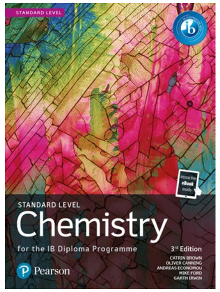
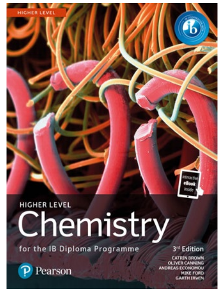
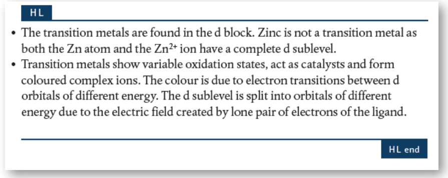
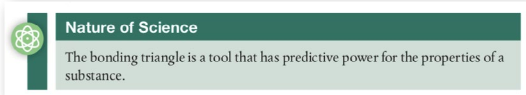
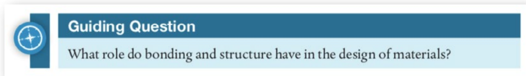
Get ready to teach the new Subject Guide with Pearson Chemistry for the IB Diploma Programme

Find out everything you need to know about the changes to the syllabus and get ready to teach the new course with our Student Books, developed in cooperation with the IB, and supported by expert advice from our experienced authors.





Key changes to the IB DP Chemistry Subject Guide	Putting it into practice with Pearson Chemistry for the IB Diploma Programme Student Books
The **syllabus content** is now presented in two main themes: • **Structure** - Models of the particulate nature of matter - Models of bonding and structure - Classification of matter • **Reactivity** - What drives chemical reactions? - How much, how fast and how far? - What are the mechanisms of chemical change? The conceptual relationship between these two themes – what chemicals are made from and how they behave – is emphasised throughout. This is reinforced by the fact there is no expectation that the syllabus will be taught in any particular order, or that any topic needs to be covered completely at one time.	Our **Standard Level and Higher Level Student Books** are structured to match the new Subject Guide, something that's been checked and **approved by the IB**. This means that it couldn't be easier to find what you're looking for from the syllabus. We've also included handy overviews of the syllabus content covered at the start of each section. The **conceptual approach** of the books means you're free to design your own route through the course, with topics linked to help you join everything up and to increase your students' depth of understanding. **Author tip!** Hear more detail about how the books have been put together in cooperation with the IB from our expert authors in an on-demand webinar >

Key changes to the IB DP Chemistry Subject Guide	Putting it into practice with Pearson Chemistry for the IB Diploma Programme Student Books
The **removal of the Options** is a main contributor to the reduction in the content of the course. However, you will note that some topics from each of the former four Options are now included in the main syllabus – for example, the bonding triangle (Option A), biofuels (Option B), fuel cells (Option C) and separation techniques (Option D). This is by no means an exhaustive list, but makes the point that all students will now be exposed to the **applications and global context of chemistry** in a range of fields. Students no longer pick HL options. All HL students coverthe same content. This is to ensure consistency in the content covered.	We've got **separate Standard Level and Higher Level resources** to offer you maximum flexibility with your teaching. All of our student books take the same approach, across all subjects, making things simple and consistent for students who are taking more than one Science.  HL • The transition metals are found in the d block. Zinc is not a transition metal as both the Zn atom and the Zn^{2+} ion have a complete d sublevel. • Transition metals show variable oxidation states, act as catalysts and form coloured complex ions. The colour is due to electron transitions between d orbitals of different energy. The d sublevel is split into orbitals of different energy due to the electric field created by lone pair of electrons of the ligand. HL end **Author tip!** Get topic-specific detail in our video explainer
The Nature of Science (NOS) continues to be an important thread that runs through the course. Some references are made to NOS in the syllabus, but mostly, you are encouraged to provide your own examples, including drawing on topical developments.	**Nature of Science boxes** are included throughout the books as related themes and questions arise to help your students understand Chemistry in the wider context of the science world.  Nature of Science The bonding triangle is a tool that has predictive power for the properties of a substance. **Author tip!** Read more on NOS and how to integrate it into your Chemistry course >
Guiding Questions are a new feature of the syllabus, given at the start of each sub-topic. These questions are purposefully open-ended, lending themselves to increasingly detailed consideration as understanding of the topic deepens. Guiding Questions may serve as openers for a topic, teasing out students' prior knowledge, and perhaps helping to suggest a sequence of what will be covered. They could also be used as a **tool for assessment**, looking for increasing depth and breadth at different stages in the learning.	We've included **Guiding Questions at the start of each chapter**. These set the context for the topic and how it relates to previous knowledge. They are revisited at the end of each chapter with a **summary checklist** that will come in handy for revision.  Guiding Question What role do bonding and structure have in the design of materials? **Our Student Books cover ALL of the Guiding Questions from the IB's Subject Guides.**

