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AS and A LEVEL
Transition Guide

CHEMISTRY A AND CHEMISTRY B (SALTERS)

H032/H432 and H033/H433
For first teaching in 2015

KS4–KS5
Amount of substance

Version 1

www.ocr.org.uk/chemistry

Contents

AS and A LEVEL
CHEMISTRY A AND CHEMISTRY B (SALTERS)

Key Stage 4 to 5 Transition guides focus on how a particular topic is covered at the different key stages and provide information on:

- Differences in the demand and approach at the different levels;
- Useful ways to think about the content at Key Stage 4 which will help prepare students for progression to Key Stage 5;
- Common student misconceptions in this topic.

Transition guides also contain links to a range of teaching activities that can be used to deliver the content at Key Stage 4 and 5 and are designed to be of use to teachers of both key stages. Central to the transition guide is a Checkpoint task which is specifically designed to help teachers determine whether students have developed deep conceptual understanding of the topic at Key Stage 4 and assess their 'readiness for progression' to Key Stage 5 content on this topic. This checkpoint task can be used as a summative assessment at the end of Key Stage 4 teaching of the topic or by Key Stage 5 teachers to establish their students' conceptual starting point.

Key Stage 4 to 5 Transition Guides are written by experts with experience of teaching at both key stages.

LOWER LEVEL KEY STAGE CONTENT

N.B. In the pre-2016 specifications (which will be the prior knowledge for learners progressing to A Level up to and including 2017) the treatment of amount of substance varies from one GCSE specification to another. The content from the OCR Gateway Chemistry specification is given below. It is worth noting that Combined and Additional Science qualifications often include no treatment of amount of substance at all.

- Balanced chemical equations, half equations, ionic equations, including state symbols.
- Recall and use the relationship between molar mass, mass and amount of substance.
- Apply the mole concept to calculate masses of products / reactants for a given balanced equation.
- Calculate empirical formulae from percentage composition and from mass of each element in a sample.
- Recall and use the relationship between amount of substance, concentration and volume.
- Acid–base titration calculations.
- Recall and use the relationship between amount of substance, gas volume and molar gas volume.
- Apply the concept of limiting reactant to conclusions about the amount of product formed.

From 2018 onwards, (most) learners will enter A Level after taking the reformed (from 2016) GCSE qualifications. These cover common subject content.

The following content is covered in GCSE Chemistry; the statements in italic are covered in GCSE Combined Science:

- *Deduce empirical formulae from the ratio of atoms present.*
- *Balanced chemical equations, half equations, ionic equations, including state symbols.*
- *Definitions of the Avogadro constant (in standard form) and the mole.*
- *Relation between the mass of a substance and the amount in moles.*
- *Deduce the stoichiometry of an equation from the masses of reactants and products; the effect of a limiting quantity of a reactant.*
- *Use of a balanced equation to calculate masses of reactants or products.*
- *Explain how mass of a solute and volume of solution are related to concentration.*
- The relationship between molar amounts of gases and their volumes (using the molar gas volume).
- The relationship between the volume of a solution of known concentration, and the volume or concentration of another substance that react completely together.

HIGHER LEVEL KEY STAGE CONTENT

The following bullet points are requirements for A Level specifications related to amount of substance; the second section lists the relevant mathematical skills expected of learners at this level.

Formulae, equations and amounts of substance

- empirical and molecular formulae
- balanced chemical equations (full and ionic)
- the Avogadro constant and the amount of substance (mole)
- relative atomic mass and relative isotopic mass
- calculation of reacting masses, mole concentrations, volumes of gases, per cent yields and atom economies
- simple acid–base titrations
- non-structured titration calculations, based solely on experimental results (officially at A Level only, though due to the mathematical requirements less structured calculations will feature at AS Level as well).

Both OCR AS/A Level Chemistry A and Chemistry B (Salters) also require coverage of the ideal gas equation.

Mathematical Skills

- Recognise and make use of appropriate units in calculation.
- Recognise and use expressions in decimal and ordinary form.
- Use ratios, fractions and percentages.
- Use an appropriate number of significant figures.
- Find arithmetic means.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined.
- Change the subject of an equation.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Solve algebraic equations.

COMMENTARY

On first glance, it can appear that there has not been a great deal of change in the content when teaching Formulae and Amounts at AS/A Level compared to Key Stage 4. In Sixth Form colleges one of the main areas of difficulty will be in dealing with a cohort of learners who have come from a wide range of different Key Stage 4 courses. Even when the A Level cohort is well known and has obtained a suitable minimum standard of competency in the subject, the formulae and amounts topic is one that divides the class like no other in terms of ability range!

