
HSC Chemistry

Modelmat

Nov 30, 2021

YEAR 11 CONTENT

1	Properties and Structure of Matter	1
1.1	Properties of Matter	1
1.2	Atomic structure and atomic mass	1
1.3	Periodicity	1
1.4	Bonding	1
2	Introduction to Quantitative Chemistry	3
2.1	Chemical Reactions and Stoichiometry	3
2.2	Mole Concept	3
2.3	Concentration and Molarity	3
2.4	Gas Laws	3
3	Reactive Chemistry	5
3.1	Chemical Reactions	5
3.2	Predicting Reactions of Metals	5
3.3	Rates of Reactions	5
4	Drivers of Reactions	7
4.1	Energy Changes in Chemical Reactions	7
4.2	Enthalpy and Hess's Law	7
4.3	Entropy and Gibbs Free Energy	7
5	Equilibrium and Acid Reactions	9
5.1	Static and Dynamic Equilibrium	9
5.2	Factors that Affect Equilibrium	9
5.3	Calculating the Equilibrium Constant (K_{eq})	9
5.4	Solution Equilibria	9
6	Acid/Base Reactions	11
6.1	Properties of Acids and Bases	11
6.2	Using Brønsted-Lowry Theory	11
6.3	Quantitative Analysis	11
7	Organic Chemistry	13
7.1	Nomenclature	13
7.2	Hydrocarbons	13
7.3	Products of Reactions Involving Hydrocarbons	13
7.4	Alcohols	13
7.5	Reactions of Organic Acids and Bases	13
7.6	Polymers	13

8 Applying Chemical Ideas	23
8.1 Analysis of Inorganic Substances	23
8.2 Analysis of Organic Substances	26
8.3 Chemical Synthesis and Design	26
9 Assessing Primary and Secondary Sources	27
9.1 Primary Sources	27
9.2 Secondary Sources	28
10 Glossary	29
Index	31

PROPERTIES AND STRUCTURE OF MATTER

1.1 Properties of Matter

1.2 Atomic structure and atomic mass

1.3 Periodicity

1.4 Bonding

INTRODUCTION TO QUANTITATIVE CHEMISTRY

2.1 Chemical Reactions and Stoichiometry

2.2 Mole Concept

2.3 Concentration and Molarity

2.4 Gas Laws

REACTIVE CHEMISTRY

3.1 Chemical Reactions

3.2 Predicting Reactions of Metals

3.3 Rates of Reactions

DRIVERS OF REACTIONS

4.1 Energy Changes in Chemical Reactions

4.2 Enthalpy and Hess's Law

4.3 Entropy and Gibbs Free Energy

EQUILIBRIUM AND ACID REACTIONS

Chemical systems may be open or closed. They include physical changes and chemical reactions that can result in observable changes to a system. Students study the effects of changes in temperature, concentration of chemicals and pressure on equilibrium systems, and consider that these can be predicted by applying Le Chatelier's principle. Students also analyse the quantitative relationship between products and reactants in equilibrium reactions to determine an equilibrium constant. From this calculation, they predict the equilibrium position, either favouring the formation of products or reactants in a chemical reaction. This module also allows students to understand that scientific knowledge enables scientists to offer valid explanations and make reliable predictions. Students make reliable predictions by comparing equilibrium calculations and equilibrium constants to determine whether a combination of two solutions will result in the formation of a precipitate.

–Chemistry Stage 6 Syllabus, NESA

5.1 Static and Dynamic Equilibrium

5.2 Factors that Affect Equilibrium

5.3 Calculating the Equilibrium Constant (K_{eq})

5.4 Solution Equilibria

5.4.1 Dissolution of Ionic Compounds

5.4.2 Use by Aboriginal and Torres Strait Islander Peoples

Cycads are a seed plant that produces a cycad fruit which was eaten by Aboriginal and Torres Strait Islander Peoples. They were farmed as the plant had:

- high drought resistance
- high yield per unit area (12kg of fruit per 200m²)
- **high in carbohydrates and proteins**
 - similar to that of an energy bar
 - 1300kJ / 100g
 - 5g of protein

However, the cycad fruit contains the toxin cycasin at levels around 1.22g / 100g [Beck, 1989]. Cycasin's lethal dose (LD50) is 50mg / 100g. In lower levels, it causes long-term nerve damage due to the removal of the myelin sheath, liver disorders, and cancer.

Thus, Aboriginal and Torres Strait Islander Peoples used solubility equilibria in order to reduce the high cycasin concentration.

The use of running water reduces the concentration of the dissolved cycasin, and hence according to Le Chatelier's Principle the equilibrium will shift to the right to increase the concentration of the dissolved cycasin. This will increase the rate at which the cycasin dissolves.

