Higher Chemistry: Unit 1 – Chemical Changes and Structure

Part B – Bonding, Structure and Properties

Lesson 7 – Properties of Bonding: Solubility and Viscosity

Learning Outcomes

By the end of this lesson you should know:

1. How the bonding and structure of substances affects ability to dissolve in polar and non-polar substances.

2. How the presence of hydrogen bonds affects the viscosity of a liquid

Success Criteria

You will have been successful in this lesson if you:

1. Watch Ms Hastie's screencast of this lesson
2. Read and learn the material given
3. Attempt the tasks set
4. Complete Exercise 1.11 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 – Polarity in molecules

- 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 Ms Hastie's lesson below…

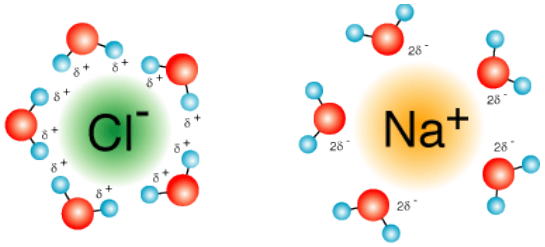
WATCH – Ms Hastie's screencast of this lesson: Solubility and Viscosity

Solubility

For one substance to be dissolved in another, the particles have to be able to mix closely with each other. There is a distinct difference between how this occurs for polar and non-polar substances.

You can try this at home. Take a glass of water, remembering that water is made of polar molecules. Try to dissolve a small amount of sugar (table sugar is sucrose which is also made polar molecules). The sugar will start to disappear because the clumps of sugar are being broken up into individual molecules by the polar water molecules. There is an attraction between the dipole in the water and the dipole in the sugar. Because they both have a positive and negative charges (albeit slight), they are able to interact. In chemistry, we use the phrase "LIKE DISSOLVES LIKE" to remember this.

Now try to dissolve a small amount of salt. Again, you will see the salt dissolving, because the polar water molecules are attracted to the positive and negative ions in the salt crystal. Again, LIKE DISSOLVES LIKE.



Slightly positive hydrogen are attracted to chlorine anions

Slightly negative oxygen are attracted to sodium cations

Liquids can also dissolve in other liquids, we call this miscibility. You can try this by mixing vinegar (polar molecules) in water.

WATCH – Youtube: salt dissolving in water: https://youtu.be/JAWiJKhmbQc

Now try a non-polar substance. Add a small amount of olive oil or any cooking oil in your glass of water. (You can also try butter, but it's messier). Fats and oils are all non-polar. You will find that the non-polar substance does not dissolve. This is because it doesn't have the charges of polar molecules. To dissolve a non-polar substance you need a non-polar solvent, eg hexane. Again "LIKE DISSOLVES LIKE"

Although LIKE DISSOLVES LIKE, it is not an absolute yes or no, but more like a sliding scale. The more polar a substance is, and the better it will be at dissolving in polar liquids. And the more non-polar the substance is, the better it will be at dissolving non-polar liquids.

WATCH – Youtube: polar vs non-polar dissolve https://youtu.be/7EpgFdbIuRs

Viscosity

Viscosity is a measure of how thick or gloopy a liquid is. This is affected by intermolecular forces. As the strength of the intermolecular forces increase, the molecules are held together more tightly. Molecular substances that display hydrogen bonding are the most viscous and those molecules that contain more than one O-H or N-H bond are even more viscous.

WATCH – Youtube: hydrogen bond viscosity https://youtu.be/977wNbFiYlc

The clip is quite long, SKIP TO 3:47

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

2. Solubility (miscibility)

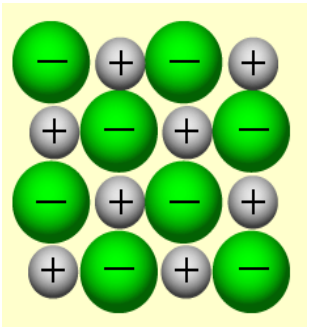
Soluble – A gas or solid that is able to dissolve in a liquid.

Miscible – A liquid that is able to mix/dissolve in another liquid.

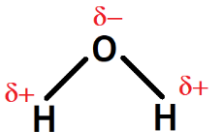
Solvent – the liquid in which the substance dissolves.

