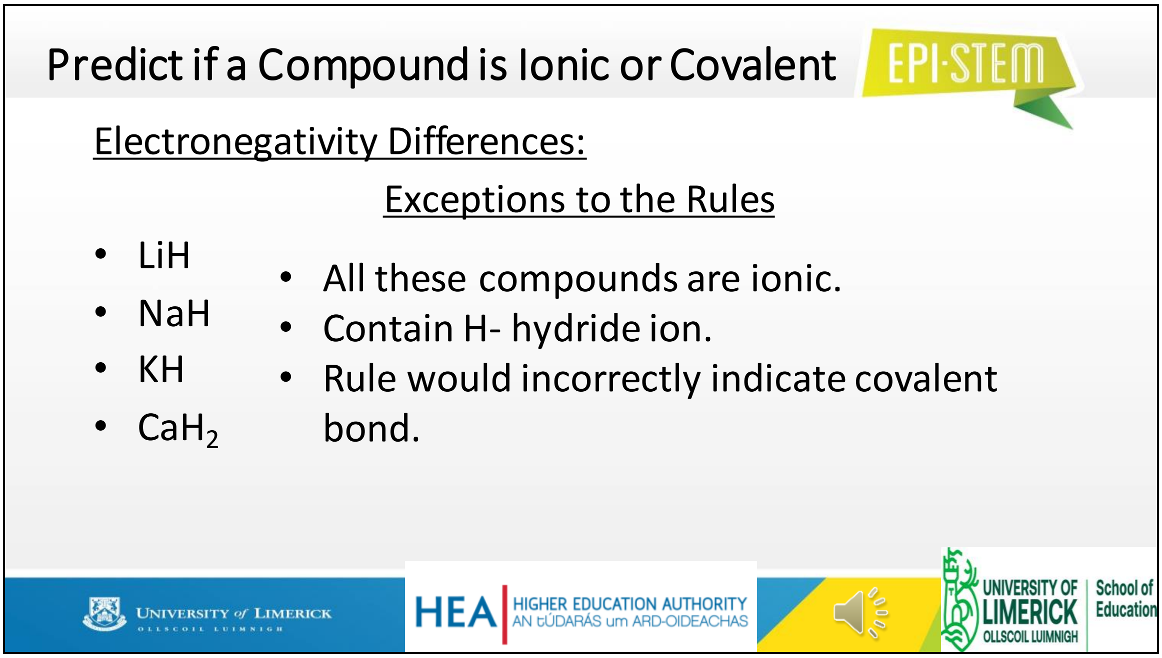
General Rule:

(some exceptions)

Electronegativity Difference	Type of Bond
1.7 <	Ionic Bond
1.7 ≥	Covalent Bond
0.4 < 1.7	Polar Covalent Bond
0.4 ≥	Non-Polar Covalent Bond

Electronegativity values can be used to predict the type of bond in a molecule. These values are just a general rule, and there are some exceptions, but typically

- If the electronegativity difference between 2 atoms that are chemically bonded is greater than 1.7, then it is ionic
- If it is less than or equal to 1.7, then it is covalent
- If it between 0.4 and 1.7, then it is polar covalent,
- And if it is less than or equal to 0.4, then it is a non-polar covalent bond.



As mentioned before, there are exceptions to the electronegativities rules on whether a compound is ionic or covalent. Some examples include lithium hydride, sodium hydride, potassium hydride, and calcium hydride. The guide would have incorrectly indicated that these contained covalent bonds, however due to the presence of the hydride ion, these compounds actually contain ionic bonds.

Electronegativity Simulation

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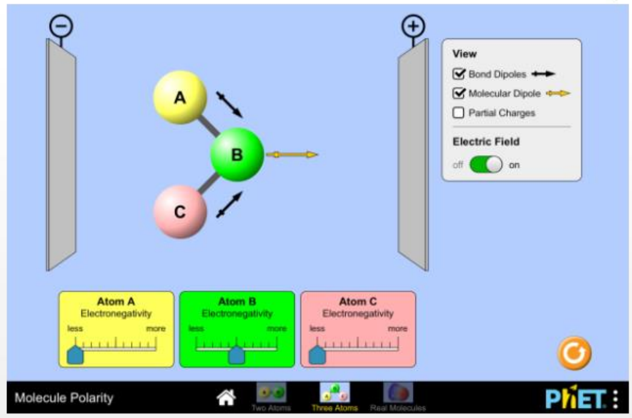
Electronegativity Simulation

Video Tutorial



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PhET have designed a simulation to allow your students to explore how differences in electronegativity values affect various molecules. Attached here is a link to the simulation and a video tutorial that guides you on how best to use it.