In areas of lower rainfall, the dissolving was a slow process, and without the running water to shift the equilibrium to the right it would take up to 5 months for all the cycasin to dissolve.

Cycad seeds could be prepared with various leaching methods, such as [Beck, 1989]:

- brief leaching
- prolonged leaching
- ageing

Brief Leaching

Cycad seeds would be roasted, then sliced, pounded/ground [increasing surface area and hence rate of reaction]. They would then be leached overnight in running water. This method would store for about a week.

Prolonged Leaching

Prolonged leaching involved drying the seed, then it would be crushed and then leached in running water for 3-9 nights, or still water for 1-5 months. It would then be eaten or made into a loaf and roasted. Either of these would store for months at a time.

Ageing

Cycad seeds could be collected from the ground, and would be sorted by smell and sound by skilled Aboriginal and Torres Strait Islander Peoples. They would then be buried in the ground for weeks. They could be eaten, or ground into a paste and roasted. These would store for long periods of time.

5.4.3 Solubility Rules

5.4.4 Equilibrium Expressions for Saturated Solutions (K_{sp})

5.4.5 Predict Formation of a Precipitate given K_{sp}

ACID/BASE REACTIONS

Students analyse how and why the definitions of both an acid and a base have changed over time, and how the current definitions characterise the many chemical reactions of acids. Acids react in particular ways to a variety of substances. These reactions follow a pattern that students identify and explore in detail. Acids and bases, and their reactions, are used extensively in everyday life and in the human body. The chemistry of acids and bases contributes to industrial contexts and the environment. Therefore, it is essential that the degree of acidity in these situations is continually monitored. By investigating the qualitative and quantitative properties of acids and bases, students learn to appreciate the importance of factors such as pH and indicators.

–Chemistry Stage 6 Syllabus, NESA

6.1 Properties of Acids and Bases

6.2 Using Brønsted-Lowry Theory

6.3 Quantitative Analysis

ORGANIC CHEMISTRY

Students focus on the principles and applications of chemical synthesis in the field of organic chemistry. Current and future applications of chemistry include techniques to synthesise new substances – including pharmaceuticals, fuels and polymers – to meet the needs of society. Each class of organic compounds displays characteristic chemical properties and undergoes specific reactions based on the functional groups present. These reactions, including acid/base and oxidation reactions, are used to identify the class of an organic compound. In this module, students investigate the many classes of organic compounds and their characteristic chemical reactions. By considering the primary, secondary and tertiary structures of organic materials, students are provided with opportunities to gain an understanding of the properties of materials – including strength, density and biodegradability – and relate these to proteins, carbohydrates and synthetic polymers

–Chemistry Stage 6 Syllabus, NESA

7.1 Nomenclature

7.2 Hydrocarbons

7.3 Products of Reactions Involving Hydrocarbons

7.4 Alcohols

7.5 Reactions of Organic Acids and Bases

7.6 Polymers

Syllabus Excerpt

Inquiry Question: What are the properties and uses of polymers?

- model and compare the structure, properties and uses of addition polymers of ethylene and related monomers, for example:
 - polyethylene (PE)
 - polyvinyl chloride (PVC)
 - polystyrene (PS)

- polytetrafluoroethylene (PTFE)
- model and compare the structure, properties and uses of condensation polymers, for example:
 - nylon
 - polyesters

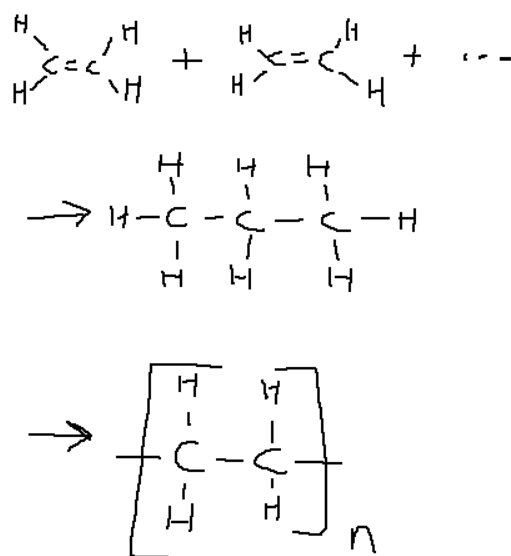
–Chemistry Stage 6 Syllabus, NESA

Polymers are long molecules made up of repeating units called *monomers*. These monomers react in a process called *polymerisation*, where the introduction of a free radical opens up a C=C double bond and this propagates down a chain of the monomers until the chain hits a terminating free radical or the end of another chain (this is mostly out of syllabus). The process propagates amongst thousands (as many as 20,000) of molecules as the polymer structure lowers the total energy of the system and is thus preferred.

