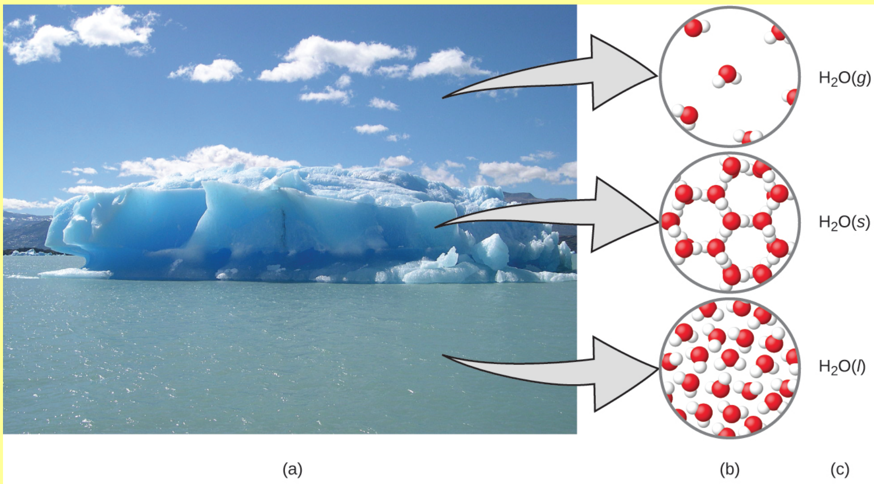
Kilbaha Chemistry



VCE Unit 1

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Cover Image: (a) Moisture in the air, icebergs, and the ocean represent water in the macroscopic domain. (b) At the molecular level (microscopic domain), gas molecules are far apart and disorganised, solid water molecules are close together and organised, and liquid molecules are close together and disorganised. (c) The formula H_2O symbolizes water, and (*g*), (*s*), and (*l*) symbolise its phases. Note that clouds are actually comprised of either very small liquid water droplets or solid water crystals; gaseous water in our atmosphere is not visible to the naked eye, although it may be sensed as humidity. (credit a: modification of work by "Gorkaazk"/Wikimedia Commons)

The content of this book has been adapted from OpenStax College Chemistry and aligned to
VCE Chemistry Study Design: Units 1 and 2: 2016 - 2021
The original text may be downloaded for free use from https://openstaxcollege.org/textbooks/chemistry/get
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Authors' Note to Biology, Chemistry, Physics Teachers – Unit 1

- Ian Alexander, Alan Reynolds and Bill Healy as the authors and editors of this series have been motivated to complete this project by the new Study Guides for the VCE sciences for the period 2016 - 2021.

- Teachers will find that the content of these books goes well beyond the content of standard Year 11 Textbooks. We believe this will suit the new emphasis on research and investigation in the new Study Guides. We also expect these books to have wide application to other Australian Biology, Chemistry and Physics courses.

- We are keen to provide all schools with quality material at a bargain basement price.

- We have been able to do this because of the relationship between Kilbaha Multimedia Publishing in Australia and OpenStax in the United States. We are grateful to OpenStax for their support. It has taken considerable work to make these texts Australian in word and context and to meet the expectations of the new VCE courses commencing in 2016.

- Try to think of these electronic books in a different way. They are like Apps on your smartphone. These are just versions 1.1 and we envisage that additional material (free to all subscribers) will be added after feedback from teachers.

- These textbooks are electronic only. Kilbaha does not offer printed copies.

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- Ian Alexander, Alan Reynolds and Bill Healy hope that you find these electronic books a valuable addition to your teaching materials for Year 11 and Year 12 or wherever else you choose to use them within your school.

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CONTENTS - Kilbaha VCE Chemistry Unit 1

How can the diversity of materials be explained?

Area of Study 1

How can knowledge of elements explain the properties of matter?

1. Elements and the periodic table

1. the relative and absolute sizes of particles that are visible and invisible to the unaided eye: small and giant molecules and lattices; atoms and sub-atomic particles; nanoparticles and nanostructures

2. the definition of an element with reference to atomic number; mass number; isotopic forms of an element using appropriate notation

3. spectral evidence for the Bohr model and for its refinement as the Schrödinger model; electronic configurations of elements 1 to 36 using the Schrödinger model of the atom, including s, p, d and f notations (with copper and chromium exceptions)

4. the periodic table as an organisational tool to identify patterns and trends in, and relationships between, the structures (including electronic configurations and atomic radii) and properties (including electronegativity, first ionisation energy, metallic/non-metallic character and reactivity) of elements.

Area of Study 1

How can knowledge of elements explain the properties of matter?

2. Metals

1. the common properties of metals (lustre, malleability, ductility, heat and electrical conductivity) with reference to the nature of metallic bonding and the structure of metallic crystals, including limitations of representations; general differences between properties of main group and transition group metals

2. experimental determination of the relative reactivity of metals with water, acids and oxygen

3. the extraction of a selected metal from its ore/s including relevant environmental, economic and social issues associated with its extraction and use

4. experimental modification of a selected metal related to the use of coatings or heat treatment or alloy production

5. properties and uses of metallic nanomaterials and their different nanoforms including comparison with the properties of their corresponding bulk materials.

Area of Study 1

How can knowledge of elements explain the properties of matter?

3. Ionic compounds

1. common properties of ionic compounds (brittleness, hardness, high melting point, difference in electrical conductivity in solid and liquid states) with reference to their formation, nature of ionic bonding and crystal structure including limitations of representations

2. experimental determination of the factors affecting crystal formation of ionic compounds

3. the uses of common ionic compounds.