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<th>Key changes to the IB DP Chemistry Subject Guide</th>
<th>Putting it into practice with Pearson Chemistry for the IB Diploma Programme Student Books</th>
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Linking Questions are another important feature of the new course. They are given in many of the syllabus Understandings, where they show a link to a different but related sub-topic. The goal of Linking Questions is to help create enhanced understanding and a network of knowledge. The content of Linking Questions is often addressed elsewhere in the text as it sometimes encourages a ‘revisiting’ of material and sometimes a preview of upcoming material.
Linking Questions are unlikely to be used as questions in examinations per se, but the related concepts are considered an essential part of the course.
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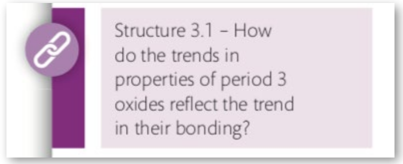
Linking Questions are highlighted throughout the books to help students make connections and build a network of knowledge. They help students join up several different concepts from across chapters in one place.


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The Subject Guide includes a section titled Skills in the Study of Chemistry. This is not intended as a topic to be taught in isolation, but is more of a checklist of skills that students must acquire during the course.
It replaces the Prescribed Practicals (or Mandatory Labs) from the 2016 curriculum, and clarifies the experimental techniques, technology and mathematical skills scope that is expected.
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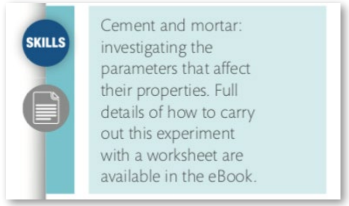
Skills boxes throughout the books indicate where you might be able to explore these different skills, in particular sub topics, as well as providing links to resources for carrying out particular labs.


You and your students get comprehensive coverage of skills beyond what’s in our books with downloadable expanded activity and lab PDFs, as well as a dedicated chapter on Skills.
Author tip! Try out some lab skills worksheets for free when you download everything you need to teach five Chemistry lessons >
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TOK links are no longer included in the syllabus to avoid the perception that the listed links are the only links students need to know. The aim is to encourage students and teachers to make their own TOK links.
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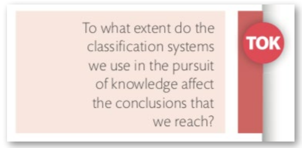
We’ve kept TOK links throughout the books, using questions that are designed to stimulate thought and consideration of knowledge issues as they arise in context, as well as including a dedicated TOK chapter.


Author tip! Read more on integrating TOK in your Chemistry course >
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All students will only sit two **external assessments:**
Paper 1A: multiple-choice questions on the syllabus.
Paper 1B: data-based questions that are syllabus-related, and questions on experimental work
Paper 2: short-answer and extended-response questions on a wide range of syllabus content, skills, concepts and understandings.
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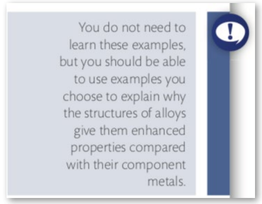
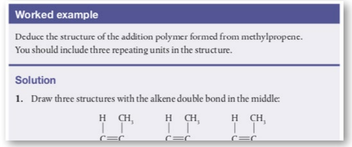
Our books include formative and summative assessment opportunities, with exercises throughout and **exam practice questions** at the end of each chapter, in the style of IB exam papers, in addition to real past paper questions. Answers are available in the eBook.

Auto-marked quizzes, with real-time results and reporting, offer practice tackling multiple-choice questions.

Hints for success boxes throughout the books give advice from experienced IB examiners on how to approach questions, identifying common pitfalls.