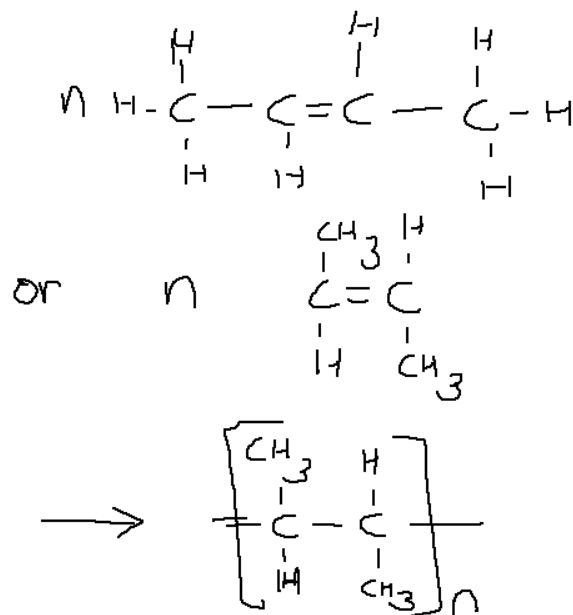
Polymers can be broken down into two categories by how they form: addition polymers and condensation polymers.

7.6.1 Addition Polymers

Addition Polymers form from the reaction of a single monomer with itself (for example, ethene to polyethene).



In this process the double bond is broken and becomes a single bond. In the case where the monomer chain is longer than a single double bond, it can be treated as a n-thyl substitute group off a repeating ethene unit:



Addition Polymers are named as poly<monomer>, e.g. *propene* → *polypropene*.

As part of this course we need to learn about the addition polymers of:

- polyethylene (PE)
- polyvinyl chloride (PVC)
- polystyrene (PS)
- polytetrafluoroethylene (PTFE)

7.6.2 Condensation Polymers

Condensation polymerisation occurs between monomers with functional groups on either end that will react with the other monomers. Condensation polymers can form copolymers, that is, a polymer derived from two different monomers. Condensation polymerisation also forms a secondary, much smaller molecule, which is often water. **Do not** forget to add this when doing condensation polymerisation reactions in your exams.

The presence of functional groups in condensation polymers often give them stronger intermolecular forces, and they also tend to form more crystalline structures (more on this later).

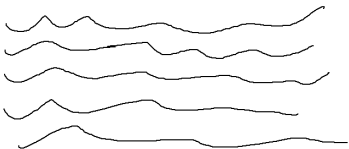
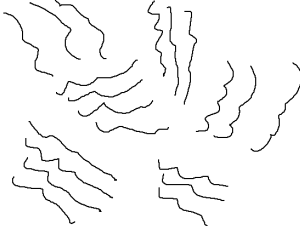
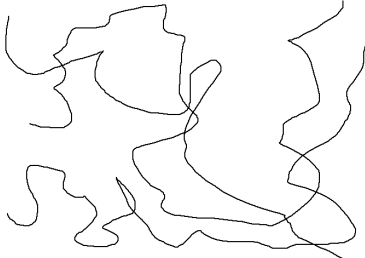
As part of this course we learn about:

- nylon
- polyester

7.6.3 Structure, Properties, and Uses

The properties of polymers can be analysed through intermolecular forces, as well as the crystallinity of the chains. The different structures provide the IMF as well as help crystallinity, as well as how they form. The different uses of each polymer arise from each property. Care should be taken such that the properties mentioned in your response justify the uses (i.e. “high boiling point” is not a good reason for why PVC is used in water pipes).

Polymers can be orientated or unorientated crystalline, or amorphous.

Orientated Crystalline	Unorientated Crystalline	Amorphous
		

Amorphous polymers have weak intermolecular bonds, and hence have low boiling points as well as low tensile strengths. They experience plastic deformation where chains easily slip past each other. There is often lots of branched chains which further decrease the packing ability of molecules.

Unorientated Crystalline polymers form naturally when monomers contain strong intermolecular bonds and are linear. This increases the packing ability and thus increases the tensile strength and boiling points of the polymer. They are a mix of crystalline sections orientated in varying directions.

Orientated Crystalline polymers do not generally form as a result of a chemical reaction. Instead they occur as the result of a cold drawing process, which pulls out the unorientated crystalline chains. This results in much higher tensile strengths and is used for the production of ropes and fibres.

Polymers can also be classified as elastomers, thermoplastic (thermosoftening), or thermosetting. All the polymers covered in the course exist as thermoplastics (generally - polyesters can sometimes by thermosetting).

Thermoplastics have only intermolecular forces between polymer chains (dispersion, dipole-dipole, and hydrogen bonds), which when heated will break apart, and thus the polymer will melt and can be remoulded.

Thermosets contain cross-links, which are intramolecular bonds between polymer chains - these require a cross-linking agent such as sulphur (in vulcanisation). The existence of cross links prevents the molecules from stretching elastically. When heating a thermosetting polymer, bonds within the carbon chain will often break before the cross-links do, resulting in the decomposition of the polymer.