Area of Study 1

How can knowledge of elements explain the properties of matter?

4. Quantifying atoms and compounds

1. the relative isotopic masses of elements and their representation on the relative mass scale using the carbon-12 isotope as the standard; reason for the selection of carbon-12 as the standard

2. determination of the relative atomic mass of an element using mass spectrometry (details of instrument not required)

3. the mole concept; Avogadro constant; determination of the number of moles of atoms in a sample of known mass; calculation of the molar mass of ionic compounds

4. experimental determination of the empirical formula of an ionic compound.

Area of Study 2

How can the versatility of non-metals be explained?

1. Materials from molecules

1. representations of molecular substances (electron dot formulas, structural formulas, valence structures, ball and-stick models, space-filling models) including limitations of representations

2. shapes of molecules and an explanation of their polar or non-polar character with reference to the electronegativities of their atoms and electron-pair repulsion theory

3. explanation of properties of molecular substances (including low melting point and boiling point, softness, and non-conduction of electricity) with reference to their structure, intramolecular bonding and intermolecular forces

4. the relative strengths of bonds (covalent bonding, dispersion forces, dipole-dipole attraction and hydrogen bonding) and evidence and factors that determine bond strength including explanations for the floating of ice and expansion of water at higher temperatures.

Area of Study 2

How can the versatility of non-metals be explained?

2. Carbon lattices and carbon nanomaterials

1. the structure and bonding of diamond and graphite that explain their properties (including heat and electrical conductivity and hardness) and their suitability for diverse applications

2. the structures, properties and applications of carbon nanomaterials including graphene and fullerenes.

Area of Study 2

How can the versatility of non-metals be explained?

3. Organic compounds

1. the origin of crude oil and its use as a source of hydrocarbon raw materials

2. the grouping of hydrocarbon compounds into families (alkanes, alkenes, alkynes, alcohols, carboxylic acids and non-branched esters) based upon similarities in their physical and chemical properties including general formulas, their representations (structural formulas, condensed formulas, Lewis structures), naming according to IUPAC systematic nomenclature (limited to non-cyclic compounds up to C10, and structural isomers up to C7) and uses based upon properties

3. determination of empirical and molecular formulas of organic compounds from percentage composition by mass and molar mass.

Area of Study 2

How can the versatility of non-metals be explained?

4. Polymers

1. the formation of polymers from monomers including addition polymerisation of alkenes

2. the distinction between linear (thermoplastic) and cross-linked (thermosetting) polymers with reference to structure, bonding and properties including capacity to be recycled

3. the features of linear polymers designed for a particular purpose including the selection of a suitable monomer (structure and properties), chain length, degree of branching, percentage crystalline areas and addition of plasticisers

4. the advantages and disadvantages of the use of polymer materials.

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.1 The origin of the elements

Questions that may be explored in this investigation include:

1. How are atoms 'seen'?
2. Are there more elements to be discovered?
3. What are electrons, protons and neutrons made of?
4. How do we know what elements are in the Universe?
5. What is the evidence that living things are made of stardust?
6. Why are the ten most abundant elements in the Universe not the same as the ten most abundant elements on Earth?
7. How does the abundance of elements on Earth compare with the abundance of elements in humans?
8. Would there be life if elements did not form compounds?
9. Why are the nuclei of some elements unstable?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.2 The development of the periodic table

Questions that may be explored in this investigation include:

1. Is alchemy chemistry?
2. How can lead be transformed into gold?
3. On what basis are alternative forms of the periodic table constructed?
4. Where would an element with an atomic number of 130 be placed in the modern periodic table, what properties would it have and how likely is it to be discovered?
5. Why is the periodic table still a ‘work in progress’?
6. Why is it difficult to place hydrogen in the modern periodic table?
7. Is it worthwhile finding any more new elements?
8. Why aren’t all the metals placed together in the periodic table?
9. What makes some elements magnetic?
10. Why do transition metals have multiple oxidation states?
11. Is it an advantage or a disadvantage for elements to be unreactive?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.3 The lanthanoids and actinoids

Questions that may be explored in this investigation include:

1. Why are some lanthanoids and actinoids so highly sought after?
2. Can we live without lanthanoids and actinoids?
3. Based on their usefulness for society, how would you compare the value of lanthanoids and actinoids with the value of other metal groups in the periodic table?
4. Is it worth sending people to the Moon to mine for lanthanoids and actinoids?
5. How are the lanthanoids and actinoids extracted from their ores?
6. Do the lanthanoids and actinoids rust or corrode?
7. Where are the lanthanoids and actinoids located in the periodic table and why have they been placed there?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.4 Using light to solve chemical puzzles

Questions that may be explored in this investigation include:

1. What is a crystal, and why do crystals have regular faces?
2. What makes synchrotron light useful?
3. What can a synchrotron tell us about the differences between salt and sugar crystals?
4. How does the composition of a crystal relate to the bonding within and the ratios of the elements present?
5. Given that crystals are not alive or functioning, how is it that crystal structures are used to understand biological functions?
6. What significant discoveries contributed to the development of X-ray crystallography as an analytical technique?
7. How does cryoprotection preserve protein samples for analysis in a synchrotron?
8. How has the use of a synchrotron enabled Nobel Prize winning research to occur?
9. Why use synchrotron light to determine crystal structure when other sources of X-rays can be used?
10. How does the IR beamline in the Australian Synchrotron enable the study of organic molecules and covalent bonding patterns?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.5 Glass

Questions that may be explored in this investigation include:

1. What would life be like without glass? What might have to be used instead?

2. How are the special properties achieved in particular forms of glass such as transition lenses, bullet-proof glass, safety glass, bendable glass, heat-proof glass, glass than can be switched on or off to become transparent or opaque, coloured glass and fibreglass?

