Structure 2.4.1

Properties of ionic and covalent compounds

Reference:

S2.4.1 Bonding is best described as a continuum between the ionic, covalent and metallic models

Aim

To relate the solubility of a compound in water or petroleum ether to the ionic or covalent character of the compound, and then measure the solution conductivity to characterize a compound as a strong or weak electrolyte.

Introduction

Ionic compounds consist of ions held together by strong electrostatic attraction. Covalent compounds consist of molecules whose elements are held together by forming bonds through the mutual sharing of electron pairs.
From the early days of chemistry, fundamental differences were observed between these categories of compounds even though, at the time they were not characterized as such. Alchemists ruled that '*similia similibus solvuntur*', which translates as 'like dissolves like' or 'similar substances will dissolve similar substances'. So, polar solvents will dissolve polar compounds, while non-polar solvents will dissolve non-polar compounds. In this lab we will test this idea using water (a polar solvent) and petroleum ether (a non-polar solvent) on a number of compounds and assign them as polar or non-polar based on their solubility.

In a second experiment, the electrical conductivity of various solutions will be tested and the compounds will be characterized as strong or weak electrolytes. Conductivity of a solution depends on the availability and mobility of ions in the solution. The greater the number of mobile ions that are available in the solution, the higher the conductivity. Therefore, compounds that fully dissociate into their ions when dissolved in water (only hydrated ions are present in the solution)

$$M_mX_x \rightarrow M^{x+}(aq) + X^{m-}(aq)$$

are considered to be strong electrolytes, while compounds that do not fully dissociate into ions (they form an equilibrium between their molecular form and their hydrated ions)

$$M_mX_x \rightleftharpoons M^{x+}(aq) + X^{m-}(aq)$$

are considered to be weak electrolytes. The strength of a weak electrolyte depends on the equilibrium constant of the dissociation above.

Pre-lab questions

1. Is iodine (I_2) a covalent or ionic molecule? Do you expect it to be more soluble in water or in petroleum ether?
2. NaCl is an ionic compound. Its solutions are considered to be strong electrolytes. Explain why solid NaCl crystals do not conduct electricity.

Equipment list

Chemicals / materials	**Apparatus (per group of students)**
Experiment 1 Solvents: deionized water petroleum ether Substances: oil iodine pellets sodium chloride powder, NaCl(s) potassium iodide powder, KI(s) sulfur (flowers), $S_8(s)$ **Experiment 2** deionized water tap water ethanol (80% vol, or higher), $C_2H_5OH(l)$ Dilute solutions of: hydrochloric acid, HCl sulfuric acid, H_2SO_4 acetic acid, CH_3COOH sodium chloride, NaCl sodium hydroxide, NaOH ammonium hydroxide, NH_4OH sucrose starch	test tubes test-tube rack bungs ammeter (or digital multimeter) wires/crocodile clips graphite electrodes lamp (1.5 V) battery (3.0 V) spatulas pipettes

Method

Experiment 1

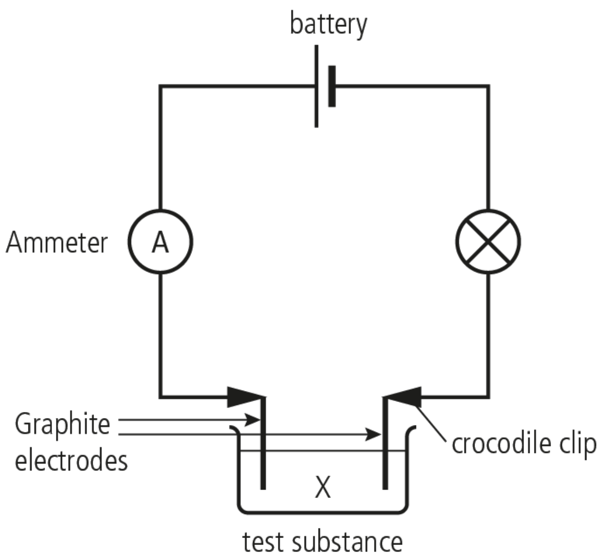
A Place a small amount of each substance (~1 g for solid substances and ~1 cm^3 for liquid substances) into five test tubes. Add 3–4 cm^3 of deionized water to each test tube, then tap the tubes and shake well to dissolve the substance. Record your observations in Table 1. Repeat the process using petroleum ether instead of water and record your observations in Table 1.

B Add 1–2 iodine pellets to a test tube. Add 2–3 cm^3 of deionized water and shake well. Record your observations. Add 2–3 cm^3 of petroleum ether to the same tube. Notice that a layer of petroleum ether forms on the top. Close the tube with a bung and shake well. Record your observations. Explain what is happening.

Experiment 2

Determining the electrical conductivity of solutions.