Warning: It should be noted the difference between as “highly elastic” polymer and an “elastomer”. Elastomers are highly amorphous polymers which, when stretched, form crystalline structures that are of a significantly different shape to the original molecule (perhaps >20% elongation). They need to contain cross-links which do not favour being stretched and create the favoured initial shape. They are unable to maintain this crystalline structure in the absence of a tensile force, and hence it is entropically favourable for them to revert to their original shape. This is perhaps what one would consider to be “elastic”, but **it is not**.

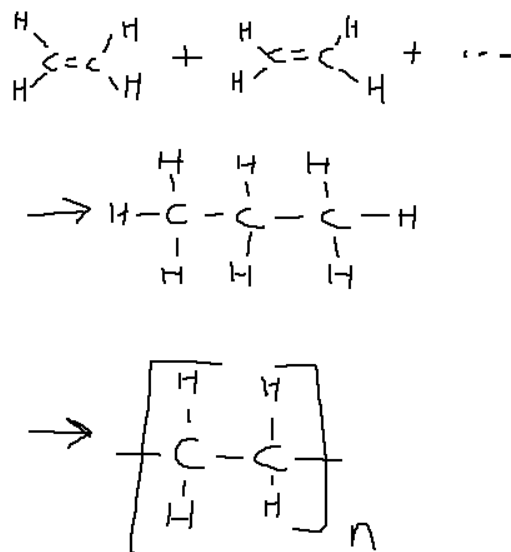
Elastic is an engineering term used to describe materials which can revert back to their original shape. Most materials are elastic - even steel - up to their elastic limit. Past the elastic limit, they plastically (i.e. permanently) deform to a different shape and eventually break at their tensile strength.

Note: A good resource on polymers is [this book from libretexts](#). Whilst much of it is out of syllabus, it gives a good

background on the properties and structure of various polymers.

Polyethylene

Polyethylene forms from the addition reaction between monomers of ethene.



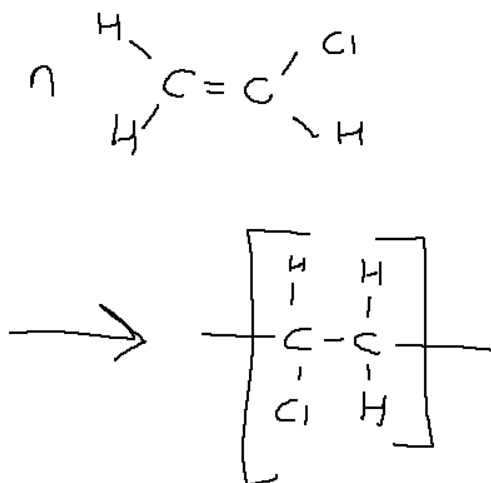
Without a catalyst, it forms the branched low-density polyethylene, which is lightweight (as the chains pack horribly). It contains only weak dispersion forces holding the molecules together, and is amorphous.

It is used for plastic bags and food containers as it is *lightweight* and *flexible*, and does not affect food contents, and is also insoluble in water (non-polar), resistant to some chemical attack (strong C-H and C-C bonds).

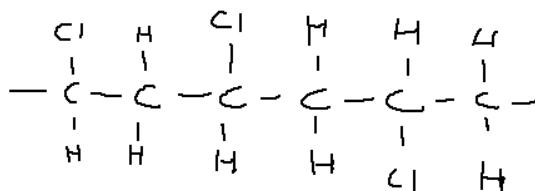
In the presence of a Ziegler-Natta catalyst, the chains form crystalline structures which allow for stronger dispersion forces between polymer chains. This gives it higher density and strength.

HDPE is used for buckets, milk crates, and pipes as it is reasonably strong and hard (due to crystallinity and strong DP), light (low molecular weight), and insoluble (non-polar), resistant to some chemical attack (strong C-H and C-C bonds)

Polyvinyl Chloride



The addition of a chlorine atom to form chloroethene creates the polymer polyvinyl chloride, commonly referred to as PVC. It tends to be rather amorphous as it forms mainly *atactic* PVC - that is, the chlorine atoms are randomly arranged on either side of the chain. This makes it difficult for chains to pack close together.



However, as the Cl is more electronegative than carbon, it attracts electrons, which make it slightly negative and the carbon slightly positive. This forms a permanent dipole and results in stronger intermolecular forces between chains, increasing the boiling point despite the amorphous nature. It also makes the chain very rigid and strong.

It is still insoluble in water as it is only weakly polar.

The C-Cl bond has a lower bond energy than C-H, meaning that it is more prone to decomposition in UV light (e.g. in the sun) but this is prevented with an inhibitor such as TiO₂.