3. How are glass ornaments, glass jewellery and specialised laboratory glassware created?

4. How does lightning make glass?

5. Is glass safer to use than other forms of storage vessels?

6. How useful is the type of glass that is produced as a by-product when iron is extracted from its ore in a blast furnace?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.6 Crude oil

Questions that may be explored in this investigation include:

1. Do we need crude oil?
2. Why does the composition of crude oil vary between different oil wells?
3. How do different crude oil extraction methods compare with reference to ease of extraction and environmental impacts?
4. What might we do if crude oil supplies run out?
5. How does the time taken to produce crude oil compare with the time taken to use it?
6. What fuels and other chemicals are derived from crude oil? How is crude oil processed to obtain them?
7. Why are tar balls found on beaches after an oil spill?
8. What are some of the issues surrounding society's demand for and use of crude oil? What strategies are being used to address some of these issues?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.7 Surfactants

Questions that may be explored in this investigation include:

1. How do surfactants help clean up oil spills?
2. Why is it so difficult to remove oil from bird feathers? Why can water birds drown if they still have detergent on their feathers?
3. How are surfactants used in cooking, cosmetics and personal hygiene?
4. How do hair shampoos differ from conditioners?
5. How are soaps different from detergents?
6. Why are different detergents made for cleaning different surfaces? How does their composition differ?
7. How are surfactants designed for biodegradability?
8. Does surfactant biodegradability affect performance?
9. How can surfactants protect dams from drying out?
10. What is the role of natural surfactants in the human body in breathing and digestion?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.8 Polymers and composite materials

Questions that may be explored in this investigation include:

1. Are the biomaterials that replace body parts as effective as the original materials with reference to their properties and function?

2. How can biomimicry help in developing new materials?

3. How do new materials improve sporting performance?

4. What are some of the new generation composite materials that have been designed to meet the emerging demands posed by space programs, and medical and technological developments?

5. Should cars be made from shape memory metals?

6. What makes some materials 'smart'?

7. How do different types of radiation affect the structure and properties of polymer films?

8. What applications for conductive polymers could be possible?

9. What properties might a new 'super material' have, what might it be made from and what difference could it make to people's lives?

10. Why would it be an advantage for polymers not to be biodegradable?

11. How are new polymer and composite materials tested for safety?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.9 Nanomaterials

Questions that may be explored in this investigation include:

1. What useful materials have resulted from nanomaterial research and what could be produced in future?
2. How are nanochemists able to ‘see’ nanoparticles and manipulate atoms to build particular nanomaterials?
3. Why do nanomaterials have different properties to their related macromaterials?
4. Are nanomaterials safe?
5. What difference can nanomaterials make to society and the environment?
6. What can nanobots do?
7. How are nanomaterials used in medicine and research?

Area of Study 3

Research investigation: Choose one of ten options.
A question from the list under each option may be selected or students may develop their own research question relevant to Area of Study 1 and/or Area of Study 2 in conjunction with their teacher. For the selected question, students outline, analyse and evaluate relevant evidence to support their conclusions.

3.10 The life cycle of a selected material or chemical

Questions that may be explored in this investigation include:

1. What is the story behind the discovery of a selected material or chemical and why is it important?

2. What is the relationship between the properties, structure and the nature and strength of the chemical bonding within the structure of a selected material or chemical?

3. What are the main features of the life cycle of a selected material or chemical and how can these features be represented (they may include the extraction and processing of the raw materials; the manufacturing processes used, its packaging, distribution and use; any recycling and reuse; and its disposal at the end of its useful life)?

4. What health and safety and environmental issues are involved in the manufacture, use and disposal of a selected material or chemical and how are these managed?

5. What happens to a selected material or chemical at the end of its life?

Area of Study 3

Research investigation

1. **Effective science communication**

   the characteristics of effective science communication: accuracy of chemical information; clarity of explanation of chemical concepts, ideas and models; contextual clarity with reference to importance and implications of findings; conciseness and coherence

2. **Chemical concepts**

   the chemical concepts specific to the investigation: definitions of key terms; use of appropriate chemical terminology, conventions, units and representations

3. **Data, models and theories**

   the use of data representations, models and theories in organising and explaining observed phenomena and chemical concepts, and their limitations

4. **Evidence and information**

   the nature of evidence and information: distinction between weak and strong evidence, and scientific and nonscientific ideas; and validity, reliability and authority of data including sources of possible errors or bias

5. **Social, economic, environmental and ethical factors**

   the influence of social, economic, environmental and ethical factors relevant to the selected chemical investigation.

Figure 1.1 Chemical substances and processes are essential for our existence, providing sustenance, keeping us clean and healthy, fabricating electronic devices, enabling transportation and much more. (credit "left": modification of work by "vxla"/Flickr; credit "left middle": modification of work by "the Italian voice"/Flickr; credit "right middle": modification of work by Jason Trim; credit "right": modification of work by "gosheshe"/Flickr)

Chapter Outline

1.1 Chemistry in Context

1.2 Phases and Classification of Matter

1.2 Physical and Chemical Properties

1.4 Measurements

1.5 Measurement Uncertainty, Accuracy and Precision

1.6 Mathematical Treatment of Measurement Results

Introduction

Your alarm goes off and, after hitting "snooze" once or twice, you get yourself out of bed. You make a cup of coffee to help you get going and then you shower, get dressed, eat breakfast and check in for Messages, Facebook, Instagram and Snapchat. As you find a seat in the classroom, you read the question projected on the screen: "Welcome to class! Why should we study chemistry?"