We've also included **worked examples** with solutions to help students tackle questions with confidence. **IB terminology is integrated** so that students become familiar with the language and terms that they will meet in exams.



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The **Internal Assessment**, now called the **Scientific Investigation**, is an open-ended task in which the student gathers and analyses data (collaboration is possible here) in order to answer their own formulated research question (which must be individual to the student).

The outcome of the scientific investigation is assessed through a written report of up to 3,000 words, which is now assessed based on four criteria:
• Exploring and designing
• Collecting and processing data
• Concluding
• Evaluating data

Extra weighting will be given to Conclusion and Evaluation. The Communication element from the old Subject Guide is embedded in the above criteria.
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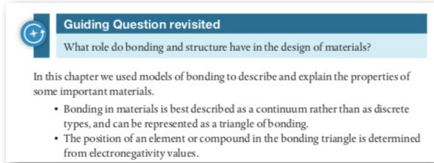
Skills boxes throughout the books give details of experiments which will support the skills needed for the Internal Assessment.

The **Guiding Question Revisited Checklist** at the end of each chapter, also available to download from the eBook version, ensures students know what's required and supports them in achieving the new criteria.



An **Internal Assessment chapter** offers support and guidance for the Scientific Investigation.
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Structure 2.4 From models to materials

Lesson 1

Topic	**Structure 2 Models of bonding and structure**
Sub-topic	**Structure 2.4 From models to materials**
Guiding Question	**What role do bonding and structure have in the design of materials?**
Understandings	2.4.1 – The bonding triangle 2.4.2 – Application of the bonding triangle
Level	SL and HL
Duration	1.5 hours
Content statements	• Bonding is best described as a continuum between the ionic, covalent and metallic models, and can be represented by a bonding triangle. • The position of a compound in the bonding triangle is determined by the relative contributions of the three bonding types to the overall bond.
Learning outcomes	• Use bonding models to explain the properties of a material. • Determine the position of a compound in the bonding triangle from electronegativity data. • Predict the properties of a compound based on its position in the bonding triangle.
Prior knowledge	The concept of the bonding triangle will make more sense if the discrete models of ionic (Structure 2.1), covalent (Structure 2.2) and metallic (Structure 2.3) bonding are first understood. An understanding of electronegativity (Structure 3.1) is also essential here, and it is recommended that the electronegativity table from Section 9 of the data booklet is available for reference throughout this lesson.
Lesson context and opening question	Consider examples of elements or compounds that are not completely described by one of the three bonding models. For example, how does the polar nature of water make it behave differently from non-polar covalent molecules? In what ways do the properties of metalloids such as silicon, Si, differ from those of metals? Leads to a discussion of 'blurred boundaries' between bonding types.
Key concepts	• Electronegativity values → position of a material in the bonding triangle → prediction and explanation of many properties. • The position of an element or compound in the bonding triangle is determined by the magnitude and difference of the electronegativities of the constituent elements.

Plan for how students will acquire knowledge, understanding and skills	• Read pages 266–268 which cover the concept of a bonding continuum represented by the bonding triangle. • Refer to the bonding triangle provided in Section 17 of the data booklet. • Consider the Linking Question on page 267 which explores an example of the link between trends in properties and trends in bonding. • Consider the Linking Question and answer on page 268. The TOK feature box on page 266 is also relevant here. • Read pages 269–270 which cover the application of electronegativity values to the bonding triangle. • Study the Worked example on page 269. Follow the steps in determining the position of a substance in the bonding triangle. • Consider the Linking Question on page 270, alongside the Global context feature box and photographs on this page. • Attempt Exercise questions 1–3 on page 270.
Activities	Lab skills PDFs: • Structure 2.4 Properties of ionic and covalent compounds • Structure 2.4 Cement and mortar
Links to IB concepts (e.g. NOS, TOK)	The TOK question on page 266 and NOS feature box on 267 can be revisited at the end of the lesson.
Key questions to check for understanding	Practice questions 2, 4, 5, 8 and 10 on pages 286–287.
Additional resources for support/extension	Think of other examples of composites that are widely used, and how their properties can be explained through their bonding.
Guiding Question re-visited	**What role do bonding and structure have in the design of materials?** • Bonding in materials is best described as a continuum rather than as discrete types, and can be represented as a triangle of bonding. • The position of an element or compound in the bonding triangle is determined from electronegativity values. • From the position of a substance in the bonding triangle, we can deduce its bonding and predict its properties.