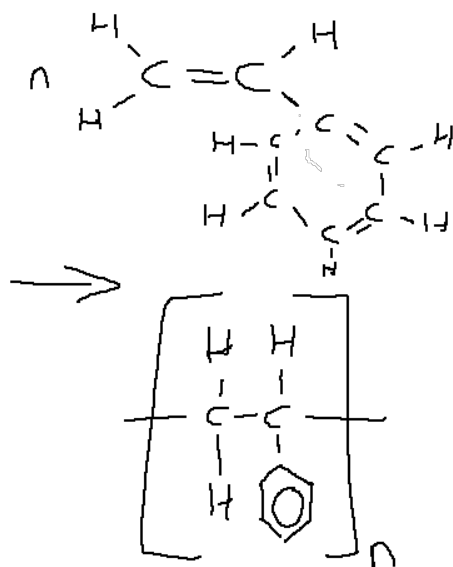
It has no shared lone pair electrons and is hence electrically non-conductive.

Plasticisers can be added to the molecule to reduce the strength of intermolecular bonds and hence make it flexible.

As PVC is rigid and water insoluble, it can be used in water piping. As it is electrically nonconductive, and flexible, it finds use in electrical insulation. As it can be flexible and water insoluble, and does not decompose under UV, it is used in garden hoses.

Polystyrene

A styrene monomer contains a bulky benzene ring which decreases packing ability but increases molar mass.



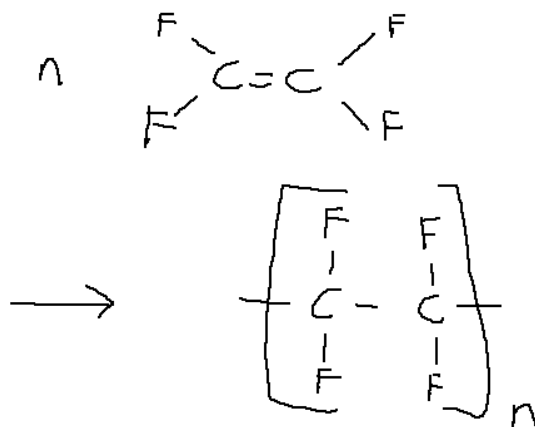
Just like PVC, polystyrene mainly forms an atactic structure, with the benzene rings randomly arranged on either side of the molecular. This makes polymer very amorphous and thus the dispersion forces are weakened due to larger distances. However, due to the higher molar mass and thus high number of electrons dispersion forces are still reasonably strong.

The large benzene ring makes the chain brittle because (and stiff) because when the chain is put under stress the benzene ring's come closer and repel each other. The polar benzene ring serves to make the molecular very rigid, which results in it being brittle. The low packing ability makes polystyrene have a low density.

As it is a very rigid molecule, this makes it suitable for use in computer cases, CD/DVD cases, and battery cases.

It can also be turned into a foam, which is filled with air molecules. These air molecules make it very low density and also a good thermal insulator.

Polytetrafluoroethylene



PTFE, also known by the brand name Teflon, is made from the polymerisation of tetrafluoroethene.

The C-F bonds that the polymer contains are highly electronegative. Each attached fluorine atom is strongly repulsed by each other, and hence the structure has one preferred shape (no rotation around bonds). The chain forms a very straight rod which (in 3D) gently spirals.

As the chains are very straight, this forms a crystalline structure. The dispersion forces produced between molecules are very strong because the molecules are so closely packed (despite the repulsion from fluorine atoms), which gives it a boiling point of ~327°C.

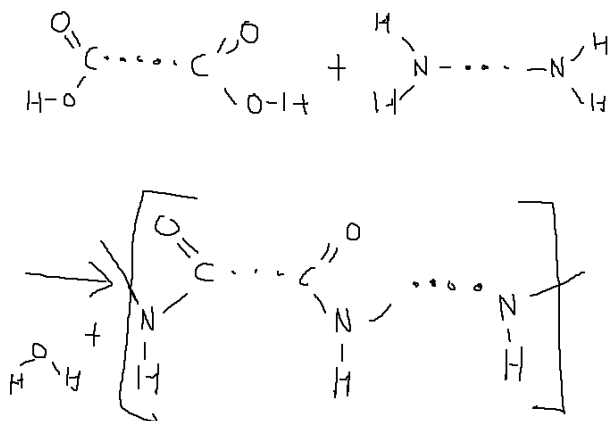
PTFE gets its non-stick properties and unreactive properties from the strength of the C-F bond; it is very difficult (practically impossible) for any other molecule to replace the C-F bond; as well as most molecules or branched polymers do not pack tight enough to overcome the repulsive fluorine atoms.

The non-stick and inert properties make it useful for frying pans, gears, and medical implants.

Note: ChemGuide produces a [nice explanation](#) on the properties of PTFE.

