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A LEVEL
Teachers Guide

CHEMISTRY B (SALTERS)

H433
For first teaching in 2015

Developing chemical literacy skills

Version 1

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INTRODUCTION

The A Level in Chemistry B (Salters) specification places a particular emphasis on the development of chemical literacy skills. These are assessed at the end of the course in each exam paper using extended response questions, questions set in unfamiliar contexts, using a pre-release Advance Notice article (component 02) and using a Practical Insert (component 03).

This guide considers in detail the skills that learners need to develop, explores the way in which these skills are assessed, provides examples of possible assessment questions and suggests strategies that teachers can use to help learners develop appropriate skills.

The Additional Information section at the end of this guide links to a range of resources that might be used in developing learners' chemical literacy skills.

LEARNING OUTCOMES

Section 2e of the A Level Chemistry B (Salters) specification describes the skills that candidates will be expected to demonstrate in the written assessments.

Extract and manipulate data

Data may be included in question stems and other stimulus material in a variety of forms such as in tables, graphs and within text. Questions assessing this skill might use questions of the type:

- Using data in the table, explain ….
- Using data in the table, calculate ….
- Using the graph, determine ……
- Combine equations 1, 2 and 3 that are given in the article.

Interpret and use information

Candidates may be asked to interpret and use information in question stems and other stimulus material in a number of ways. They could be asked to pick out specific examples, bring together related information from different parts of a question or article, or discuss or comment on aspects of the information. Questions assessing this skill could be of the type:

- Give examples of ….
- Give reasons why ….
- Predict the effect of …
- Comment on the statement …
- Suggest reasons for and against ….

This is a particularly demanding skill and many learners will need help in making connections between different pieces of information and in martialling their thoughts to present logical arguments or to make judgements on evidence.

Show comprehension by written communication with regard to logical presentation and the correct use of appropriate technical terms

Some questions will require extended response, and this includes some items in each of the three papers at A Level which are marked by Level of Response mark schemes. It is important that learners think about what they wish to include before they start to write so that they can order their thoughts in a logical manner. Outline planning by noting down key points can be helpful, making use of any additional space / continuation booklets in exam papers.

It is in the nature of pre-release material that it may contain technical terms that learners may not have met before. Usually the context of the word or phrase, as well as known prefixes and suffixes (e.g. endo-, -ene), will give a strong indication about meaning, but learners may have to look up words to be absolutely sure about this. Learners could be encouraged to invest in a Chemistry dictionary for such purposes (see Additional Information). Questions that assess the correct use of technical terms can usually be easily recognised as they will be of the type:

- Explain the meaning of ….
- Explain what is meant by ….
- Explain the statement …….

Questions marked through Level of Response explicitly assess the quality of the extended response, in terms of whether they are coherent, relevant, substantiated and logically structured. These questions are identified in papers with an asterisk (*) next to the question (part) number.

EXTENDED RESPONSE QUESTIONS

Extended response questions provide learners with the opportunity to demonstrate their ability to construct answers that are coherent, relevant, substantiated and logically structured. At least two extended response questions in each paper at A Level (and paper 2 at AS) use 'level of response' mark schemes in which the quality of chemical literacy in the extended response is explicitly rewarded.

Types of extended response question

Extended response questions can be of a variety of types. The examples below illustrate the types of topics that could be covered through extended response questions. However, this list is by no means exclusive, and it should be expected that a question may be set in an unfamiliar context and require analysis of new information.

- Identifying organic compounds by analysing evidence from sources such as percentage composition data, mass spectra, IR spectra and/or NMR spectra.
- Describing an experimental procedure and the way in which data collected from the experiment can be manipulated.
- Devising a sequence of tests to distinguish between groups of organic or inorganic compounds.
- Comparing the structures and reactions of different organic compounds.
- Describing and explaining the relative reactivity of similar compounds.
- Describing, comparing and explaining different types of isomerism.
- Describing and explaining aspects of atmospheric chemistry.
- Evaluating the relative benefits and drawbacks of two practical methods, synthesis routes, etc.
- Explaining a phenomenon in terms of chemical understanding, e.g. differences in boiling points in terms of bonding.

Coherence

Learner responses to extended questions should be clearly thought out with connected ideas brought together. This means that learners need to think about all of the things they might want to include in their answer before starting to put pen to paper. It could even be worth jotting down brief notes on the points to make, and the order in which to make them, before writing the answer out in full. (In exams, rough working should be crossed out afterwards.) Responses that lack coherence are often caused by muddled thinking where learners use a 'stream of consciousness / brain–dump' approach of writing down bits of their answer in the order that they think of them.