Do you have an answer? You may be studying chemistry because it fulfills an academic requirement, but if you consider your daily activities, you might find chemistry interesting for other reasons. Nearly everything you do and encounter during your day involves chemistry. Making coffee, cooking eggs and toasting bread involve chemistry.

The products you use—like soap and shampoo, the fabrics you wear, the electronics that keep you connected to your world, the petrol for your car—all of these and more involve chemical substances and processes. Whether you are aware or not, chemistry is part of your everyday world. In this course, you will learn many of the essential principles underlying the chemistry of modern-day life.

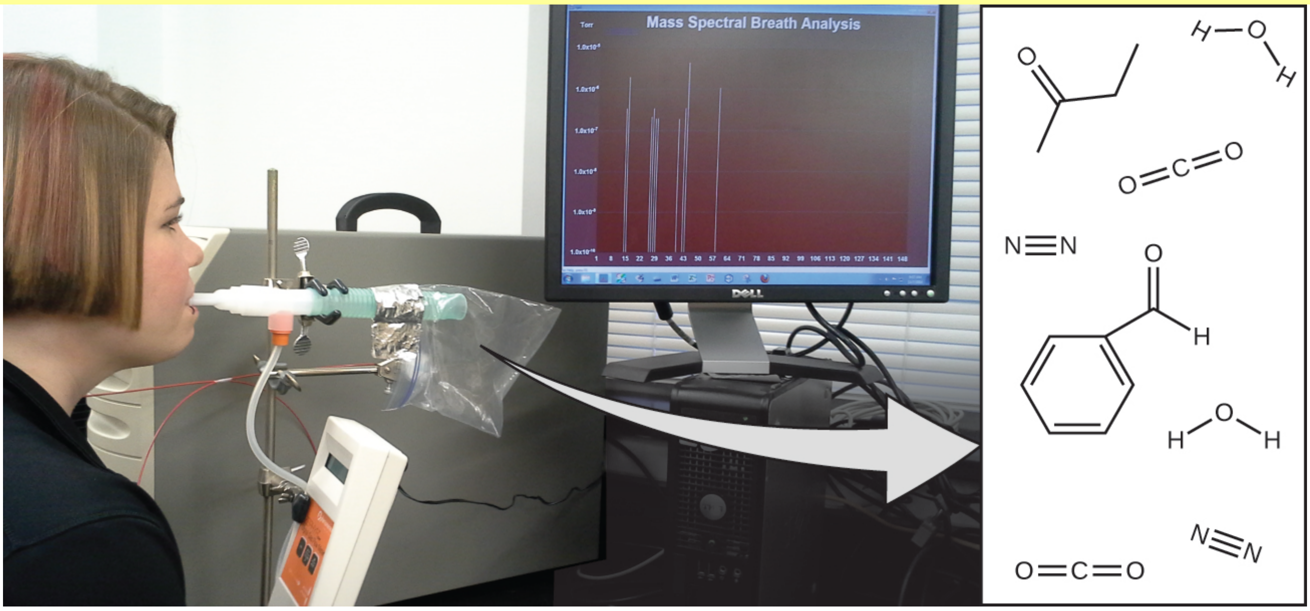


Figure 2.1 Analysis of molecules in an exhaled breath can provide valuable information, leading to early diagnosis of diseases or detection of environmental exposure to harmful substances.
(credit: modification of work by Paul Flowers)

Chapter Outline

2.1 Early Ideas in Atomic Theory

2.2 Evolution of Atomic Theory

2.3 Atomic Structure and Symbolism

2.4 Chemical Formulas

2.5 The Periodic Table

2.6 Molecular and Ionic Compounds

2.7 Chemical Nomenclature

Introduction

Your overall health and susceptibility to disease depends upon the complex interaction between your genetic makeup and environmental exposure, with the outcome difficult to predict. Early detection of biomarkers, substances that indicate an organism's disease or physiological state, could allow diagnosis and treatment before a condition becomes serious or irreversible.

Recent studies have shown that your exhaled breath can contain molecules that may be biomarkers for recent exposure to environmental contaminants or for pathological conditions ranging from asthma to lung cancer.

Figure 3.1 The water in a swimming pool is a complex mixture of substances whose relative amounts must be carefully maintained to ensure the health and comfort of people using the pool.
(credit: modification of work by Vic Brincat)

Chapter Outline

3.1 Relative formula mass and the Mole Concept

3.2 Determining Empirical and Molecular Formulas

3.3 Molarity

3.4 Other Units for Solution Concentrations

Introduction

Swimming pools have long been a popular means of recreation, exercise and physical therapy. Since it is impractical to refill large pools with fresh water on a frequent basis, pool water is regularly treated with chemicals to prevent the growth of harmful bacteria and algae. Proper pool maintenance requires regular additions of various chemical compounds in carefully measured amounts. For example, the relative amount of calcium ion, Ca^{2+}, in the water should be maintained within certain limits to prevent eye irritation and avoid damage to the pool base and plumbing. To maintain proper calcium levels, calcium cations are added to the water in the form of an ionic compound that also contains anions; thus, it is necessary to know both the relative amount of Ca^{2+} in the compound and the volume of water in the pool in order to achieve the proper calcium level. Quantitative aspects of the composition of substances (such as the calcium-containing compound) and mixtures (such as the pool water) are the subject of this chapter.

