HIGHER LEVEL

PEARSON BACCALAUREATE • DIPLOMA LEVEL

PEARSON BACCALAUREATE

HIGHER LEVEL

Chemistry

2nd Edition

CATRIN BROWN • MIKE FORD

Supporting every learner across the IB continuum

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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 ${}^{A}_{Z}X$ 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

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 g mol^{-1}. What is its molecular formula?

Solution

First calculate the mass of the empirical formula:

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

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

$$\therefore x = 2$$

$$\text{molecular formula} = Hg_2Cl_2$$

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 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 $CuSO_4.5H_2O$?

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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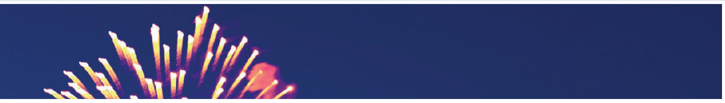

Solution

$$\text{heat change} = m \times c \times \Delta T$$

$$= 10.0\text{ g} \times 0.385\text{ J g}^{-1}\text{ °C}^{-1} \times -60.0\text{ °C}$$ (the value is negative as the Cu has lost heat)

$$= -231\text{ J}$$

Exercises

1 When a sample of NH_4SCN is mixed with solid $Ba(OH)_2.8H_2O$ 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?

- **A** The process is endothermic and ΔH is –
- **B** The process is endothermic and ΔH is +
- **C** The process is exothermic and ΔH is –
- **D** The process is exothermic and ΔH is +

2 Which one of the following statements is *true* of all exothermic reactions?

- **A** They produce gases.
- **B** They give out heat.
- **C** They occur quickly.
- **D** They involve combustion.

3 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 / $J\ g^{-1}\ K^{-1}$
A	gold	0.129
B	silver	0.237
C	copper	0.385
D	water	4.18

4 The temperature of a 5.0 g sample of copper increases from 27 °C to 29 °C. Calculate how much heat has been added to the system. (Specific heat capacity of Cu = 0.385 $J\ g^{-1}\ K^{-1}$)

A 0.770 J **B** 1.50 J **C** 3.00 J **D** 3.85 J

5 Consider the specific heat capacity of the following metals.

Metal	Specific heat capacity / $J\ g^{-1}\ K^{-1}$
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.

A Al **B** Be **C** Cd **D** Cr

6 The specific heat of metallic mercury is 0.138 $J\ g^{-1}\ °C^{-1}$. If 100.0 J of heat is added to a 100.0 g sample of mercury at 25.0 °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).

CHALLENGE YOURSELF

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

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Animation

Select the icon to see a related animation

Quiz

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

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