In a question, for example, that asks for a comparison of the structures and reactions of two organic compounds, learners might compare the structures and then move on to compare the reactions, describing a range of reactants in turn and comparing how the two compounds react with each. Alternatively, a learner might discuss the structure and reactions for one compound first, and then for the other – but in this case it would be important to make links back from the second compound to the first to make sure the comparison aspect is covered.

Relevance

Learner answers should be relevant to the specific question posed rather than a general response to the topic involved. Learners need to think about all the points that they might include in their answer before choosing those points that are relevant. It also means that they must carefully read the question so that they provide appropriate information.

In response to a question, for example, that asks for a plan to distinguish between different alcohols using simple chemical tests, only those tests that will distinguish between alcohols should be included. Tests involving oxidation might reveal useful information but the preparation of esters would not since all the alcohols behave in a similar way. While including irrelevant information does not directly lead to loss of marks as negative marking is not used, it does use up exam time with no benefit, and increases the chance of writing down incorrect/ contradictory ideas.

Substantiated response

A substantiated response is one in which statements are supported by evidence. Often a cause and its effect will be identified. The evidence and the consequence of the evidence should be clearly linked together.

In a question, for example, that requires learners to use information from spectra to identify the structure of an organic compound they need to specifically link detail in the spectra with the information about the structure that the detail provides. The line produced by the molecular ion in the mass spectrum, for example, provides evidence for the molecular mass of the substance; absorptions in the IR spectrum provide evidence for the functional groups present in the molecule; splitting patterns in the proton NMR spectrum provide evidence about the number of hydrogen atoms on adjacent carbon atoms. Learners also need to appreciate that lack of absorptions at particular frequencies in the IR spectrum also provides useful evidence, this time about functional groups that are not in the molecule. Often, unique identification of the compound requires that several pieces of evidence must be used together, a bit like putting together the pieces of a jigsaw puzzle. Use of tables to compile information from interpretation of specta can be a useful way to ensure all relevant information has been extracted, and is presented in a logical fashion.

Logical structure

Learner responses should show a clear line of reasoning and a logical progression of ideas. Gathering thoughts together before starting to write is again critical to producing a clear narrative. Learners need to decide what they are going to write about and in what order they will present their ideas so that there is a logical flow from one point to the next. Often a question will be made up of several parts or ask for several pieces of information. It is important that learners check that they have answered all the parts of the question and have not spent a disproportionate time on just one part. Annotation of the question to identify all of these parts can provide a helpful check for learners when they are reviewing their outline plan and/or final answer.

In answering a question, for example, that asks for a plan of an experiment to determine the enthalpy change of combustion of a fuel learners need to think about all of the stages involved. It may help them to try and visualise themselves at the laboratory bench so they can imagine what they would need to do and in what sequence they need to carry out the experimental procedures. They may also need to continue this line of reasoning to explain how data recorded during the experiment can be used to carry out the calculations required. Labelled diagrams can be helpful in descriptions of experimental planning as they can contain a large amount of information in a concise and coherent form.

Connecting words

Different types of questions require answers that include appropriate words connecting phrases together. If learners explicitly remember to use the right kind of word it will help them produce answers that are logical and coherent.

In an answer, for example, to a question that requires a substantiated response, words and phrases such as 'therefore, so, consequently, hence, for this reason, because' may well prove useful.

Where a learner sets out to contrast different structures or reactions, words and phrases such as 'in contrast to, on the other hand, conversely, however, whereas' would be helpful. If a particular sequence of events is required then words and phrases such as 'firstly, secondly, then, next, after, finally' might be chosen.

Where experimental methods are being written, a numbered list of steps is an appropriate structure.

Technical terms

Many extended answer questions require learners to make sense of and to use technical terms correctly. If they have an uncertain grasp of these terms their responses are likely to be vague and may reveal misconceptions.

It is worth spending time on the meaning of key technical terms at the point at which they are introduced. Groups of learners can be asked to discuss the meaning of a term and to compare their ideas with those of other groups. This can help bring out misconceptions that learners may have. An alternative approach that can be used towards the end of a topic is to provide learners with alternative definitions for technical terms and ask them to critically discuss the alternative wording and to decide which is correct.

The kind of technical terms that can cause some difficulty include radical, substitution, elimination, delocalisation, absorption, adsorption, reactivity, redox, mirror image, polydentate and most terms relating to intermolecular bonding.

It is worth demonstrating that correct use of technical terms can help formulate answers that are more concise, demonstrate better understanding of the chemistry, and ultimately take less time to write. For example, 'Describe the reaction between chloroethane and sodium hydroxide' may be answered concisely as 'chloroethane reacts with sodium hydroxide by nucleophilic substitution forming ethanol and sodium chloride', making good use of the technical phrase 'nucleophilic substitution'.