Figure 4.1 Many modern rocket fuels are solid mixtures of substances combined in carefully measured amounts and ignited to yield a thrust-generating chemical reaction. (credit: modification of work by NASA)

Chapter Outline

Introduction

Solid-fuel rockets are a central feature in the world's space exploration programs, including the new Space Launch System being developed by the National Aeronautics and Space Administration (NASA) to replace the retired Space Shuttle fleet (**Figure 4.1**). The engines of these rockets rely on carefully prepared solid mixtures of chemicals combined in precisely measured amounts. Igniting the mixture initiates a vigorous chemical reaction that rapidly generates large amounts of gaseous products. These gases are ejected from the rocket engine through its nozzle, providing the thrust needed to propel heavy payloads into space. Both the nature of this chemical reaction and the relationships between the amounts of the substances being consumed and produced by the reaction are critically important considerations that determine the success of the technology. This chapter will describe how to symbolize chemical reactions using chemical equations, how to classify some common chemical reactions by identifying patterns of reactivity and how to determine the quantitative relations between the amounts of substances involved in chemical reactions—that is, the reaction *stoichiometry*.

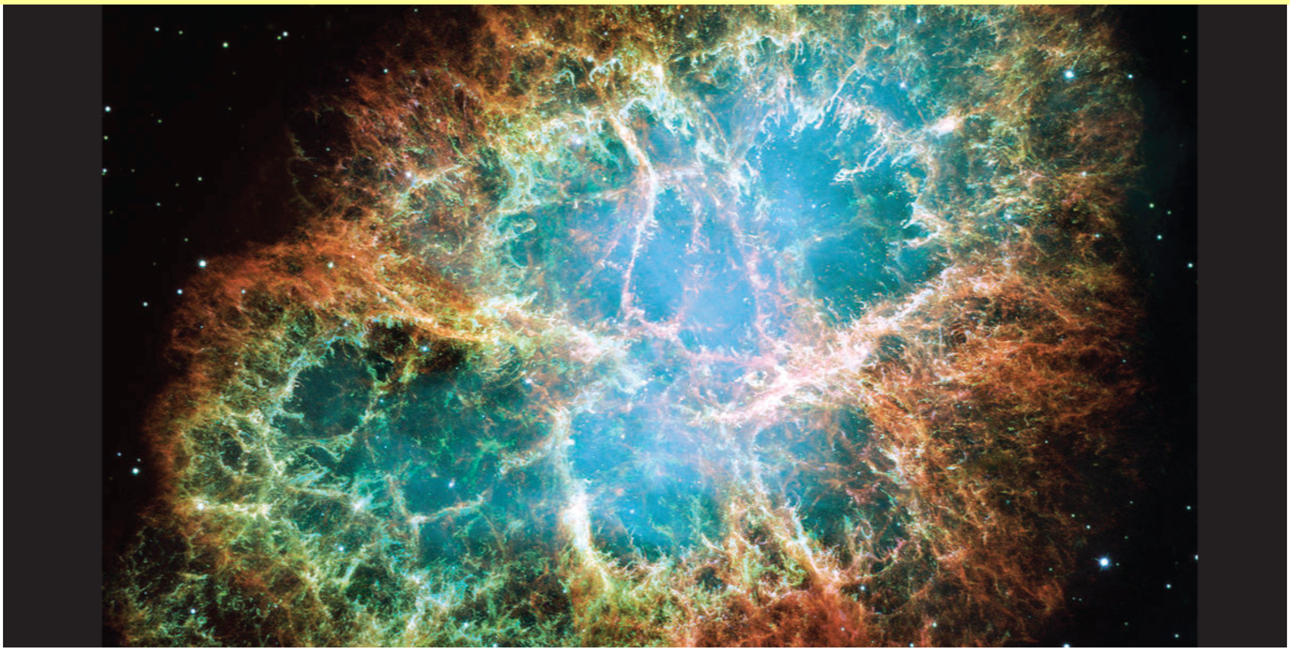


Figure 5.1 The Crab Nebula consists of remnants of a supernova (the explosion of a star). NASA's Hubble Space Telescope produced this composite image. Measurements of the emitted light wavelengths enabled astronomers to identify the elements in the nebula, determining that it contains specific ions including S^{+} (green filaments) and O^{2+} (red filaments). (credit: modification of work by NASA and ESA)

Chapter Outline

5.1 Electromagnetic Energy

5.2 The Bohr Model

5.3 Development of Quantum Theory

5.4 Electronic Structure of Atoms (Electron Configurations)

5.5 Periodic Variations in Element Properties

Introduction

In 1054, Chinese astronomers recorded the appearance of a "guest star" in the sky, visible even during the day, which then disappeared slowly over the next two years. The sudden appearance was due to a supernova explosion, which was much brighter than the original star. Even though this supernova was observed almost a millennium ago, the remaining Crab Nebula (**Figure 5.1**) continues to release energy today. It emits not only visible light but also infrared light, X-rays and other forms of electromagnetic radiation. The nebula emits both continuous spectra (the blue-white glow) and atomic emission spectra (the coloured filaments). In this chapter, we will discuss light and other forms of electromagnetic radiation and how they are related to the electronic structure of atoms. We will also see how this radiation can be used to identify elements, even from thousands of light years away.