Bibliography

- https://janeskoresearchgroup.wordpress.com/from-covalent-to-ionic/
- https://slideplayer.com/slide/14963646/
- https://www.toppr.com/ask/content/story/amp/introduction-to-inductive-effects-1288/
- https://www.khanacademy.org/science/ap-biology/chemistry-of-life/structure-of-water-and-hydrogen-bonding/a/hs-water-and-life-review
- https://www.youtube.com/watch?v=FUlb5w8xDaE
- https://phet.colorado.edu/en/simulations/molecule-polarity/about
- https://www.youtube.com/watch?v=68RWfWy5sU4

Contact Details

Register for on-line CPD resources: https://epistem.ie
EPI•STEM project: Resources
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This on-line CPD project [HEA funded] is an initiative with EPI•STEM for science and mathematics secondary teachers in Ireland. The research-led development team include:

Geraldine Mooney Simmie, Niamh O'Meara, Merrilyn Goos, Stephen Comiskey, Ciara Lane, Tracey O'Connell, Vo Van De, Tara Ryan, Martina Scully, Jack Nealon, Daniel Casey, Keith Kennedy, Annette Forster, Céren O'Connell, Martha Cosgrave, Veronica Ryan, Gemma Hemstock

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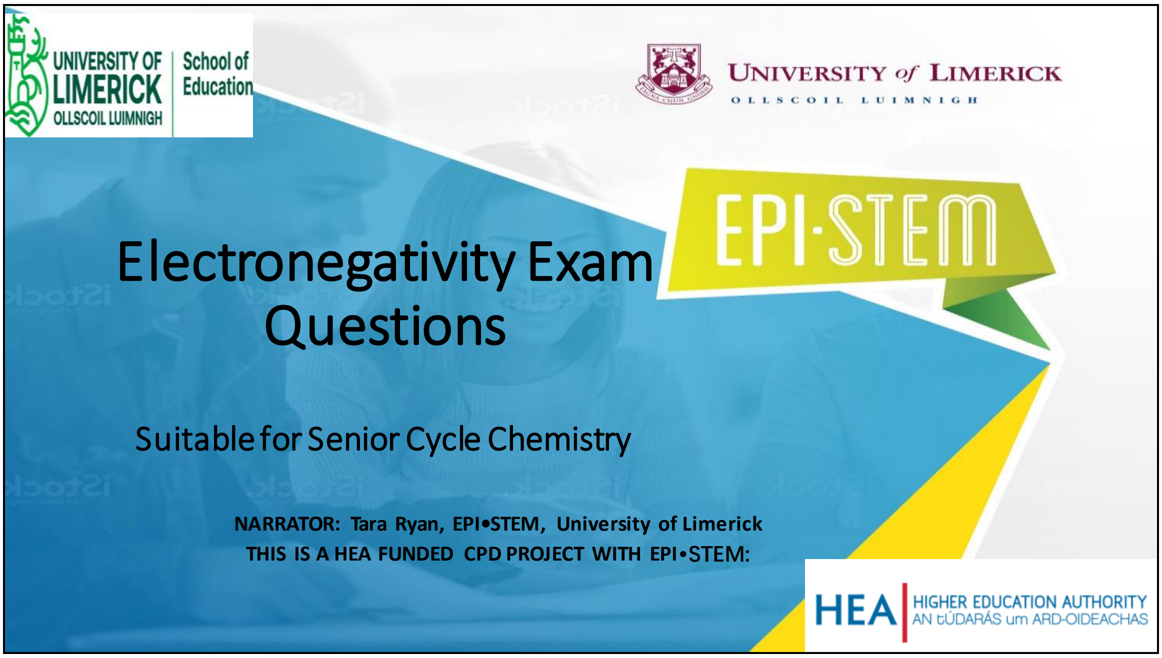
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Electronegativity Exam Questions
Suitable for Senior Cycle Chemistry
NARRATOR: Tara Ryan, EPI•STEM, University of Limerick
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List of Exam Questions

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Higher Level

2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
10b	4e	11a	11a	11a	11b	none	11a	11a	none	5c

Ordinary Level

2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
5	5a	11a	5c,d	5	10b	5c	5e	4b	10a	4e

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Provided here are lists of exam questions for both higher and ordinary levels.

