

HIGHER LEVEL



PEARSON BACCALAUREATE

HIGHER LEVEL

Chemistry^{2nd Edition}

CATRIN BROWN • MIKE FORD

Supporting every learner across the IB continuum

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Contents

Introduction

vii

01 Stoichiometric relationships

- 1.1 Introduction to the particulate nature of matter and chemical change 3
- 1.2 The mole concept 14
- 1.3 Reacting masses and volumes 28

02 Atomic structure

- 2.1 The nuclear atom 58
- 2.2 Electron configuration 69
- 12.1 Electrons in atoms 85

03 Periodicity

- 3.1 The Periodic Table 98
- 3.2 Periodic trends 102
- 13.1 First-row d-block elements 119
- 13.2 Coloured complexes 130

04 Chemical bonding and structure

- 4.1 Ionic bonding and structure 140
- 4.2 Covalent bonding 148
- 4.3 Covalent structures 155
- 4.4 Intermolecular forces 173
- 4.5 Metallic bonding 181
- 14.1 Further aspects of covalent bonding and structure 185
- 14.2 Hybridization 199

05 Energetics and thermochemistry

- 5.1 Measuring energy changes 211
- 5.2 Hess's law 225
- 5.3 Bond enthalpies 230
- 15.1 Energy cycles 237
- 15.2 Entropy and spontaneity 247

06 Chemical kinetics

- 6.1 Collision theory and rates of reaction 272
- 16.1 Rate expression and reaction mechanism 286
- 16.2 Activation energy 300

07	Equilibrium	
7.1	Equilibrium	311
17.1	The equilibrium law	330
08	Acids and bases	
8.1	Theories of acids and bases	346
8.2	Properties of acids and bases	350
8.3	The pH scale	355
8.4	Strong and weak acids and bases	360
18.1	Lewis acids and bases	363
18.2	Calculations involving acids and bases	366
18.3	pH curves	378
8.5	Acid deposition	393
09	Redox processes	
9.1	Oxidation and reduction	406
9.2 & 19.1	Electrochemical cells	425
10	Organic chemistry	
10.1	Fundamentals of organic chemistry	464
10.2	Functional group chemistry	482
20.1	Types of organic reactions	496
20.2	Synthetic routes	512
20.3	Stereoisomerism	514
11	Measurement and data processing and analysis	
11.1	Uncertainties and errors in measurement and results	530
11.2	Graphical techniques	540
11.3	Spectroscopic identification of organic compounds	548
21.1	Spectroscopic identification of organic compounds	566
12	Option A: Materials	
A.1	Materials science introduction	582
A.2	Metals and inductively coupled plasma (ICP) spectroscopy	589
A.3	Catalysts	603
A.4	Liquid crystals	609
A.5	Polymers	616
A.6	Nanotechnology	626
A.7	Environmental impact: plastics	633
A.8	Superconducting metals and X-ray crystallography	639
A.9	Condensation polymers	653
A.10	Environmental impact: heavy metals	659

13 Option B: Biochemistry

B.1	Introduction to biochemistry	672
B.2 & B.7	Proteins and enzymes	679
B.3	Lipids	710
B.4	Carbohydrates	721
B.5	Vitamins	725
B.8	Nucleic acids	729
B.9	Pigments	739
B.10	Stereochemistry in biomolecules	749
B.6	Biochemistry and the environment	755

14 Option C: Energy

C.1	Energy sources	768
C.2	Fossil fuels	773
C.3 & C.7	Nuclear fusion and fission	787
C.4	Solar energy	814
C.5	Environmental impact: global warming	823
C.6	Electrochemistry, rechargeable batteries, and fuel cells	829
C.8	Photovoltaic and dye-sensitized solar cells (DSSC)	844