A Set-up a simple system to test the electrical conductivity of various solutions. Use a 3 V battery or a DC power supply of similar voltage.



B Submerge the electrodes in the solution to be tested. If an analogue ammeter (galvanometer) is used, just record the deviation of the galvanometer needle instead. Record your observations in Table 2.

Analysis

Table 1

Substance	Better soluble in		The compound is	
	Water (polar solvent)	Petroleum ether (non-polar solvent)	Ionic or polar covalent	Non-polar
NaCl				
KI				
I_2				
S_8				
oil				

A polar compound dissolves better in a _______________ solvent.

Table 2

Substance solutions	Ammeter deviation			Substance can be characterized as:		
	high	low	none	strong electrolyte	weak electrolyte	not an electrolyte
deionized water						
tap water						
C_2H_5OH						
HCl						
H_2SO_4						
CH_3COOH						
NaCl						
NaOH						
NH_4OH						
sucrose						
starch						

Post–lab report:

Write a report where you:

- Summarize the important theoretical concepts described in this lab.
- Summarize the experimental procedures.
- Highlight any important health and safety matters.
- Discuss whether the solubility in polar and non-polar solvents is a good method of determining the polarity of a compound.
- Consider how the investigation could be expanded.

Structure 2.4.1

Cement and mortar: Investigating the parameters that affect their properties

Reference:

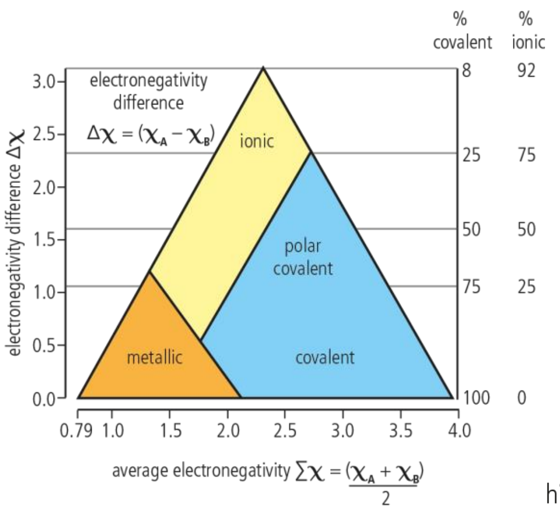
S2.4.1 Bonding is best described as a continuum between the ionic, covalent and metallic models, and can be represented by a bonding triangle.

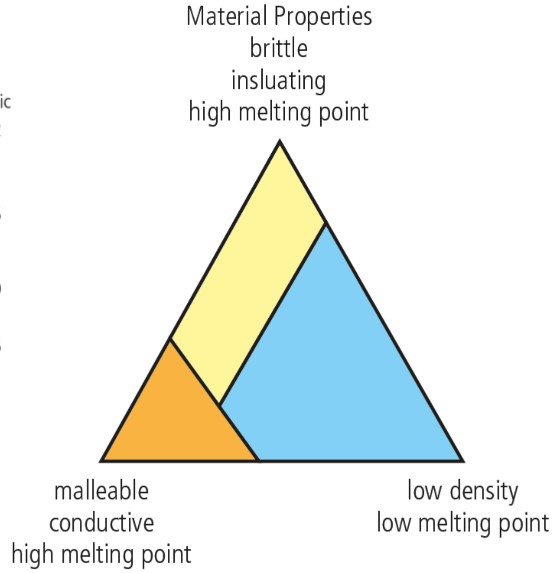
Aim

To use the van Arkel-Ketelaar triangle of bonding to explain the properties of a material. Discuss the properties of different construction materials.

Introduction

Chemical bonding is important in material science as it is responsible for the characteristic properties and behaviour of the materials we use in everyday life.
In this lab we will prepare small ornaments using plaster of Paris and cement in small silica moulds, then use the Van Arkel-Ketelaar triangle of bonding to explain their properties.





Pre-lab question

Cement is primarily comprised of calcium oxide and silicon dioxide (and other additives). Plaster of Paris is a white powder (calcium sulfate hemihydrate).
Find the positions of calcium oxide, silicon dioxide and calcium sulfate hemihydrate on the van Arkel-Ketelaar triangle and predict the properties of cement and of plaster of Paris.

Please note

- A full risk assessment should be carried out prior to commencing this experiment.
- Personal safety equipment should be worn.
- Chemicals should be disposed of safely and with due regard to any environmental considerations.

Risk assessment

Material name and chemical formula	Associated risks	Measures taken

Environmental risks

Waste products (if any)	Associated risks	Waste management

Ethical risks

Small amounts should be used when possible. No harm to people and the environment will be caused by this experiment.