HELPING LEARNERS DEVELOP CHEMICAL LITERACY SKILLS

Helping learners develop their ability to analyse data and interpret information

It is important that learners become accustomed to using different sources of information and reading different takes on the areas of chemistry that they are studying. A way of incorporating this into general teaching can be to use different source texts to support learning of the specification concepts. For example, teachers might use the endorsed textbook from Oxford University Press, which is developed by the University of York Science Education Group, for explanations and reference in class. For homework, they can be directed to read general chemistry support websites such as Chemguide or Knockhardy, or other general textbooks such as Chemistry in Context. This will help learners get used to reading about the same concepts from different angles. Moreover, it helps support a deeper understanding of the concepts rather than memorisation of particular descriptions.

The storyline sections in the endorsed textbook can be used to practice linking contextual information to the specification content. For example, in The chemical industry, the production of nitric acid is used as a context for the discussion of the equilibrium constant. Learners could examine this content and discuss how the manufacturing process is linked to the idea of 'opposing change', making use of the descriptions as well as the enthalpy change data.

Again, it is advisable to bring in third-party sources to develop literacy skills. Learners can be provided with sets of data and asked to draw conclusions. For example, they could be provided with solubility product data for a range of salts, and asked to use this data to support a plan for testing for a range of ions in solution. In responses, they should explicitly reference the data, not just rely on memorised information – using unfamiliar examples will help develop this.

An important form of practice is studying experimental data to draw conclusions, consider the experimental method and evaluate the results. Teachers may have repositories of experimental results obtained by students in previous years, or by staff in trialling experiments. Alternatively, many examples of student laboratory reports are available online. Questions to discuss in class might include:

- What does the data show?
- How can the result be explained using chemical understanding?
- How confident might we be in these results?
- By what procedure can results like these be obtained?
- What might be sources of error in this procedure?
- What alternative methods can be used?
- What other reactions / investigations could the same technique be used for?

Finally, reading around the specification topics is important practice for chemical literacy generally, and in particular for the Advance Notice article. Learners should be encouraged to read e.g. popular science articles, and try to relate the stories to the chemistry learnt in class. Any story about chemistry might be linked to some of the basic concepts, such as oxidation numbers, bonding and structure, energy or organic functional groups. The legacy specification unit F332 also contained an Advance Notice article, so these papers can be used specifically to practice answering questions based on a source article. However, take note that this unit covered only a limited range of topics, while in the 2015 specification the Advance Notice question in paper 2 may cover any topic. It is therefore recommended that learners do not limit themselves to these articles in their reading.

Helping learners develop their ability to write extended answers

A useful way to help learners develop their ability to write extended answers is to initially provide scaffolding to help them prepare their responses. In order to create a response to a suitable question groups of learners can, for example, be provided with cards, most of which contain sections of text that together will make up an appropriate answer. Other cards contain text that is related to the topic but is not needed for the answer to the set question.

The learners in groups must decide:

- what cards should be excluded because the text is not relevant to the question asked
- what cards should be grouped together because the text on them is closely related or because on one card there is a statement and on another card there is evidence to support that statement
- in what sequence the cards or groups of cards should be arranged so that there is a clear line of reasoning evident in the response and the response has a logical structure.

After this initial activity, groups of learners can be presented with another question but this time without the scaffolding. Now the group must suggest possible ideas for themselves. They must decide about the relevance of these ideas, which ideas are related and how to structure their response so that it is coherent and has a clear thread of ideas running through it. They might also consider the type of connecting words that would be useful to include in their response.

Discussion in groups is an excellent way for learners to develop their literacy skills. They are able to compare their ideas with those of other members of the group and later with those from other groups. These discussions may reveal misconceptions about technical terms and enable learners to articulate their ideas and use appropriate words to connect ideas together.

THE PRE-RELEASE ADVANCE NOTICE ARTICLE

The paper 'Scientific literacy in chemistry' (component 02) includes a pre-release Advance Notice article and questions within this paper require learners to refer to this article. Learners are expected to be able to extract and manipulate data, interpret and use information and to show comprehension by written communication with regard to logical presentation and the correct use of appropriate chemical terms.

Helping learners with the pre-release article

Learners should be given opportunities throughout their course to develop the skills that they will need to answer questions based on a pre-release article. They can be given short articles with questions that require them to extract and manipulate data and interpret and use information. Sources of suitable articles are described in the next section. Articles can be adapted from the original by leaving out equations, calculations or comments and these removed parts can then form the basis of suitable questions.

An alternative approach is to present groups of learners with different articles and ask them to construct questions based upon them. These questions can be given to other groups. The ensuing discussion between setters and learners who answer the questions can embed a clear understanding of skills involved.

In preparation for the exam, the pre-release article is made available to teachers and learners well before the date of the assessment. There is no restriction on the support that teachers can provide for learners in terms of the advice they can give in helping learners interpret the content.