15 Option D: Medicinal chemistry

D.1	Pharmaceutical products and drug action	860
D.2	Aspirin and penicillin	870
D.3	Opiates	879
D.4	pH regulation of the stomach	885
D.5	Antiviral medications	892
D.7	Taxol: a chiral auxiliary case study	900
D.8	Nuclear medicine	905
D.9	Drug detection and analysis	916
D.6	Environmental impact of some medications	930

	Green chemistry	940
	Experimental work in chemistry	942
	Internal assessment	945
	Theory of knowledge	950
	Advice on the extended essay	961
	Strategies for success	968
	Index	972

Introduction

Authors' introduction to the second edition

Welcome to your study of IB Higher Level chemistry. This book is the second edition of the market-leading Pearson Baccalaureate HL chemistry book, first published in 2009. It has been completely rewritten to match the specifications of the new IB chemistry curriculum, and gives thorough coverage of the entire course content. While there is much new and updated material, we have kept and refined the features that made the first edition so successful. Our

personal experience and intimate knowledge of the entire IB chemistry experience, through teaching and examining, curriculum review, moderating internal assessment and leading workshops for teachers in different continents, has given us a unique understanding of your needs in this course. We are delighted to share our enthusiasm for learning chemistry in the IB programme with you!

Content

The book covers the three parts of the IB syllabus: the core, the AHL (additional higher level) material and the options, of which you will study one. Each chapter in the book corresponds to a topic or option in the IB guide, in the same sequence. The core and AHL material for a topic are combined in the same

chapter, so that you can see the full development of each concept. The sequence of sub-topics within each chapter is given in the contents page.

Each chapter starts with a list of the Essential ideas from the IB chemistry guide, which summarize the focus of each sub-topic.

Essential ideas

3.1

The arrangement of elements in the Periodic Table helps to predict their electron configuration.

This is followed by an introduction, which gives the context of the topic and how it relates to your previous knowledge. The relevant sections from the IB chemistry guide for each sub-topic are then given

as boxes showing Understanding, and Applications and skills, with notes for Guidance shown in italics where they help interpret the syllabus.

Understandings:

- Atoms contain a positively charged dense nucleus composed of protons and neutrons (nucleons).

Guidance

Relative masses and charges of the sub-atomic particles should be known, actual values are given in section 4 of the IB data booklet. The mass of the electron can be considered negligible.

Applications and skills:

- Use of the nuclear symbol notation ${}^A_Z\text{X}$ to deduce the number of protons, neutrons, and electrons in atoms and ions.

The text covers the course content using plain language, with all scientific terms explained and shown in bold as they are first introduced. It follows IUPAC nomenclature and definitions throughout.

We have been careful also to apply the same terminology you will see in IB examinations in all worked examples and questions.

The nature of science

Throughout the course you are encouraged to think about the nature of scientific knowledge and the scientific process as it applies to chemistry. Examples are given of the evolution of chemical theories as new information is gained, the use of models to conceptualize our understanding, and the ways in which experimental work is enhanced by modern technologies. Ethical considerations, environmental impacts, the importance of objectivity, and the

responsibilities regarding scientists' code of conduct are also considered here. The emphasis is not on learning any of these examples, but rather appreciating the broader conceptual themes in context. We have included at least one example in each sub-section, and hope you will come up with your own as you keep these ideas at the surface of your learning.

Key to information boxes

A popular feature of the book is the different coloured boxes interspersed through each chapter.

These are used to enhance your learning as explained using examples below.



Nature of science

This is an overarching theme in the course to promote concept-based learning. Through the book you should recognize some similar themes emerging across different topics. We hope they help you to develop your own skills in scientific literacy.



NATURE OF SCIENCE

The story of Fleming's discovery of penicillin is often described as serendipitous – a fortunate discovery made by chance or by accident. But it was more than that. Would not the majority of people who noticed the plates were contaminated simply have thrown them away, likely disappointed at the 'failed experiment'? The difference was that Fleming had the insight to observe the plates carefully and ask the right questions about why a clear ring appeared around the fungal growth. Scientists are trained to be observant and to seek explanations for what they see, and this must include the unexpected. As Louis Pasteur once famously said, 'Chance favours only the prepared mind'. Consider to what extent scientific discoveries are only possible to scientists who are trained in the principles of observation and interpretation.