One way round this is to adopt a 'flipped learning' approach to this topic, where learners consolidate ideas and read through examples (or watch some of the excellent video resources – see the links to the Fuse School website below) and attempt simple calculations in their independent study time. More class time can then be devoted to more challenging and open ended questions, allowing the teacher more time to circulate and deal with problems as they arrive. It is more than likely that a fair number of learners will need extension work while others are bogged down in minor details. Extension work should be varied rather than providing learners with 'more of the same' and on-the-spot open ended activities are an excellent way to achieve this. For example, get learners to estimate the mass of argon in the room, or the mass of carbon dioxide released when driving to school. Alternatively, encourage more able learners to make up their own questions. One easy exercise for this is '1–5': learners must make up five examination style questions (or a multi-part question) for which the first question is worth one mark, the second two marks and so forth.

Learners at GCSE often 'survive' calculations topics by using formula triangles and rote learning steps, with very little understanding of the meaning behind the calculations they are carrying out. The 'Moles True or False' checkpoint activity will help to guage how much of their calculating know-how is simply going through the motions, and how much of it is down to understanding of the processes. It is very helpful at Key Stage 4 to steer learners away from formula triangles and to make the interconversion of units very explicit. The RSC Gridlocks worksheets are very good for interconversion of volume units so that learners know why they are dividing by or multiplying by 1000 in concentration calculations! Another confusion that can develop from Key Stage 4 teaching is that molar mass is often given no units. A little time devoted to class discussion and derivation of the correct units (g mol^{-1}) would be useful even if they do not then encounter this unit again until A Level.

At Key Stage 4 calculations are often very structured, with each stage being made very explicit. If this is the only way calculations are taught at this stage, learners will have great difficulty adapting to the more open-ended style of calculation question offered at A Level. A three stage approach (which can start at Key Stage 4) allows learners to build up their confidence in the following manner:

1. Allow learners time to build up competency in all of the relationships they need to be familiar with. Provide them with short questions which provide them with a piece of numerical data and ask them to calculate another. For example, learners could be given a balanced equation and asked to state the molar ratio between two reagents; they could be given the mass of a substance and asked to calculate amount in moles, etc. These questions should be mixed up and out of context so that learners are able to extract the correct information and process it without resorting to rote learning. Use of personal whiteboards, or an insistence that the work be carried out 'in rough' will alleviate fear of failure in those learners who feel they don't know where to start.

2. Give learners difficult unstructured questions, worth 4–6 marks. Without using **any** calculations, learners should be encouraged to discuss with a partner and come up with a 'plan' for answering the question. They can jot down bullet points or a flow diagram that shows how they would work through the question to get to the final answer. This removes some of the fear factor of getting questions wrong, as well as encouraging learners to consider the available marks in comparison to the number of calculation steps, and also removes the temptation to 'dive in' without thinking.

3. Only when learners are feeling more confident, give them examples of unstructured questions to work through **on their own**. You may even wish to impose a rule of 'no asking for help within the first ten minutes'. This is best done in class where the temptation to 'confer' can be removed. If they struggle, point out all the simple things they can do to earn marks such as calculating formula masses or molar ratios. If they fly through the work with ease, they can make up their own questions as an extension.

One significant barrier to the novice learner in processing more open-ended calculations is that of working memory. The more pieces of information or processes that learners need to hold within their working memory, the more likely they are to experience 'cognitive overload'. In particular problems arise in learners who are inexpert at moving between the three 'domains' in which chemistry is taught: that of the macroscopic, sub-microscopic and symbolic (often referred to as Johnstone's Triangle[1]). For example, when dealing with a lengthy question about a redox titration or an experiment to determine water of crystallisation, learners will have to deal with macroscopic observations and information about the experimental set-up, alongside often complex symbolic information such as symbol equations, state symbols and mathematical relationships, as well as having some understanding of the particle-level events that result in the macroscopic observations. Working across these domains is straightforward in experienced practitioners but can represent an enormous barrier to learning as it leaves learners with no mental capacity for carrying out the necessary steps to complete a calculation.

Another issue with the heavy use of symbolic representation such as balanced equations, is that they can be interchangeably used to represent and explain both macroscopic and sub-microscopic events. For example, an equation representing the reaction of an acid with a carbonate can be used to explain the observation of effervescence or of an indicator colour change; or to explain the macroscopic amounts of carbonate needed to neutralise an acid solution; or to explain the movement and rearrangement of individual particles within the reaction. For chemistry teachers it is no massive cognitive leap to understand that the same equation holds so much information, but for beginners the distinctions are not clear and the links are not always explicit.