Figure 6.1 Nicknamed "buckyballs," buckminsterfullerene molecules (C_{60}) contain only carbon atoms. Here they are shown in a ball-and-stick model (left). These molecules have single and double carbon-carbon bonds arranged to form a geometric framework of hexagons and pentagons, similar to the pattern on a soccer ball (centre). This unconventional molecular structure is named after architect R. Buckminster Fuller, whose innovative designs combined simple geometric shapes to create large, strong structures such as this weather radar dome near Tucson, Arizona (right). (credit middle: modification of work by "Petey21"/Wikimedia Commons; credit right: modification of work by Bill Morrow)

Chapter Outline

Introduction

It has long been known that pure carbon occurs in different forms (allotropes) including graphite and diamond. But it was not until 1985 that a new form of carbon was recognised: buckminsterfullerene, commonly known as a "buckyball." This molecule was named after the architect and inventor R. Buckminster Fuller (1895–1983), whose signature architectural design was the geodesic dome, characterised by a lattice shell structure supporting a spherical surface. Experimental evidence revealed the formula, C_{60} and then scientists determined how 60 carbon atoms could form one symmetric, stable molecule. They were guided by bonding theory—the topic of this chapter—which explains how individual atoms connect to form more complex structures.

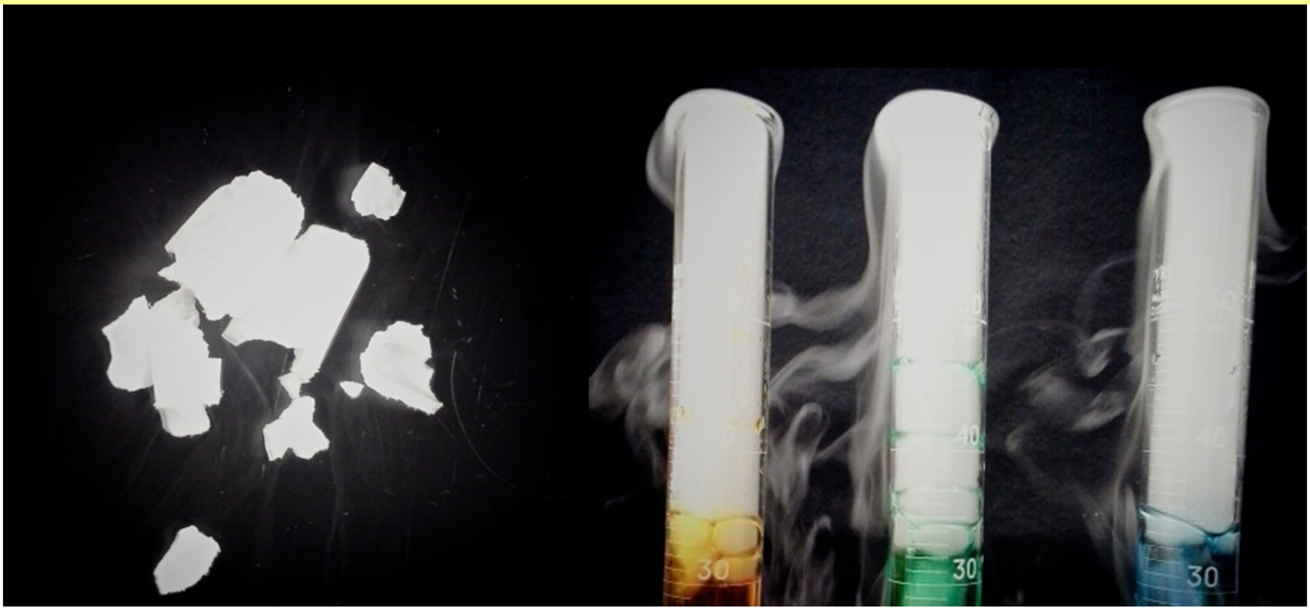


Figure 7.1 Solid carbon dioxide (“dry ice”, left) sublimes vigorously when placed in a liquid (right), cooling the liquid and generating a fog of condensed water vapour above the cylinder.
(credit: modification of work by Paul Flowers)

Chapter Outline

7.1 Intermolecular Forces

7.2 Properties of Liquids

7.3 Phase Transitions

7.4 Phase Diagrams

7.5 The Solid State of Matter

7.6 Lattice Structures in Crystalline Solids

Introduction

The great distances between atoms and molecules in a gaseous phase and the corresponding absence of any significant interactions between them, allows for simple descriptions of many physical properties that are the same for all gases, regardless of their chemical identities. As described in the final module of the chapter on gases, this situation changes at high pressures and low temperatures—conditions that permit the atoms and molecules to interact to a much greater extent. In the liquid and solid states, these interactions are of considerable strength and play an important role in determining a number of physical properties that *do* depend on the chemical identity of the substance. In this chapter, the nature of these interactions and their effects on various physical properties of liquid and solid phases will be examined.