Equipment list

Chemicals / materials	Apparatus (per group of students)
mould release spray rapid set cement plaster of Paris deionized water	silicone baking moulds small disposable cups and wooden stir sticks plastic volumetric cylinders spatulas

Method

1. In a well ventilated area, spray the silicone baking moulds with the mould release spray.
2. Measure approximately 40 cm^3 of cement powder and 50–60 cm^3 of deionized water into a disposable cup.
3. Stir using a wooden stir stick until the mixture resembles the texture of pancake mix.
4. If the mixture is too thick, add deionized water in small increments (~5 cm^3). If the mixture is too thin, add small amounts of cement until the desired consistency is reached.
5. Fill your silicone moulds with the mixture. Leave the moulds overnight before removing the solid casts from the moulds.
6. Repeat the procedure using plaster of Paris in step 2 instead of cement. Use about 40 cm^3 of plaster to 20 cm^3 of deionized water.
7. Test the resulting materials for brittleness, conductivity and melting point.

Analysis

- Did the materials have the expected properties of brittleness, conductivity and melting point?
- How does the ratio of substance to water affect the final product properties?
- A major component of cement is calcium oxide (CaO). If you decreased the pH of the water you used (by adding a small amount of acid), how would the properties of the solid product be affected?
- Design and carry out an experiment to investigate this relationship.

Post–lab report

Write a report on the lab you have designed where you:

- State your research question.
- Summarize the important theoretical concepts described in your lab.
- State and justify your hypothesis.
- Describe your methodology.
- Highlight any important health and safety matters.
- Present and analyze your results.

- State your conclusion on how your selected variable (in the experiment you designed) affects the properties of the product.
- Research whether your conclusion agrees with the scientific consensus or not. Based on this, evaluate your results and your experimental process.

Structure 2.4.4 and 2.4.6

Making polymers: ‘milk plastic’

Reference:

S2.4.4 Polymers are large molecules, or macromolecules, made from repeating sub-units called monomers.
S2.4.6 Condensation polymers form by the reaction between functional groups in each monomer with the release of a small molecule.

Aim

To form a biodegradable polymer by denaturing milk protein (casein).

Introduction

Milk is rich in casein proteins. Casein proteins have significant nutritional value and their properties are important in the food industry as the characteristic texture of dairy products is due to chemical processes involving these proteins.

Caseins can ‘denature’ when exposed to high temperatures or low pH solutions. Denaturing a protein involves the destruction of the intermolecular bonds that give the protein its specific structure. By breaking these intermolecular forces, the protein ‘unfolds’ into long chains of repeating units – a polymer. This polymer can be shaped by hand or by being pressed into a mould.

Casein polymer, or ‘milk plastic’ as it is sometimes called, was widely used in the 20th century for making buttons, beads and ornaments. Unlike most polymers synthesized from other hydrocarbons, casein polymer is biodegradable.

Pre-lab questions

1. Research the terms primary, secondary, and tertiary structure of a protein. What are the differences? How are intermolecular forces involved in the various structures of proteins?

HL

2. Amino acids combine between themselves to form polypeptides through a peptide bond. Identify the structures of the amino acids Arg, Glu and Leu and draw the structure of the Arg-Glu-Leu tripeptide.
3. Locate the peptide bonds in the Arg-Glu-Leu tripeptide.
4. Explain the biodegradation process of milk plastic.

Please note

- A full risk assessment should be carried out prior to commencing this experiment.
- Personal safety equipment should be worn.
- Chemicals should be disposed of safely and with due regard to any environmental considerations.

Risk assessment

Material name and chemical formula	Associated risks	Measures taken

Environmental risks

Waste products (if any)	Associated risks	Waste management

Ethical risks

Small amounts should be used when possible. No harm to people and the environment will be caused by this experiment.

Equipment list

Chemicals / materials	Apparatus (per group of students)
milk household vinegar or dilute acetic acid solution	hot plate beakers measuring cylinders funnel soft muslin cloth glass rod thermometer paper towels

Method

General procedure

1. Pour 100 cm^3 of milk (preferably full fat or heavy cream) into a 250 cm^3 beaker. Heat the milk to 80°C and remove from the hot plate.
2. Slowly add 20 cm^3 of vinegar (or dilute acetic acid solution) while stirring with a glass rod and observe the white precipitate that forms.
3. Collect the precipitate by filtering the mixture through soft muslin cloth.
4. Dry the collected material over paper towels, then mould into different shapes. It usually takes about 48 hours to harden.

Analysis

The temperature of the milk and the concentration and volume of the acetic acid solution can affect the process. Other acids such as citric acid can also be used instead.
Design and carry out a quantitative lab to investigate the effect of one of these variables on the quantity of milk plastic produced.

Post–lab report

Write a report on your designed lab where you:

- State your research question.
- Summarize the important theoretical concepts described in your lab.
- State a hypothesis on how your selected variable affects the quantity of milk plastic produced in your proposed investigation.
- Describe your methodology.
- Highlight any important health and safety matters.
- Present your results.