Learners should be encouraged to read the article carefully, and to investigate the topics covered in the article for themselves. This is important as they will not have time to read the article if they meet it for the first time during the examination. An effective approach is to ask learners to discuss the article with other learners as this will enable them to identify aspects they are unsure about and enable them to clarify their understanding of technical terms.

THE PRACTICAL INSERT

The paper 'Practical skills in chemistry' (component 03) includes a Practical Insert on which learners must draw in order to answer one of the questions. This requires them to extract and manipulate data and to interpret and manipulate information in the context of a practical activity. The key difference from the Advance Notice article in paper 2 is that in paper 3 learners must demonstrate these skills in situ, absorbing and interpreting information in the examination without the opportunity to discuss things with other learners or their teacher and without the opportunity to carry out background research.

It is highly likely that the Practical Insert will include experimental data. Learners should be prepared to manipulate this data by drawing appropriate graphs or by carrying out suitable calculations. They may be asked to comment on aspects of data in terms, for example, of significant figures, accuracy, error, precision and uncertainty or to comment on and to use provided graphs. They may also be asked to comment on experimental design, to identify limitations in experimental procedures and to suggest improvements to the procedures.

The OCR GCE Chemistry Practical Skills Handbook is a valuable source of information about aspects of practical work that may be assessed using the Practical Insert. It covers the skills of planning, analysis and evaluation with appendices that go into greater detail about measurements, units and graphical skills.

Helping prepare learners for using the Practical Insert

Learners may often be given instructions to follow when carrying out practical work. It is good practice to ask them why particular equipment is chosen and why the sequence of procedures may be important. It is important that learners think about what they do rather than just treat the instructions as a recipe to follow.

Sometimes they should be given the task of designing their own experiments. These tasks may take the form of mini investigations. They might include planning an experiment to:

- find the concentration of ethanoic acid in vinegar
- find the most cost effective bleach

- 'crack' a liquid paraffin
- compare the effectiveness of different sunscreens
- determine the identify of a group of organic compounds.

Other sources of ideas are given in the Additional Information below.

A popular activity is one in which learners are offered a range of apparatus in a tray from which they must choose suitable items to carry out a specified experiment. Discussion of choices can really help highlight key issues.

Learners might also be given information about experiments that is flawed and asked how the procedure might be improved. This could take the form of an incorrectly drawn diagram or text in which the sequence of procedures is incorrect or important features such as re-weighing a sample container are missed out.

Learners will usually be supplied with safety information when they carry out practical work but it is helpful sometimes if they devise their own risk assessment by looking up the hazards associated with the materials they are to use. Learners should, however, make sure that they think about the actions that they will take in the light of these hazards.

Learners should have many opportunities to draw graphs and carry out calculations arising from their own practical work during their course. It is worth presenting the whole class with examples of data, graphs and calculations and asking groups of learners to comment on them. Copies of learners' work can be a rich source of such useful stimlulus material.

ADDITIONAL INFORMATION

Sources of suitable articles that can be used to develop chemical literacy skills include the Royal Society of Chemistry publications:

The Mole: http://www.rsc.org/eic/mole

Education in Chemistry: http://www.rsc.org/eic/

Chemistry World: http://www.rsc.org/chemistryworld/

Other sources include:

The essential chemical industry online: http://www.essentialchemicalindustry.org/

Chemistry Review: http://www.york.ac.uk/chemistry/schools/chemrev/

ChemMatters: https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters.html

Molecule of the Month: http://www.chm.bris.ac.uk/motm/motm.htm

The Nuffield Advanced Science Book of Data can be obtained from the STEM Learning e-library: https://www.stem.org.uk/elibrary/resource/28236

Guidance about practical skills is given in:

OCR Chemistry Practical Skills handbook. http://ocr.org.uk/Images/208932-practical-skills-handbook.pdf

Sources of information for practical investigation:

RSC Problem Based Practical Activities: http://www.rsc.org/learn-chemistry/resource/res00000939/problem-based-practical-activities

F336 Examplar starter pages: https://interchange.ocr.org.uk/Downloads/45_F336_Support_Materials_Exemplar_Starter_Pages.zip

Good general guides to A Level Chemistry topics include

Chemguide: http://www.chemguide.co.uk/

Knockhardy: http://www.knockhardy.org.uk/sci.htm

Chemistry in Context, Graham Hill and John Holman, ISBN 978-1408514962

A-Level Chemistry, Eileen Ramsden, ISBN 978-0748752997

Chemistry dictionaries

A Dictionary of Chemistry (Oxford Quick Reference), ISBN 978-0198722823

Oxford Student's Science Dictionary (Oxford Dictionary), ISBN 978-0192733580

The small print

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