Nylon

Nylon is a type of polyamide formed from the reaction between dicarboxylic acids and diamines.



A common example of a nylon polymer is nylon 6,6 which is produced with the reaction of hexanedioic acid and hexane-1,6-diamine.

The initial polymer is formed as unorientated crystalline but when cold-drawn into ropes the crystalline structures becomes orientated.

The amide groups in the chains are polar and can form hydrogen bonds between chains. The strong intermolecular forces results in high boiling points as well as making it hard to stretch the chain - resulting in a high stiffness and elastic limit.

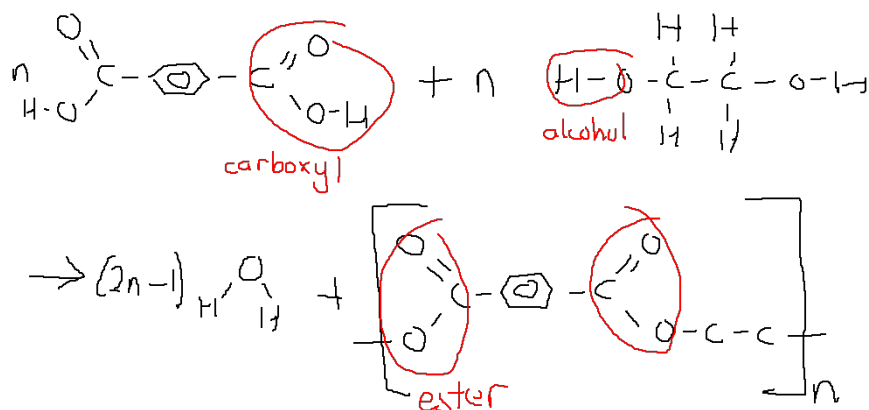
The high tensile strength of the nylon means that it can be used for rope, fishing lines, and other fibres.

When not cold-drawn (solid), the hydrogen bonds afford the structure rigidity which allows it to be used in gears or bearings.

Polyester

Polyesters are formed by combining dicarboxylic acids and diols.

A common polyester is polyethene terephthalate (PET), which is made from benzenen-1,4-dioic acid and ethane-1,2-diol.



The C=O bond formed in the polyester is polar and this allows dipole-dipole interactions to occur, this combined with mostly linear chains creates a highly crystalline structure that affords it high strength and boiling points.

The high strength means it is often formed into clothes or parachutes, through cold-drawing.

Polyesters are susceptible to attack by alkaline substances (the C=O reacts)

As this does not have cross-links, it is a thermoplastic polymer, which means it can be melted into a mould and can be used in packaging. It is suitable for this as it is very recyclable and has a high strength to weight ratio.

APPLYING CHEMICAL IDEAS

The identification and analysis of chemicals is of immense importance in scientific research, medicine, environmental management, quality control, mining and many other fields. Students investigate a range of methods used to identify and measure quantities of chemicals. They investigate and process data involving the identification and quantification of ions present in aqueous solutions. This is particularly important because of the impact of adverse water quality on the environment. Students deduce or confirm the structure and identity of organic compounds by interpreting data from qualitative tests of chemical reactivity and determining structural information using proton and carbon-13 nuclear magnetic resonance (NMR) spectroscopy.