Lesson 2

Topic	**Structure 2 Models of bonding and structure**
Sub-topic	**Structure 2.4 From models to materials**
Guiding Question	**What role do bonding and structure have in the design of materials?**
Understanding	2.4.3 – Alloys
Level	SL and HL
Duration	1 hour
Content statement	• Alloys are mixtures of a metal and other metals or non-metals. They have enhanced properties.
Learning outcome	• Explain the properties of alloys in terms of non-directional bonding.
Prior knowledge	This will be better understood if students already have a sound grasp of metallic bonding as a lattice of cations with delocalized electrons (Structure 2.3), and the definition of mixtures as containing more than one substance in no fixed ratio (Structure 1.1.1).
Lesson context and opening question	An opening question asking to identify and name metallic objects in the immediate environment should reveal that alloys are more commonly used than pure metals (e.g. steel, brass, solder, sterling silver). Why is this? Leads to a discussion of enhanced properties.
Key concept	• Alloys are homogeneous mixtures containing at least one metal, and held together by metallic bonding.
Plan for how students will acquire knowledge, understanding and skills	• Provide examples of metals and alloys for students to see and feel, to help identify physical properties. • Demonstrate a homogeneous mixture, for example adding ethanol to water, to illustrate its properties. • Read pages 271–273 which cover how alloys are produced by mixing metals in the liquid state, and their structure as a modification of the metallic model of bonding. • Consider the Linking Question on page 273. • Attempt Exercise questions 4–7 on page 273.
Activities	Use the table of alloys on page 272 to spark observation and discussion of common alloys, and what properties make them fit for purpose. Note there should *not* be any emphasis on learning the component metals of specific alloys.
Links to IB concepts (e.g. NOS, TOK)	The steel industry (Global context feature box and photo page 273) is an excellent topic to consider the impact of chemical industries from the environmental, economic and sustainability perspectives.

Key questions to check for understanding	Practice questions 1 and 7 on pages 285–286.
Additional resources for support/extension	Discuss the Challenge yourself question on page 273.
Guiding Question re-visited	Alloys are an excellent example of how understanding the models of bonding and structure has led to the design of materials for specific functions. **What role do bonding and structure have in the design of materials?** • Alloys are homogeneous mixtures of metals with enhanced properties. • Metals are able to form alloys because of the non-directional nature of metallic bonding.

Lesson 3

Topic	**Structure 2 Models of bonding and structure**
Sub-topic	**Structure 2.4 From models to materials**
Guiding Question	**What role do bonding and structure have in the design of materials?**
Understanding	2.4.4 – Polymers
Level	SL and HL
Duration	Less than 1 hour
Content statement	• Polymers are large molecules, or macromolecules, made from repeating subunits called monomers.
Learning outcome	• Describe the common properties of plastics in terms of their structure.
Prior knowledge	This will be better understood if students already have a good knowledge of covalent bonding (Structure 2.2), and some introductory understanding of organic chemistry, specifically carbon's ability to form single and multiple bonds with itself and strong bonds with other elements (Structure 3.2). Some familiarity with IUPAC nomenclature will also be useful here.
Lesson context and opening question	An opening demonstration of linking paper clips (see photograph on page 274) can lead to the question of why this is possible. For example, why could tennis balls not join together in this way? This leads to a discussion of what properties monomers must possess that enable them to form polymers.
Key concept	• Polymers form when monomers link together by covalent bonds, forming large molecules with repeating units.