The disposal of plastics is a major global problem. The very features that make plastics so useful, such as their impermeability to water and low reactivity, mean they are often non-biodegradable and so remain in landfill sites for indefinite periods of time. It is estimated that about 10% of plastics produced end up in the ocean, causing widespread hazards to marine life. Measures to try to address this problem include developments of more efficient recycling processes, biodegradable plastics, and plastic-feeding microorganisms. A reduction in the quantities of plastic produced and used is also urgently needed – which is something for which every individual can share responsibility.



International-mindedness

The impact of the study of chemistry is global, and includes environmental, political and socio-economic considerations. Examples of this are given to help you to see the importance of chemistry in an international context.



Utilization

Applications of the topic through everyday examples are described here, as well as brief descriptions of related chemical industries. This helps you to see the relevance and context of what you are learning.



Freeze-drying is an effective process for the preservation of food and some pharmaceuticals. It differs from standard methods of dehydration in that it does not use heat to evaporate water, but instead depends on the sublimation of ice. The substance to be preserved is first frozen, and then warmed gently at very low pressure which causes the ice to change directly to water vapour. The process is slow but has the significant advantage that the composition of the material, and so its flavour, are largely conserved. The freeze-dried product is stored in a moisture-free package that excludes oxygen, and can be reconstituted by the addition of water.

The person who researched and patented tetraethyl lead as a petroleum additive was the same person who later was responsible for the discovery and marketing of chlorofluorocarbons (CFCs) as refrigerants. Thomas Midgley of Ohio, USA, did not live to know the full extent that the long-term impact his findings would have on the Earth's atmosphere. He died in 1944, aged 55, from accidental strangulation after becoming entangled in ropes and pulleys he had devised to get himself in and out of bed following loss of use of his legs caused by polio. Perhaps his epitaph should have been 'The solution becomes the problem'.



Interesting fact

These give background information that will add to your wider knowledge of the topic and make links with other topics and subjects. Aspects such as historic notes on the life of scientists and origins of names are included here.



Laboratory work

These indicate links to ideas for lab work and experiments that will support your learning in the course, and help you prepare for the Internal Assessment. Some specific experimental work is compulsory, and further details of this are in the eBook.



Experiment to determine the empirical formula of MgO

Full details of how to carry out this experiment with a worksheet are available online.

A sample of magnesium is heated and the change in mass recorded. From this, the ratio of moles of magnesium to oxygen can be determined.

Hess's law is a natural consequence of the law of conservation of energy. If you know the law of conservation of energy, do you automatically know Hess's law?

TOK

TOK TOK

These stimulate thought and consideration of knowledge issues as they arise in context. Each box contains open questions to help trigger critical thinking and discussion.



Key fact

These key facts are drawn out of the main text and highlighted in bold. This will help you to identify the core learning points within each section. They also act as a quick summary for review.



The concentrations of H^+ and OH^- are inversely proportional in an aqueous solution.

In writing the ionization reactions of weak acids and bases, it is essential to use the equilibrium sign.



Hints for success

These give hints on how to approach questions, and suggest approaches that examiners like to see. They also identify common pitfalls in understanding, and omissions made in answering questions.

Challenge yourself

These boxes contain open questions that encourage you to think about the topic in more depth, or to make detailed connections with other topics. They are designed to be challenging and to make you think.

CHALLENGE YOURSELF

- 6 Explain why oxygen behaves as a free radical despite having an even number of electrons.

eBook

In the eBook you will find the following:

- Interactive glossary of scientific words used in the course
- Answers and worked solutions to all exercises in the book
- Fast facts and labs worksheets
- Interactive quizzes
- Animations
- Videos

For more details about your eBook, see the following section.