There are a few ways in which the cognitive demand of tasks can be reduced to facilitate learning and these are summarised below. For a more in-depth appreciation there are many excellent articles which can be accessed freely from the Royal Society of Chemistry (RSC)[2].

i) 'Missing steps' approach: For a calculation involving multiple steps, give example problems in which all steps are described, explained and worked through. Follow this by giving learners their own examples where all steps are described. Follow this with further examples in which one or two steps have been removed (from different parts of the problem). As learners gain more experience they will be able to process more information and finally can be exposed to multi-step calculations with no provided framework.

ii) Writing things down: Learners are often loathe to actually write anything unless they are sure they are making the correct start to the calculation. Providing personal whiteboards for them to make notes, extract information and write down calculations as they carry them out will decrease the amount of information they need to process at any one time.

iii) Drawing the problem: When presented with a lengthy description of a procedure, such as one used to find the percentage by mass of metal in an alloy, cognitive load can be reduced by learners representing the steps in the process as a simple diagram showing each step in the method along with its relevant numerical information. This reduces the demand for constantly referring to complex written information and learners can more easily manipulate the data involved.

iv) Separating experimental methodology from numerical analysis: eventually learners will need to be able to make links between the methods used in titration or empirical measurement and the relevant symbol equations and mole calculations. However, attempting to teach the specialised techniques and equipment used in these experiments at the same time as the calculations and equations used will likely result in instant cognitive overload. The concept of reacting mass or titration can be discussed using simple equipment (for example, counting the number of drops of acid needed to neutralise an alkali as an approximate measure of concentration) so that the underlying chemical ideas are explored independently of the equipment needed.

[1] Johnstone, A.H. and El-Banna, H. (1986) Capacities, demands and processes – a predictive model for science education, *Education in Chemistry*, **23**, 80–84.

[2] Taber, S. (2013) Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education, *Chemistry Education Research and Practice*, **14**, 156–168.

Activities

Gridlocks Level 2, RSC
http://www.rsc.org/learn-chemistry/resources/gridlocks/level-2.html
These are Sudoku-style activities that consolidate learning and add an extra challenge of filling in the grid correctly. The Level 2 version includes activities on mole equations, multiples of units and the units used in gas volume calculations.

Chemical Calculations, Fuse School
http://www.fuseschool.org/topics/64?PHPSESSID=19399a32a61011dec022162f7fa8b5a0
A series of short and informative videos related to bonding and structure that can be used to consolidate or introduce different topics.

Gridlocks, RSC
http://www.rsc.org/learn-chemistry/resources/gridlocks/puzzles/level-2/types-of-bonding.html
This website includes a wide range of introductory and explanatory videos around the topic of calculations. They are nicely animated and if learners are able to watch them independently (either in class with headphones or outside of lessons) they can work at their own pace and focus on the topics they find most challenging.

Formula mass and mole calculations, BBC Bitesize
http://www.bbc.co.uk/education/guides/zysk7ty/revision
Nice revision resource with plenty of straightforward mass and volume calculations that learners can use to test themselves. Some of the language is oversimplified and so it would not be advisable to use this website for definitions or explanations.

Balancing chemical equations simulation, PhET
http://phet.colorado.edu/en/simulation/balancing-chemical-equations
This simulation works on a PC (Java) or mobile device (HTML5) and is an excellent simple resource that allows learners to work at their own pace and level with balanced equations. The simulation uses visual representations of molecules to aid learners in making links between microscopic particles and the symbols used to represent them in equations.

Concentration of solutions simulation, PhET
http://phet.colorado.edu/en/simulation/concentration
This simulation works on a PC (Java) or mobile device (HTML5). It provides a visual construct for learners to compare the numerical values of concentration, volume and amount of substance and how these relate to one another. It could be used either as a class exercise or group activity to aid learners in deriving the relationship between amount of substance, volume and concentration.

Checkpoint task

Learners are often able to carry out familiar mole calculations with apparent ease and can manipulate the most common equations that relate amount of substance to mass, volume or concentration. However, they often come unstuck when relating these calculations to the information provided in balanced symbol equations, and can also take a very formulaic approach to the calculations with little real understanding of the underpinning concepts. In particular learners often have little understanding of the flexible nature of the mole as a unit of measurement and this comes to problems when they are asked to determine the amount of atoms in a given amount of molecules, for example. In particular this becomes apparent when learners try to determine reagents in excess, changes in amount for equilibrium calculations, or the concentration of an individual ion in a solution of a known amount of ionic compound.

The moles 'True or False' activity does not include any calculations, as learners can often arrive at the correct numerical answer by chance or educated guesses. Instead, learners must consider each statement carefully and decide whether it is true or false. Once they have done so they must provide an example or explanation as to why they have chosen their answer – this prevents learners rushing to the end by guessing and also means that misconceptions and confused reasoning will be quickly highlighted. The first four questions will help to identify if learners are confusing the conservation of mass, which is usually ingrained at a fairly early stage in their education, with conservation of other units such as volume or amount of substance. Questions 5–7 test the learners' understanding of the term mole and again help to identify whether or not learners appreciate that it is a concept that can simultaneously apply to the amount of molecules, atoms, ions or other particles. Questions 8 and 9 test the learners' understanding of molar volume and the last question tests whether learners can apply the concept of a balanced equation to reagents in excess.