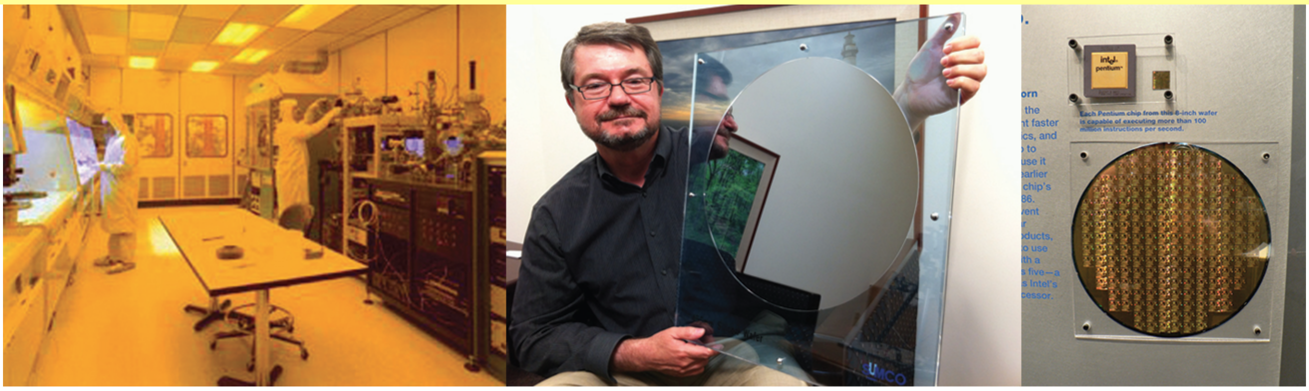


Figure 8.1 Purity is extremely important when preparing silicon wafers. Technicians in a cleanroom prepare silicon without impurities (left). The CEO of VLSI Research, Don Hutcheson, shows off a pure silicon wafer (centre). A silicon wafer covered in Pentium chips is an enlarged version of the silicon wafers found in many electronics used today (right). (credit middle: modification of work by "Intel Free Press"/Flickr; credit right: modification of work by Naotake Murayama)

Chapter Outline

Introduction

The development of the periodic table in the mid 1800s came from observations that there was a periodic relationship between the properties of the elements. Chemists, who have an understanding of the variations of these properties, have been able to use this knowledge to solve a wide variety of technical challenges. For example, silicon and other semiconductors form the backbone of modern electronics because of our ability to fine tune the electrical properties of these materials. This chapter explores important properties of representative metals, metalloids and nonmetals in the periodic table.

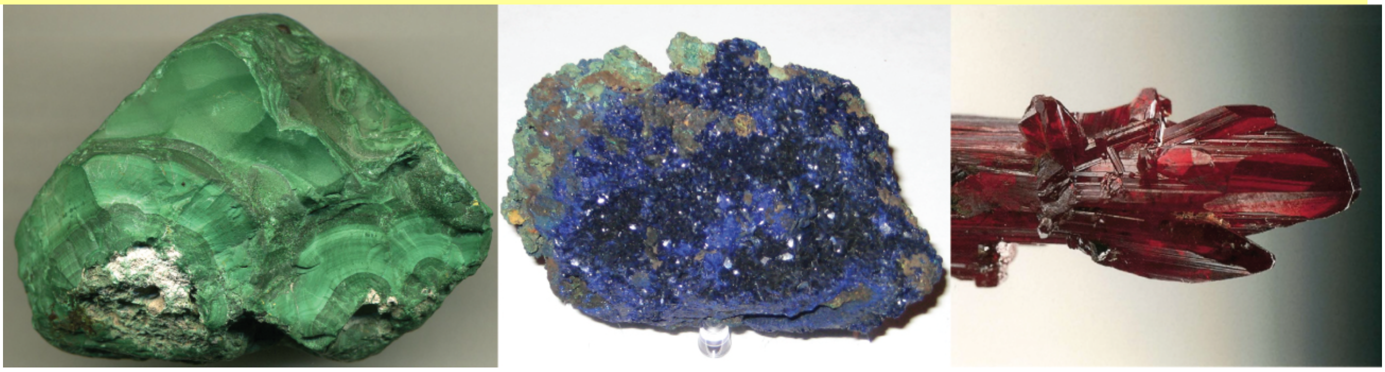


Figure 9.1 Transition metals often form vibrantly coloured complexes. The minerals malachite (green), azurite (blue) and proustite (red) are some examples. (credit left: modification of work by James St. John; credit middle:modification of work by Stephanie Clifford; credit right: modification of work by Terry Wallace)

Chapter Outline

Introduction

We have daily contact with many transition metals. **Iron** occurs everywhere—from the rings in your spiral notebook and the cutlery in your kitchen to cars, ships, buildings and in the hemoglobin in your blood. **Titanium** is useful in the manufacture of lightweight, durable products such as bicycle frames, artificial hips and jewellery. **Chromium** is useful as a protective plating on plumbing fixtures and automotive detailing.

In addition to being used in their pure elemental forms, many compounds containing transition metals have numerous other applications. **Silver** nitrate is used to create mirrors, **zirconium** silicate provides friction in automotive brakes, and many important cancer-fighting agents, like the drug cisplatin and related species, are **platinum** compounds.

The variety of properties exhibited by transition metals is due to their complex valence shells. Unlike most main group metals where one oxidation state is normally observed, the valence shell structure of transition metals means that they usually occur in several different stable oxidation states. In addition, electron transitions in these elements can correspond with absorption of photons in the visible electromagnetic spectrum, leading to coloured compounds.

Because of these behaviours, transition metals show a rich and fascinating chemistry.

Figure 10.1 All organic compounds contain carbon and most are formed by living things, although they are also formed by geological and artificial processes.