–Chemistry Stage 6 Syllabus, NESA

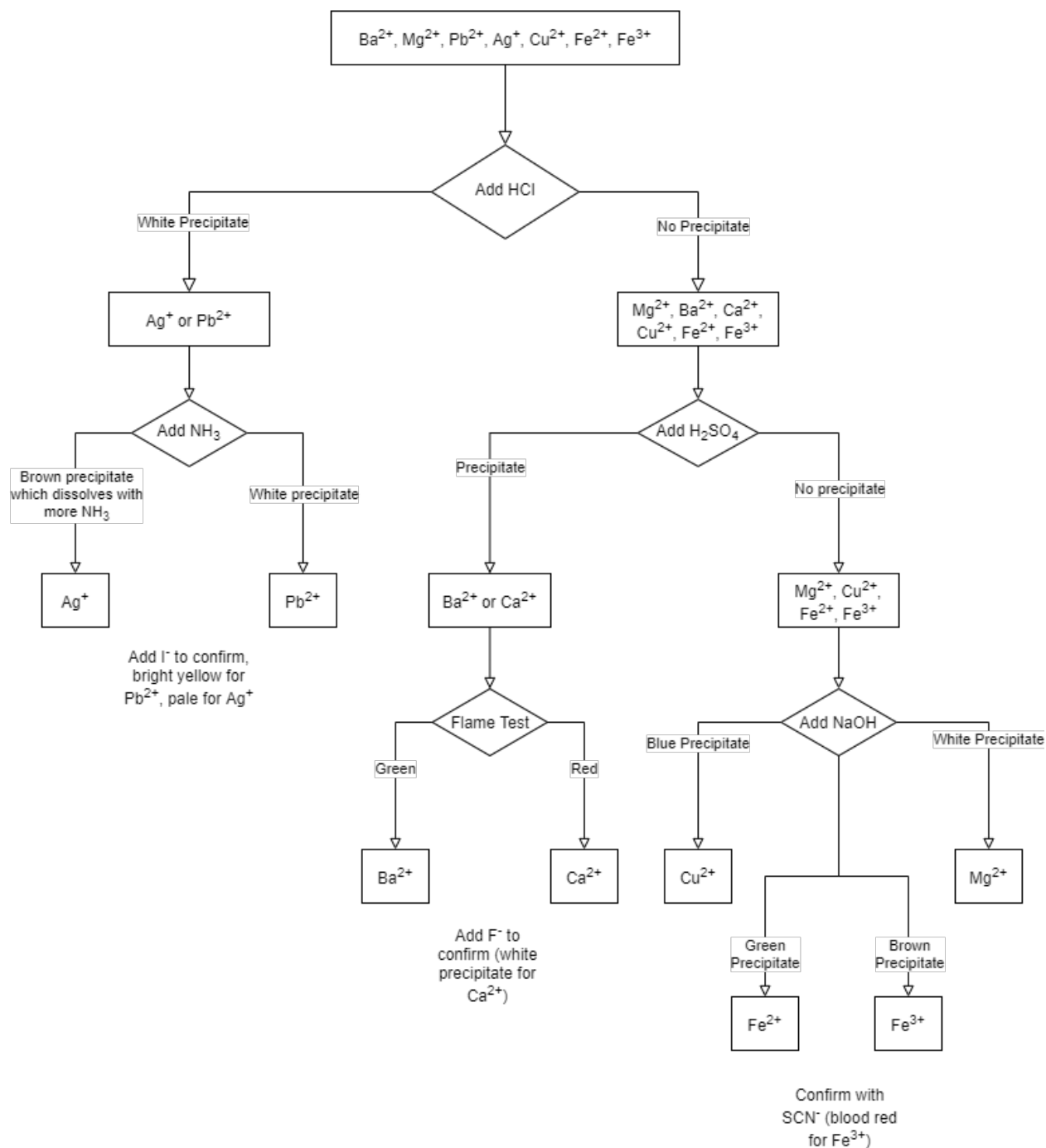
8.1 Analysis of Inorganic Substances

8.1.1 Analyse the need for monitoring the environment

8.1.2 Qualitative investigations to test for the presence of aqueous ions

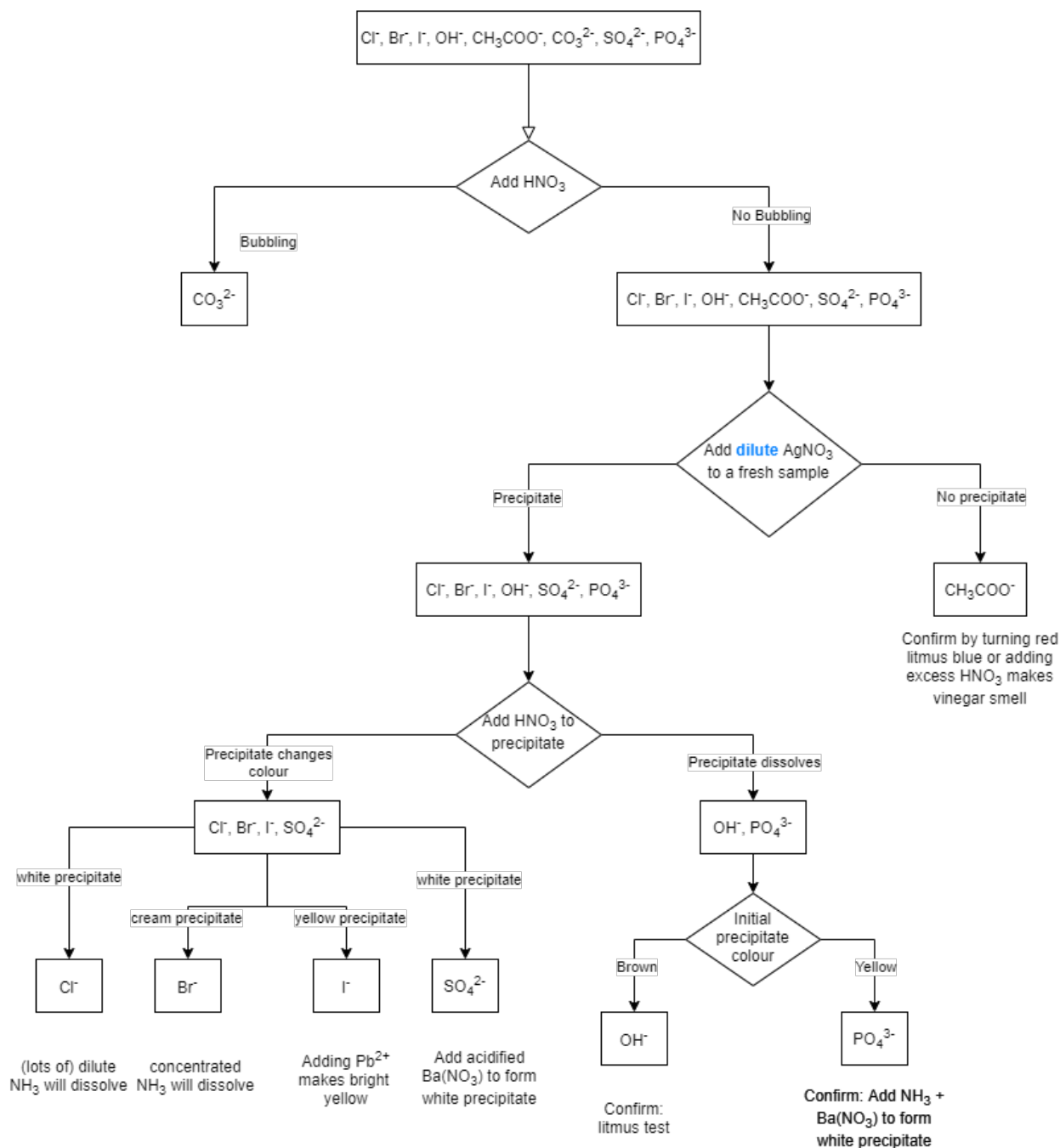
Cations: Ba^{2+} , Ca^{2+} , Mg^{2+} , Pb^{2+} , Ag^{+} , Cu^{2+} , Fe^{2+} , Fe^{3+}