Plan for how students will acquire knowledge, understanding and skills	• Read page 274 which covers the concept of monomers linking together by covalent bonds to form polymers, shown using repeating units. • Read pages 274–276 which describe natural and synthetic polymers, including the benefits and burdens of plastics. • Demonstrate and describe the widespread occurrence and diversity of polymers in nature, for example by showing egg white and hair as proteins, starch from rice and cellulose in paper as carbohydrates. Nucleic acids are harder to visualise, but the names DNA and RNA will be familiar. • Demonstrate and describe a wide range of synthetic polymers, for example nylon, polystyrene, polythene, PVC, Kevlar etc. • Use the immediate environment of the classroom to identify the widespread use of plastics and the properties that make them useful for diverse functions. • Discuss some of the problems resulting from large-scale global production of plastics, and why their disposal is difficult. • Consider the Linking Question and answer on page 276.
Activities	Lab skills PDFs: • Structure 2.4 Properties of polymers • Structure 2.4 Making polymers
Links to IB concepts (e.g. NOS, TOK)	The plastics industry raises many questions of global concern, as noted in the Global context feature box on page 275 and the NOS feature box on page 276. This can lead to debate and possible CAS projects.
Guiding Question re-visited	**What role do bonding and structure have in the design of materials?** • Polymers are macromolecules composed of subunits called monomers held together by covalent bonds. • Plastics are polymers with properties that give them widespread uses in almost all aspects of society. • The distinct properties of plastics also cause them to accumulate in the environment without being broken down. • Use of biodegradable plastics and recycling programs are important steps to improve the processing of plastic waste, but the urgent need is to reduce the global production of plastic.

Lesson 4

Topic	**Structure 2 Models of bonding and structure**
Sub-topic	**Structure 2.4 From models to materials**
Guiding Question	**What role do bonding and structure have in the design of materials?**
Understanding	2.4.5 – Addition polymers
Level	SL and HL
Duration	Less than 1 hour
Content statement	• Addition polymers form by the breaking of a double bond in each monomer.
Learning outcome	• Represent the repeating unit of an addition polymer from given monomer structures.
Prior knowledge	This will likely be taught immediately after, or alongside, Structure 2.4.3. Knowledge of carbon-carbon double bonds in organic chemistry, and the tendency of alkenes to undergo addition reactions (Reactivity 3.4.5) is essential background here.
Lesson context and opening question	What must happen for alkenes to react together? Students can act out the cartoon diagram on page 277, starting with arms folded (double bond), then uncrossing the arms (bond breakage) to link with a neighbour (bond formation). Does anything have to be lost for this to occur?
Key concept	• An addition polymer is formed when the double bonds of monomer molecules break and make new covalent bonds with neighbouring molecules to form a chain. No other product is formed.
Plan for how students will acquire knowledge, understanding and skills	• Consider the Linking Question on page 277, which is addressed in the opening question above. • Read pages 277–278 which show the repeating units of addition polymers from different monomers. • Study the Worked example on page 278 to see the steps in determining the repeating unit. Note how this uses the approach suggested in the Hint on page 277. • Use this same approach to answer the Challenge yourself question on page 279. • Consider the Linking Question and answer on page 278. • <HL ONLY> Compare the atom economy of addition and condensation polymers. • Attempt Exercise questions 8–11 on page 279.
Activities	Identify common plastics which are addition polymers by considering familiar names such as polythene, polystyrene, polypropylene - and noting the ‘ene’ suffix. Labels on clothing may yield additional names of fabrics based on addition polymers.

	Video: Animation showing the formation of a long chain of the plastic polythene from molecules of ethene. https://www.sciencephoto.com/media/483210/view
Links to IB concepts (e.g. NOS, TOK)	The vast impact of the manufacture and disposal of addition polymers on everyday life, health and the environment lends itself to discussion and debate. See the Global context feature box on page 276 and the information about microplastics on page 278. There is potential here for individual investigations and CAS projects.
Key questions to check for understanding	Practice questions 3, 6 and 9 on pages 286–287.
Additional resources for support/extension	
Guiding Question re-visited	**What role do bonding and structure have in the design of materials?** • Addition polymers form from monomers that possess a double bond which can break to create new bonding positions for the attachment of neighbouring monomers. • Addition polymerization reactions do not yield a by-product.

Lesson 5

Topic	**Structure 2 Models of bonding and structure**
Sub-topic	**Structure 2.4 From models to materials**
Guiding Question	**What role do bonding and structure have in the design of materials?**
Understanding	2.4.6 – Condensation polymers
Level	HL ONLY
Duration	1 hour
Content statement	• Condensation polymers form by the reaction between functional groups in each monomer with the release of a small molecule.
Learning outcome	• Represent the repeating unit of polyamides and polyesters from given monomer structures.
Prior knowledge	This might be taught immediately after Structure 2.4.3 and Structure 2.4.4, or as an extension to the chemistry of functional groups in Structure 3.2.4. Students who also study biology may be aware of condensation and hydrolysis reactions from anabolic and catabolic processes respectively.