- State your conclusion on how your selected variable affects the quantity of milk plastic produced.
- Research whether your conclusion agrees with the scientific consensus or not. Based on this, evaluate your results and your experimental process.

Structure 2.4.4

Properties of polymers: polycaprolactone

Reference:

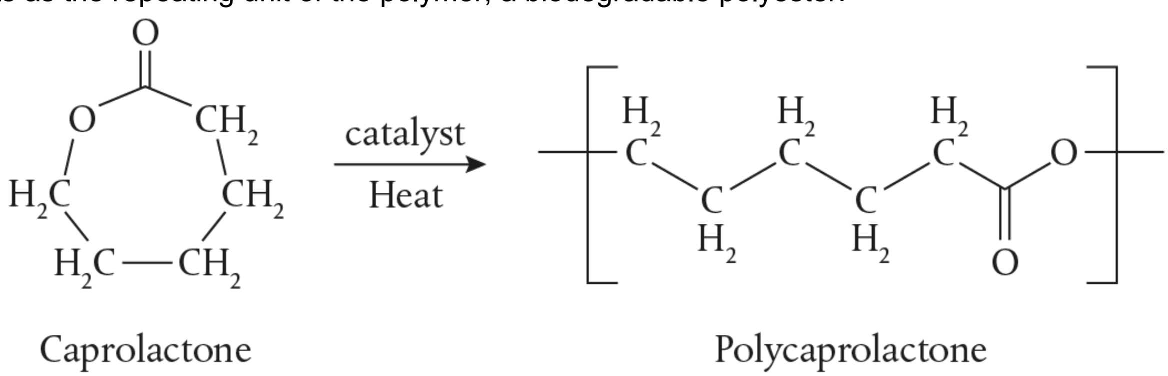
S2.4.4 Polymers are large molecules, or macromolecules, made from repeating sub-units called monomers.

Aim

To investigate the properties of polymers.

Introduction

Polycaprolactone (PCL) is a biodegradable polyester with a low melting point of around 60 °C. PLC is formed by the polymerization of ε-caprolactone, a cyclic ester. The ring breaks under the effect of a catalyst, in a process called ring-opening polymerization, to form the monomer that acts as the repeating unit of the polymer, a biodegradable polyester.



Polycaprolactone is easily sourced. It is sold as small white pellets for arts and crafts. Its thermal properties, exceptional mechanical and chemical properties, and its biocompatibility and biodegradability, have made it an ideal material for applications ranging from casual 3D printing to biomedical tissue engineering, and even for targeted drug delivery.

Pre-lab questions

1. Polycaprolactone is considered to be a thermoplastic. Define the term thermoplastic.
2. Where in the van-Arkel-Ketelaar triangle should polycaprolactone be? What other properties can you predict for this polymer based on this position in the triangle?

Please note

- A full risk assessment should be carried out prior to commencing this experiment.
- Personal safety equipment should be worn.
- Chemicals should be disposed of safely and with due regard to any environmental considerations.

Risk assessment

Material name and chemical formula	Associated risks	Measures taken

Environmental risks

Waste products (if any)	Associated risks	Waste management

Ethical risks

Small amounts should be used when possible. No harm to people and the environment will be caused by this experiment.

Equipment list

Chemicals / materials	Apparatus (per group of students)
polycaprolactone pellets hot water	beaker heat gun spatula or scoop paper towels

Method

General method

1. Add 2 or 3 spatulas of polycaprolactone pellets to half a beaker of hot, but not boiling, water. Notice that the pellets gradually become translucent.
2. When the PCL pellets are completely clear in colour, remove them from the water, taking care not to burn yourself, and place on a paper towel. For a short while the pellets will be elastic and malleable.

Experiment 1: Elasticity

1. While they are still warm, shape the pellets into a sphere, and then bounce the sphere on the bench. Record what happens.
2. Allow the sphere to cool. Record any colour and texture changes as it cools.
3. Try to bounce the sphere on the bench as you did when it was warm, and record what happens now.

Experiment 2: The thread challenge

1. Place the polycaprolactone ball back in the hot water and reshape it into a worm.
2. Pinch a side and pull. Notice that a thread of plastic is pulled out. How long a thread can you make before it breaks?
3. Work with a classmate who can hold the main mass of the polymer, and gently warm it with a heat gun to see how long a thread you can pull out.

Post–lab report

Write a report where you:

- Summarize the important theoretical concepts described in this lab.
- Summarize the experimental procedures.
- Highlight any important health and safety matters.
- This was a qualitative lab. Present your observations and relate them to your understanding of polymer properties.
- Evaluate the experimental procedures. Suggest how the experiment could have been extended.