Cation Identification Flowchart



Anions: Cl^- , Br^- , I^- , OH^- , CH_3COO^- , CO_3^{2-} , SO_4^{2-} , PO_4^{3-}

Anion Identification Flowchart



8.2 Analysis of Organic Substances

8.3 Chemical Synthesis and Design

ASSESSING PRIMARY AND SECONDARY SOURCES

Students identify trends, patterns and relationships; recognise error, uncertainty and limitations in data; and interpret scientific and media texts. They evaluate the relevance, accuracy, validity and reliability of the primary or secondary-sourced data in relation to investigations.

–Chemistry Stage 6 Syllabus, NESA

Note: The definitions of accuracy, reliability, and validity are taken from [Resources for science instruction \(NSW Education\)](#)

9.1 Primary Sources

9.1.1 Accuracy

The extent to which a measured value agrees with the true value. Requires prior knowledge about the value to be measured.

An experiment which is accurate should show a value that is close to the true value.

9.1.2 Reliability

The extent to which the findings of repeated experiments, conducted under identical or similar conditions, agree with each other. Repeating the experiment minimises the effect of outliers, etc.

9.1.3 Validity

The extent to which an experiment addresses the question under investigation. Requires the experiment to be reliable, accurate, and precise. In addition, you must be only changing ONE *independent variable*, and *controlling* all the other variables. It must also be using the correct equipment, and addressing the aim. Validity can be assessed with:

- mention variables being controlled
- only ONE variable should be changed, and its effect on ONE dependent variable
- state how errors (e.g. friction in a pendulum swing gravity experiment) have been minimised (or not)

9.1.4 Precision

Note: This is not part of the chemistry syllabus. However, it is important to know this as it is a **distinct** category to accuracy or reliability.

The extent to which multiple measurements, made under identical or similar conditions, agree with each other (i.e. variations within a dataset).

This is referring to the *uncertainty* of measurements, i.e. how close the measured value is to the value being measured. Can be quantified with the range of values, written as: 5 ± 1 .

Note: See *Mainpulating Uncertainties* in [Resources for science instruction \(NSW Education\)](#) for how to combine uncertainties.

9.2 Secondary Sources

9.2.1 Reliability

The consistency of information between sources. Can be evaluated through showing that various sources all gave the same information.

9.2.2 Validity

The appropriateness of the information. Needs to consider:

- the author's credentials (are they qualified in that field)
- the purpose of the article - is it biased?
- is it current (not outdated - this is not "recent")
- is the publisher reputable?

9.2.3 Accuracy

The information needs to be both valid and reliable.

GLOSSARY

accuracy See *Accuracy*.

reliability See *Reliability*.

validity See *Validity*.

monomer A small molecule which reacts with other molecules to combine to form a polymer.

INDEX

A

accuracy, [29](#)

M

monomer, [29](#)

R

reliability, [29](#)

V

validity, [29](#)