Lesson context and opening question	A possible extension of the cartoon to illustrate addition polymerization on page 277 would be for students to stand alongside each other, all wearing gloves. In order to link hands, the gloves must be removed. The discarded gloves form a pair at each link, representing the small molecule that is lost in the condensation reaction. Note for a chain to form, each person (monomer) must have two gloved hands (functional groups).
Key concept	• Condensation polymers form between monomers which each have two functional groups to react. A small molecule is released for each covalent bond that forms between the monomers.
Plan for how students will acquire knowledge, understanding and skills	• Study or review the structure of carboxylic acid, alcohol, amine, ester and amide functional groups. • Read pages 280–281 which cover condensation reactions and the formation of ester linkages. • Note the suggestion of drawing the monomer structures to focus on the two functional groups and consider the rest of the molecule as an unreactive ‘box’. Use this format to practise drawing the reaction that produces an ester linkage. • Study the Worked Example on page 282 which shows how to deduce the reactants from a given repeating unit. This is an example of a hydrolysis reaction described on pages 283–284. • Attempt Exercise questions 13 and 14a on page 284. • Read pages 282–283 which cover the formation of amide linkages. • Study the formation of nylon, and of Kevlar in the Worked example, on page 283. Note that the amide link that forms between carboxylic acid and amine groups is the same in these different examples. • Attempt Exercise questions 12, 14b and 15 on page 284. • Deduce the structure of monomers by considering hydrolysis reactions of condensation polymers. • Discuss the wide-spread occurrence of condensation polymers, both natural and synthetic and their diverse properties and functions. • Consider the Linking Question on page 283, which summarises much of this lesson.
Activities	Identify common plastics which are condensation polymers by considering familiar names such as polyesters and polyamides. **Video:** Making nylon. The two monomers are mixed without stirring and react at the interface to produce nylon threads, which are drawn out of the solution. https://www.sciencephoto.com/media/578357/view

Links to IB concepts (e.g. NOS, TOK)	Further discussion on the impact of polymers on everyday life can focus on condensation polymers. Understanding that natural polymers decompose by hydrolysis reactions catalyzed by enzymes leads to a discussion about the features of biodegradable and compostable plastics, as described on page 276. Further reference to recycling, as described on page 281, is also relevant here.
Key questions to check for understanding	Practice questions 11 and 12 on page 287.
Additional resources for support/extension	• Consider which monomers would produce small molecule by-products other than H_2O. • Compare the atom economy of addition and condensation reactions.
Guiding Question re-visited	**What role do bonding and structure have in the design of materials?** • Condensation polymers form from monomers with two functional groups which can react with the functional groups on neighbouring monomers. • Condensation polymerization reactions release a small molecule for each covalent bond formed. • Condensation polymers break down by hydrolysis reactions in which a small molecule is added for each bond broken in the polymer.

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	test tubes
Solvents:	test-tube rack
deionized water	bungs
petroleum ether	ammeter (or digital multimeter)
Substances:	wires/crocodile clips
oil	graphite electrodes
iodine pellets	lamp (1.5 V)
sodium chloride powder, NaCl(s)	battery (3.0 V)
potassium iodide powder, KI(s)	spatulas
sulfur (flowers), S_8(s)	pipettes
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	

Method

Experiment 1

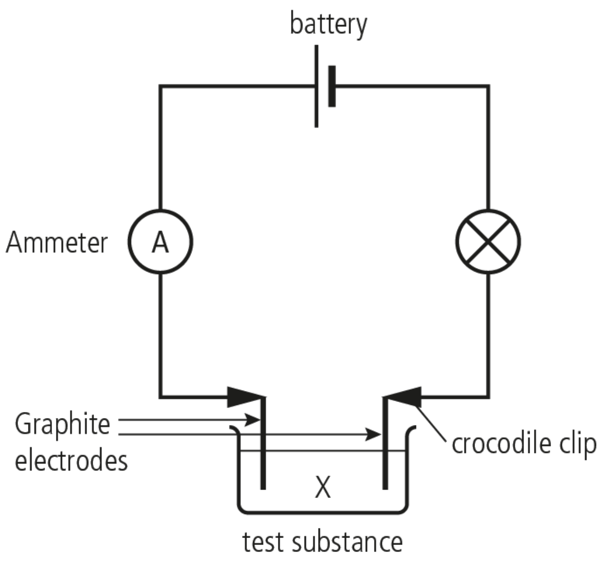
A Place a small amount of each substance (~1 g for solid substances and ~1 cm^3 for liquid substances) into five test tubes. Add 3–4 cm^3 of deionized water to each test tube, then tap the tubes and shake well to dissolve the substance. Record your observations in Table 1. Repeat the process using petroleum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