Questions

There are three types of question in this book:

1. Worked example with Solution

These appear at intervals in the text and are used to illustrate the concepts covered.

They are followed by the solution, which shows the thinking and the steps used in solving the problem.

Worked example

Calomel is a compound once used in the treatment of syphilis. It has the empirical formula HgCl and a molar mass of $472.08 \text{ g mol}^{-1}$. What is its molecular formula?

Solution

First calculate the mass of the empirical formula:

$$\text{mass}(\text{HgCl}) = 200.59 + 35.45 = 236.04 \text{ g mol}^{-1}$$

$$(236.04) \times x = M = 472.08$$

$$\therefore x = 2$$

$$\text{molecular formula} = \text{Hg}_2\text{Cl}_2$$

2. Exercises

These questions are found throughout the text. They allow you to apply your knowledge and test your understanding of what you have just been reading.

The answers to these are given on the eBook at the end of each chapter.

Exercises

- 64** Calculate the mass of potassium hydroxide, KOH, required to prepare 250 cm^3 of a $0.200 \text{ mol dm}^{-3}$ solution.

3. Practice questions

These questions are found at the end of each chapter. They are mostly taken from previous years' IB examination papers. The mark-schemes used by

examiners when marking these questions are given in the eBook, at the end of each chapter.

Practice questions

1 How many oxygen atoms are in 0.100 mol of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$?

A 5.42×10^{22}

B 6.02×10^{22}

C 2.41×10^{23}

D 5.42×10^{23}

Answers and worked solutions

Full worked solutions to all exercises and practice questions can be found in the eBook, as well as regular answers.



Hotlink boxes can be found at the end of each chapter, indicating that there are weblinks available for further study. To access these links go to www.pearsonhotlinks.com and enter the ISBN or title of this book. Here you can find links to animations, simulations, movie clips and related background material, which can help to deepen your interest and understanding of the topic.

We truly hope that this book and the accompanying online resources help you to enjoy this fascinating subject of IB Higher Level chemistry. We wish you success in your studies.

Catrin Brown and Mike Ford

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Page 74

107%

05 Energetics and thermochemistry

It takes considerably more heat energy to increase the temperature of a swimming pool by 5 °C than boil a kettle of water from room temperature. The swimming pool contains more water molecules and so has a larger heat capacity.

The water in the kettle has a higher temperature but the water in the swimming pool has more heat energy. Temperature is a measure of the average kinetic energy of the molecules.

Video
Select the icon to watch a video

A temperature rise of 1 K is the same as a temperature rise of 1 °C.

Worksheets
Select the icon to view a worksheet with further activities

This relationship allows the heat change in a material to be calculated from the temperature change.

When considering the relationship between different objects the **heat capacity** is often a more convenient property. The heat capacity (C) is defined as the heat needed to increase the temperature of an object by 1 K.

$$\text{heat capacity (C)} = \frac{\text{heat change (q)}}{\text{temperature change (}\Delta T\text{)}}$$

A swimming pool has a larger heat capacity than a kettle.

- The **specific heat capacity (c)** is defined as the heat needed to increase the temperature of unit mass of material by 1 K.

$$\text{specific heat capacity (c)} = \frac{\text{heat change (q)}}{\text{mass (m)} \times \text{temperature change (}\Delta T\text{)}}$$

- The **heat capacity (C)** is defined as the heat needed to increase the temperature of an object by 1 K.

$$\text{heat capacity (C)} = \frac{\text{heat change (q)}}{\text{temperature change (}\Delta T\text{)}}$$