1. **Polar covalent** solvents (eg water, alcohols) will dissolve:

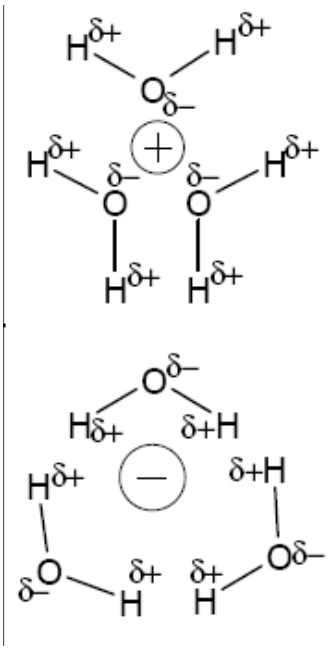
eg. ionic compounds or **polar covalent** compounds



ionic substance

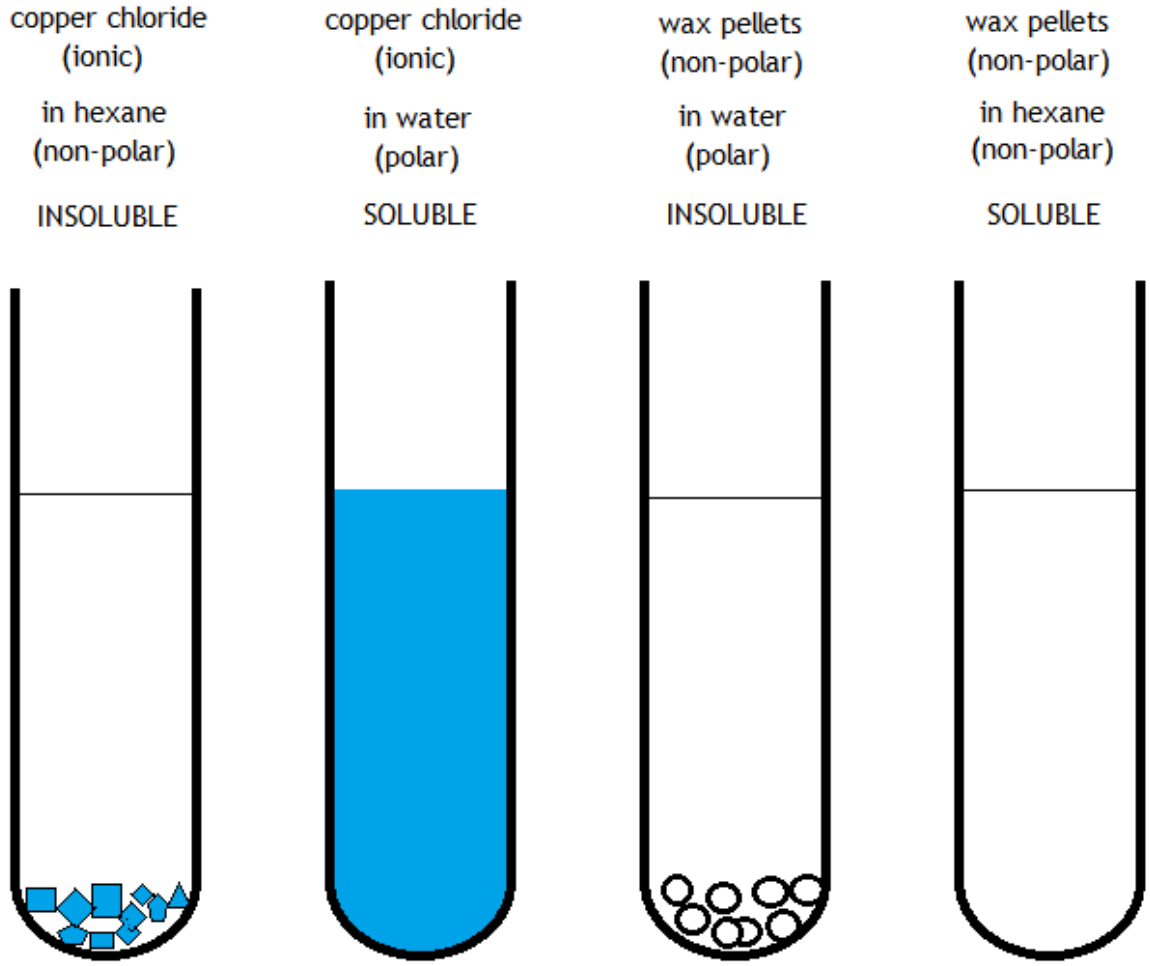


water



2. **Non-polar covalent** solvents (alkanes) will only dissolve other **non-polar substances**.