Overview of Topics

Higher Level	❑ Exam Question
Ordinary Level	❑ Exam Question

2019 Q11 a) HL

(*i*) Define electronegativity. (6)

(*ii*) Account for the increase in electronegativity values across the second period of the periodic table. (6)

(*iii*) Use electronegativity values to predict the type of bonding in oxygen difluoride (**OF_2**). (3)

(*iv*) State and account for the shape of the **OF_2** molecule. (6)

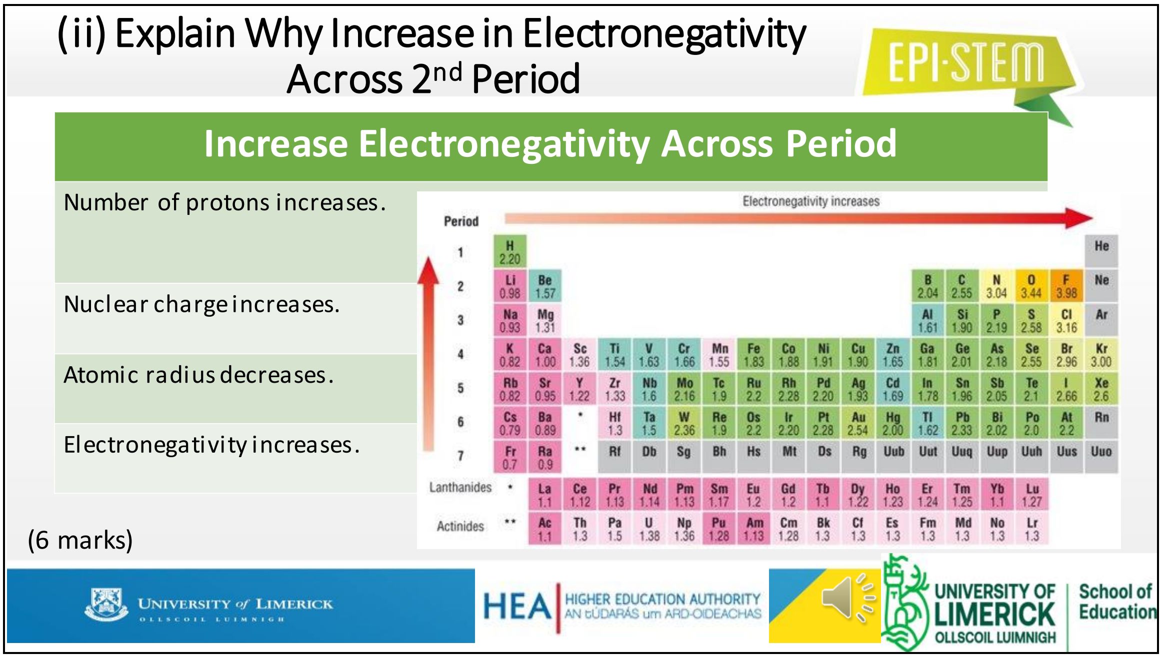
(*v*) **180.0°** **109.5°** **120.0°** **103.0°**

Select, giving your reasons, which of these angles is the most probable value for the bond angle in oxygen difluoride. (4)

Let's look at 2019 Q11a higher level exam.
We will just be looking at the first 3 parts of the question, as these focus on electronegativity.
It is common that an exam question with electronegativity will also ask about other aspects of chemical bonding.

(i) Define Electronegativity

Term	Definition	Marks Awarded
Electronegativity	• The relative attraction of an atom • For a shared pair of electrons • In a covalent bond.	4+2



Secondly, the student was asked to account for the increase in electronegativity values across the second period of the periodic table

<u>Across a Period:</u>

•Number of protons increases
•Nuclear charge increases
•Atomic radius decreases
•Electronegativity increases.

(iii) Predict the Type of Bonding in OF_2

Type of Bond	Polar Covalent Bonding
Compound	OF_2
Electronegativity Values	O 3.44 F 3.98
Electronegativity Difference	0.54

Electronegativity Difference	Type of Bond
1.7 <	Ionic Bond
1.7 ≥	Covalent Bond
0.4 < 1.7	Polar Covalent Bond
0.4 ≥	Non-Polar Covalent Bond

(3 marks)

The student was then asked to predict what type of bond would occur in the oxygen difluoride molecule.