NATURE OF SCIENCE

Although heat is a concept that is familiar to us all – we need it to cook our food and to keep us warm – it is a subject that has proved to be difficult for science to understand. We are equipped by our sense of touch to distinguish between high and low temperature but heat has proved challenging on a more fundamental level. The development of different temperature scales was an important technological and scientific step as it recognized the need for objectivity in scientific measurement, and the need to calibrate the instruments to one or more fixed points. However, scientific understanding in this area was still confused at the time. The original Celsius scale, for example, had the boiling point of water at a lower temperature than its melting point, so it was not clear what it was quantifying and other scales used arbitrary fixed points such as the melting points of butter, or the temperatures of the Paris wine cellars. The observation that heat can be added to melting ice or boiling water without changing its temperature was a significant observation in the distinction between the heat and temperature. Our modern distinction is based on our particulate theory of matter. Temperature is a measure of the individual particles' kinetic energy and heat is a process by which energy is transferred.

TOK

Our shared knowledge is passed on from one generation to the next by language. The language we use today is often based on the shared knowledge of the past which can sometimes be incorrect. What do such phrases as "keep the heat in and the cold out" tell us about previous concepts of heat and cold? How does the use of language hinder the pursuit of knowledge?

PRIVATE NOTE Close

Do exercises 1–6, and worksheet for homework.

Edit

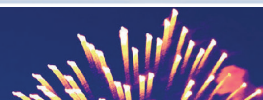
Note

216

See the definitions of key terms in the glossary

Create a bookmark

Switch to whiteboard view



Solution

$$\begin{aligned}\text{heat change} &= m \times c \times \Delta T \\ &= 10.0 \text{ g} \times 0.385 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1} \times -60.0 \text{ }^{\circ}\text{C} \text{ (the value is negative as the Cu has lost heat)} \\ &= -231 \text{ J}\end{aligned}$$

Exercises

- When a sample of NH_4SCN is mixed with solid $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ in a glass beaker, the mixture changes to a liquid and the temperature drops sufficiently to freeze the beaker to the table. Which statement is true about the reaction?
 - The process is endothermic and ΔH is -
 - The process is endothermic and ΔH is +
 - The process is exothermic and ΔH is -
 - The process is exothermic and ΔH is +
- Which one of the following statements is true of all exothermic reactions?
 - They produce gases.
 - They give out heat.
 - They occur quickly.
 - They involve combustion.
- If 500 J of heat is added to 100.0 g samples of each of the substances below, which will have the largest temperature increase?

	Substance	Specific heat capacity / $\text{J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$
A	gold	0.129
B	silver	0.237
C	copper	0.385
D	water	4.18

- The temperature of a 5.0 g sample of copper increases from 27 $^{\circ}\text{C}$ to 29 $^{\circ}\text{C}$. Calculate how much heat has been added to the system. (Specific heat capacity of Cu = $0.385 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$)
 - 0.770 J
 - 1.50 J
 - 3.00 J
 - 3.85 J
- Consider the specific heat capacity of the following metals.

Metal	Specific heat capacity / $\text{J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$
Al	0.897
Be	1.82
Cd	0.231
Cr	0.449

1 kg samples of the metals at room temperature are heated by the same electrical heater for 10 min. Identify the metal which has the highest final temperature.

- Al
 - Be
 - Cd
 - Cr
- The specific heat of metallic mercury is $0.138 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$. If 100.0 J of heat is added to a 100.0 g sample of mercury at 25.0 $^{\circ}\text{C}$, what is the final temperature of the mercury?

Enthalpy changes and the direction of change

There is a natural direction for change. When we slip on a ladder, we go down, not up. The direction of change is in the direction of lower stored energy. In a similar way, we expect methane to burn when we strike a match and form carbon dioxide and water. The chemicals are changing in a way which reduces their enthalpy (Figure 5.5).

Animation

Select the icon to see a related animation



Quiz

Select the icon to take an interactive quiz to test your knowledge



CHALLENGE YOURSELF

- Suggest an explanation for the pattern in specific heat capacities of the metals in Exercise 3.

Worked solutions

Select the icon at the end of the chapter to view worked solutions to exercises in this chapter

Answers

Select the icon at the end of the chapter to view answers to exercises in this chapter