Chapter Outline

Introduction

All living things on earth are formed mostly of carbon compounds. The prevalence of carbon compounds in living things has led to the title “carbon-based” life. The truth is we know of no other kind of life. Early chemists regarded substances isolated from *organisms* (plants and animals) as a different type of matter that could not be synthesized artificially and these substances were thus known as *organic compounds*. The widespread belief called vitalism held that organic compounds were formed by a vital force present only in living organisms. The German chemist Friedrich Wohler was one of the early chemists to refute this aspect of vitalism, when, in 1828, he reported the synthesis of urea, a component of many body fluids, from nonliving materials.

Since then, it has been recognised that organic molecules obey the same natural laws as inorganic substances and the category of organic compounds has evolved to include both natural and synthetic compounds that contain carbon. Some carbon-containing compounds are *not* classified as organic, for example, carbonates and cyanides and simple oxides, such as CO and CO_2. Although a single, precise definition has yet to be identified by the chemistry community, most agree that a defining trait of organic molecules is the presence of carbon as the principal element, bonded to hydrogen and other carbon atoms.

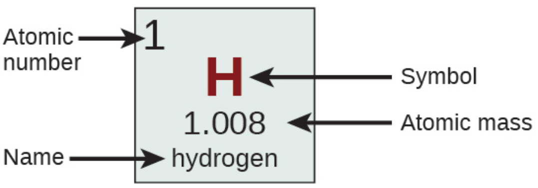
Today, organic compounds are key components of plastics, soaps, perfumes, sweeteners, fabrics, pharmaceuticals and many other substances that we use every day. The value to us of organic compounds ensures that organic chemistry is an important discipline within the general field of chemistry. In this chapter, we discuss why the element carbon gives rise to a vast number and variety of compounds, how those compounds are classified and the role of organic compounds in representative biological and industrial settings.

Appendix A - The Periodic Table

Periodic Table of the Elements

Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008 hydrogen																	2 He 4.003 helium
2	3 Li 6.94 lithium	4 Be 9.012 beryllium											5 B 10.81 boron	6 C 12.01 carbon	7 N 14.01 nitrogen	8 O 16.00 oxygen	9 F 19.00 fluorine	10 Ne 20.18 neon
3	11 Na 22.99 sodium	12 Mg 24.31 magnesium											13 Al 26.98 aluminum	14 Si 28.09 silicon	15 P 30.97 phosphorus	16 S 32.06 sulfur	17 Cl 35.45 chlorine	18 Ar 39.95 argon
4	19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.87 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	28 Ni 58.69 nickel	29 Cu 63.55 copper	30 Zn 65.38 zinc	31 Ga 69.72 gallium	32 Ge 72.63 germanium	33 As 74.92 arsenic	34 Se 78.97 selenium	35 Br 79.90 bromine	36 Kr 83.80 krypton
5	37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.95 molybdenum	43 Tc [97] technetium	44 Ru 101.1 ruthenium	45 Rh 102.9 rhodium	46 Pd 106.4 palladium	47 Ag 107.9 silver	48 Cd 112.4 cadmium	49 In 114.8 indium	50 Sn 118.7 tin	51 Sb 121.8 antimony	52 Te 127.6 tellurium	53 I 126.9 iodine	54 Xe 131.3 xenon
6	55 Cs 132.9 cesium	56 Ba 137.3 barium	57-71 La–Lu *	72 Hf 178.5 hafnium	73 Ta 180.9 tantalum	74 W 183.8 tungsten	75 Re 186.2 rhenium	76 Os 190.2 osmium	77 Ir 192.2 iridium	78 Pt 195.1 platinum	79 Au 197.0 gold	80 Hg 200.6 mercury	81 Tl 204.4 thallium	82 Pb 207.2 lead	83 Bi 209.0 bismuth	84 Po [209] polonium	85 At [210] astatine	86 Rn [222] radon
7	87 Fr [223] francium	88 Ra [226] radium	89-103 Ac–Lr **	104 Rf [267] rutherfordium	105 Db [270] dubnium	106 Sg [271] seaborgium	107 Bh [270] bohrium	108 Hs [277] hassium	109 Mt [276] meitnerium	110 Ds [281] darmstadtium	111 Rg [282] roentgenium	112 Cn [285] copernicium	113 Uut [285] ununtrium	114 Fl [289] flerovium	115 Uup [288] ununpentium	116 Lv [293] livermorium	117 Uus [294] ununseptium	118 Uuo [294] ununoctium

*	57 La 138.9 lanthanum	58 Ce 140.1 cerium	59 Pr 140.9 praseodymium	60 Nd 144.2 neodymium	61 Pm [145] promethium	62 Sm 150.4 samarium	63 Eu 152.0 europium	64 Gd 157.3 gadolinium	65 Tb 158.9 terbium	66 Dy 162.5 dysprosium	67 Ho 164.9 holmium	68 Er 167.3 erbium	69 Tm 168.9 thulium	70 Yb 173.1 ytterbium	71 Lu 175.0 lutetium
**	89 Ac [227] actinium	90 Th 232.0 thorium	91 Pa 231.0 protactinium	92 U 238.0 uranium	93 Np [237] neptunium	94 Pu [244] plutonium	95 Am [243] americium	96 Cm [247] curium	97 Bk [247] berkelium	98 Cf [251] californium	99 Es [252] einsteinium	100 Fm [257] fermium	101 Md [258] mendelevium	102 No [259] nobelium	103 Lr [262] lawrencium



Colour Code	
Metal	Solid
Metalloid	Liquid
Nonmetal	Gas

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5. Electricity in Circuits	10. Energy from the atom

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