To do this, the student would have to open their log tables to the periodic table and look at the electronegativity values of oxygen and fluorine. The difference between these values would indicate what type of bond was occurring in the atom.

We found the value to be 0.54, which would mean that the bond is slightly polar covalent.

Overview of Topics

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Higher Level	✓Exam Question
Ordinary Level	❑Exam Question

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2020 Q11 a) OL

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Refer to pages 79 and 81 of the *Formulae and Tables* booklet when answering this question.

Ammonia (**NH_3**) is produced when urine decomposes. Ammonia is a colourless gas with a characteristic, pungent smell. Each ammonia molecule consists of a nitrogen atom bonded covalently to three hydrogen atoms.

(*i*) Draw a dot and cross diagram to show the arrangement of the electrons in one ammonia molecule. (The electrons in nitrogen's first shell need *not* be shown.) (9)

(*ii*) Define *electronegativity*.

(*iii*) Write down the electronegativity values for nitrogen and hydrogen and use these values to predict whether the bonding in an ammonia molecule is polar covalent or non-polar (pure) covalent.

(*iv*) Would you expect ammonia gas to be water-soluble? Explain your answer. (16)

(i) Dot and Cross Diagram of Ammonia

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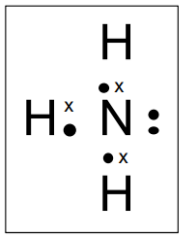
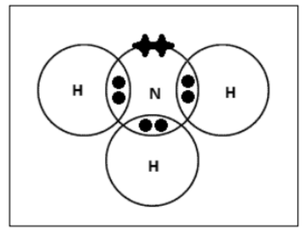
(*i*) DRAW:



or



three bond pairs in nitrogen valence shell (6)

one lone pair (two separate non-bonding electrons) in nitrogen valence shell (3)

[Any electron can be represented by a dot or a cross]

(9 marks)

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(ii) Define Electronegativity

Term	Definition	Marks Awarded
Electronegativity	• The relative attraction of an atom • For a shared pair of electrons • In a covalent bond.	4+2

(iii) Predict the Type of Bonding in NH_3

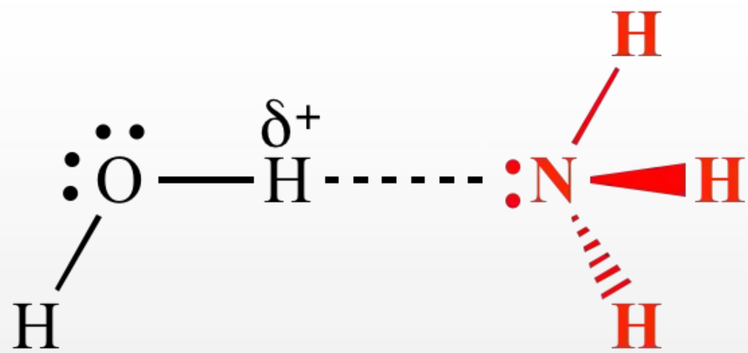
Type of Bond	Polar Covalent Bonding
Compound	NH_3
Electronegativity Values	N 3.04; H 2.20
Electronegativity Difference	0.84

Electronegativity Difference	Type of Bond
1.7 <	Ionic Bond
1.7 ≥	Covalent Bond
0.4 < 1.7	Polar Covalent Bond
0.4 ≥	Non-Polar Covalent Bond

(6 marks)

The student was then asked to predict what type of bond would occur in the ammonia molecule.
To do this, the student would have to open their log tables to the periodic table and look at the electronegativity values of nitrogen and hydrogen. The difference between these values would indicate what type of bond was occurring in the atom. We found the value to be 0.84, which would mean that the bond is polar covalent.

(iv) Is Ammonia Gas Water Soluble?



Finally, students are asked to explain why ammonia gas is soluble in water.
Water is polar. It contains hydrogen bonds. These dipole-dipole attractions can form between ammonia and water.

Overview of Topics

Higher Level	✓Exam Question
Ordinary Level	✓Exam Question

Bibliography

- https://www.examinations.ie/exammaterialarchive/
- https://www.toppr.com/ask/question/give-reasonwhy-is-ammonia-highly-soluble-in-water/

Contact Details

Register for on-line CPD resources: https://epistem.ie

EPI•STEM project: Resources

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