eg. **candle wax** or **oil**



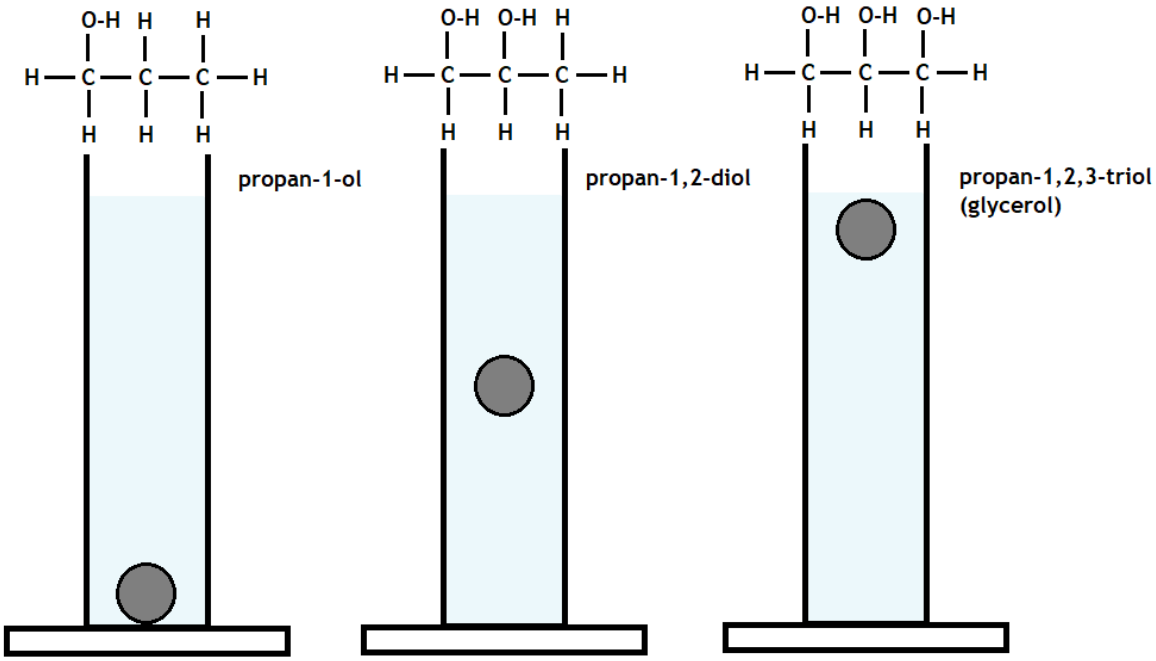
GENERAL RULE: LIKE DISSOLVES LIKE

3. Viscosity

Viscosity of liquids are affected by the presence of hydrogen bonding:

As the **number of O-H bonds** increases the **viscosity increases**.

This can be demonstrated by dropping a weight into different measuring cylinders, each containing a different test substance. The longer it takes for the weight to reach the bottom of the cylinder, the more viscous the liquid is.



Fastest to fall — slowest to fall

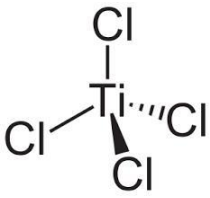
least viscous — most viscous

Using properties to determine type bonding – Ionic or covalent?

It is important to remember that a compound made of a metal and non-metal, is not necessarily an ionic compound. There are a few compounds that are exceptions to this generalisation.

Physical properties of a compound, such as its state at room temperature, melting point, boiling point, solubility, electrical conductivity, should be used to deduce the type of bonding and structure in the compound.

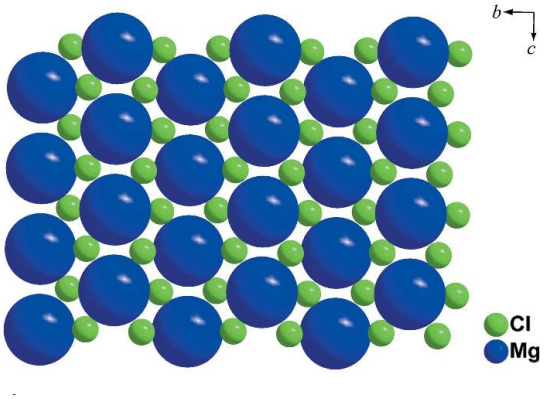
Titanium(IV) chloride ($TiCl_4$), for example, is a liquid at room temperature, does not conduct electricity and is soluble in non-polar liquids.



$TiCl_4$, therefore is likely to be made of **non-polar covalent molecules.**

Magnesium chloride ($MgCl_2$), on the other hand, is a solid at room temperature, has a melting point of 714°C, is soluble in water and conducts electricity when dissolved in water.

$MgCl_2$ therefore is likely to have an **ionic lattice structure.**



Learning Outcomes

You should now know:

1. Properties such as viscosity and solubility can be explained in terms of the type and strength of the intermolecular forces that exist between molecules.