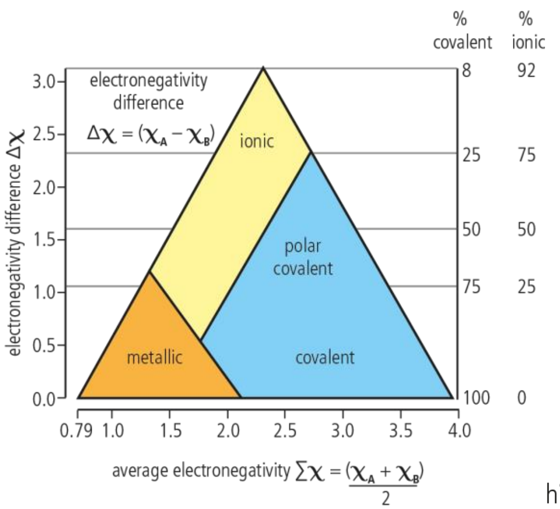
S2.4.1 Bonding is best described as a continuum between the ionic, covalent and metallic models, and can be represented by a bonding triangle.

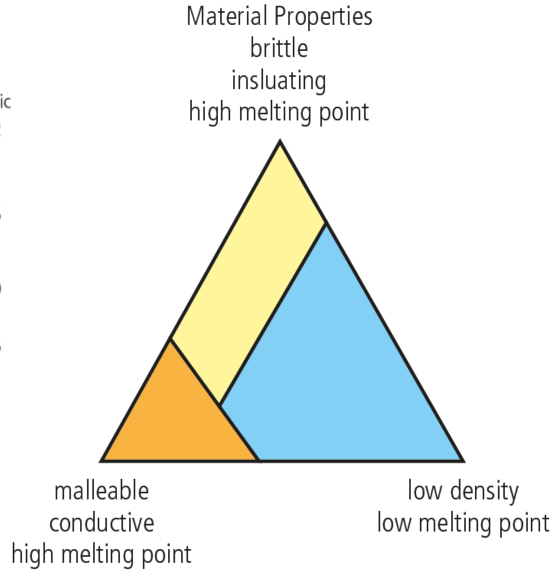
Aim

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:

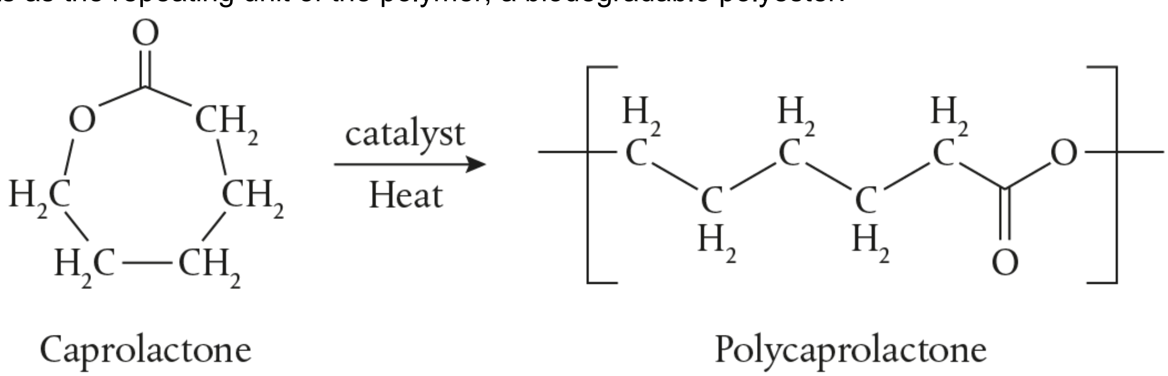
S2.4.4 Polymers are large molecules, or macromolecules, made from repeating sub-units called monomers.

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.