2. To predict solubility/miscibility, a general rule is LIKE DISSOLVES LIKE.

3. Ionic and polar covalent substances tend to be more soluble in polar solvents such as water.

4. Non-polar substances tend to be more soluble in non-polar solvents, such as hydrocarbons.

5. To predict the solubility of a compound, key features to be considered are the:
   - presence in molecules of O-H or N-H bonds, which implies hydrogen bonding
   - Spatial arrangement of polar covalent bonds, which could result in a molecule possessing a permanent dipole.

6. Viscous liquids have strong intermolecular forces between molecules, e.g. substances with hydrogen bonding will be more viscous than substances with no hydrogen bonding.

7. Physical properties of a compound, such as its state at room temperature, melting point, boiling point, solubility, electrical conductivity, should be used to deduce the type of bonding and structure in the compound.

Further Reading

To learn more about this lesson. Follow the links below:

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

Read page 9 & 10 and try the TEST

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

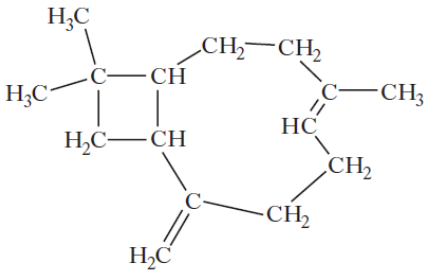
Questions

Complete Exercise 1.11 and check your answers

Exercise 1.11 – Properties: Solubility and Viscosity

1. Caryophyllene is a natural product which can be extracted from clove oil using a solvent (Shown to the right).

Is caryophyllene more likely to dissolve in water or hexane? Explain your answer.



caryophyllene

2. On the basis of what you learned in National 5 Chemistry, you may expect sodium chloride and aluminium chloride to be typical ionic solids. Sodium chloride is a solid which melts at 801°C while aluminium chloride is a solid which sublimes (changes directly from a sold to a gas) at 180°C.

(a) Given the information above, suggest what type of bonding, ionic or covalent, exists in each compound?

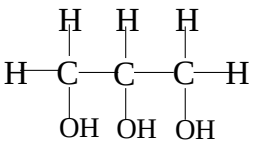
(b) Aluminium chloride is more likely to dissolve in a non-polar solvent than in water. What does this suggest about the polarity of aluminium chloride?

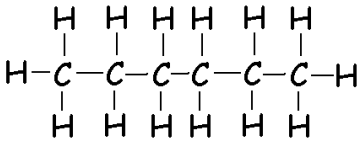
3. Tin iodide is soluble in non-polar solvents, whilst caesium iodide is insoluble in non-polar solvents but very soluble in water.

(a) Suggest the type of bonding which is likely to be present in each compound. Explain your answer.

(b) Use electronegativity data to suggest why the compounds have two different bonding types.

4. Glycerol and hexane are both liquids with similar molecular masses. However, their viscosities are very different.





(a) Give the molecular formula for each compound.

(b) Describe an experiment that could be carried out in the laboratory to determine which of the two liquids is the more viscous.

(c) It was discovered that glycerol is the more viscous of the two liquids. By discussing the structures of both compounds, explain why glycerol is more viscous than hexane.

Exercise 1.11 – Properties: Solubility and Viscosity ANSWERS

1. Caryophyllene is more likely to dissolve in hexane. This is because both caryophyllene and hexane are non-polar molecules and like dissolves like.

2. (a) Sodium chloride-ionic

aluminium chloride-covalent molecular

(b) Aluminium chloride is likely to be made of non-polar covalent molecules

3. (a) Lithium iodide-covalent as it soluble in a non-polar covalent solvents. Caesium iodide-ionic as it is soluble in polar covalent solvents (water).

(b) The difference in electronegativity of caesium (0.8) and iodine (2.6) is greater than the difference in electronegativity of tin (1.8) and iodine. Due to this Caesium iodide has greater ionic character.

caesium (0.8) and iodine (2.6) , 2.6 -0.8 = 1.8

tin (1.8) and iodine (2.6) , 1.8-2.6 – 1.8 = 0.8

4.(a) $C_3H_8O_3$ C_6H_{14}

(b) Two measuring cylinders could be prepared, one containing glycerol and the other the same volume of hexane. A student could time how long it takes for a weight (object / ball bearing) to fall to the bottom of the measuring cylinders containing each substance.

(c) Hexane is non-polar and therefore contains only weak London dispersion forces between its molecules. However, as glycerol has three hydroxyl (O-H) groups per molecule it will have a significant degree of hydrogen bonding (in addition to LDFs). Due to the presence of hydrogen bonding, glycerol will be more viscous.