Checkpoint task
www.ocr.org.uk/Images/357661-amount-of-substance-ks4-ks5-transition-guide-checkpoint-task.doc

Activities

Isotopes and RAM simulation, PhET
http://phet.colorado.edu/en/simulation/isotopes-and-atomic-mass
This simulations works on PCs (Java) or mobile devices (HTML5). It offers a visual representation of how the abundance of different isotopes affects the relative atomic mass of the sample, and can be used as a class exercise or independently.

Finding the formula of copper(II) oxide, RSC
http://www.rsc.org/learn-chemistry/resource/res00000727/finding-the-formula-of-copper-ii-oxide
This is a really engaging experiment which learners love. Black copper(II) oxide is reduced by heating with a stream of methane gas (excess methane is burnt off at the end of the tube which adds to the excitement of the activity!) and the resulting copper can be weighed to determine the empirical formula of the oxide.

Microscale and reduced scale chemistry, CLEAPSS
https://uwaterloo.ca/chemed2013/sites/ca.chemed2013/files/uploads/files/Microscale%20chem%20experimental%20notes-Bob%20Worley_0.pdf
These notes include some smaller scale versions of many popular experiments and include relevant activities such as titration, finding the formula of hydrated copper(II) sulfate and a Hoffman voltameter. The small scale approach to these experiments has a number of advantages, including less chemical waste, safer procedures and a shorter time required. In addition, removing the obfuscation of complex practical apparatus (such as pipette fillers and burettes) allows learners to focus on the underlying principles and resulting calculations.

Starters for ten, RSC
http://www.rsc.org/learn-chemistry/resource/res00000954/starters-for-ten#!cmpid=CMP00001406
The 'Quantitative Chemistry' resource includes nine worksheets that work well as a starter, consolidation exercise or plenary. The questions vary in difficulty and include engaging contexts and approaches that offer a bit of variety compared to the usual mole calculations.

Gridlocks Level 3, RSC
http://www.rsc.org/learn-chemistry/resources/gridlocks/level-3.html6
These are Sudoku-style activities that consolidate learning and add an extra challenge of filling in the grid correctly. The Level 3 version has a wide range of activities relating to amount of substance including concentration, gas laws, volumetric apparatus and significant figures.

Gas properties simulation, PhET
http://phet.colorado.edu/en/simulation/legacy/gas-properties
This simulation allows learners to investigate the relationship between temperature, pressure and volume. It can be used as a class activity or as a small group or individual exercise (this simulation only works on PCs or Java-enabled devices at present).

Vitamin C titration, RSC
http://www.rsc.org/learn-chemistry/resource/res00000539/measuring-the-amount-of-vitamin-c-in-fruit-drinks
An experiment to find the Vitamin C content of different fruit drinks – this provides a little more context than the usual acid-alkali titrations and also provides more challenging concepts such as standardising a solution, back-titrations and the stoichiometry of redox titrations.

Activities

Astounding Numbers, RSC
http://www.rsc.org/learn-chemistry/resource/res00000625/astounding-numbers
This worksheet encouraged learners to really get to grips with the amazing scales that are needed when working with particles. It is also a nice open ended activity as it encourages learners to develop their own questions.

Creative Problem Solving – Amount of CO_2, RSC
http://www.rsc.org/learn-chemistry/resource/res00000653/amount-of-co2
This is an open ended activity which requires learners to make links between experimental measurements and calculations involving amount of substance, as well as linking these to formulae and equations. There are a range of different approaches learners can take to the problem which promotes class discussion and evaluation.

Creative Problem Solving – Argon, RSC
http://www.rsc.org/learn-chemistry/resource/res00000654/argon?cmpid=CMP00000731
These notes include some smaller scale versions of many popular experiments and include relevant activities such as titration, finding the formula of hydrated copper(II) sulfate and a Hoffman voltameter. The small scale approach to these experiments has a number of advantages, including less chemical waste, safer procedures and a shorter time required. In addition, removing the obfuscation of complex practical apparatus (such as pipette fillers and burettes) allows learners to focus on the underlying principles and resulting calculations.

Resources, links and support

Science Spotlight – Our termly update Science Spotlight provides useful information and helps to support our Science teaching community. Science Spotlight is designed to keep you up-to-date with Science here at OCR, as well as to share information, news and resources. Each issue is packed full with a series of exciting articles across the whole range of our Science qualifications: www.ocr.org.uk/qualifications/by-subject/science/science-spotlight/

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[1] Johnstone, A.H & El-Banna, H. (1986) Capacities, demands and processes – a predictive model for science education, Education in Chemistry, 23, 80-84
[2] Taber, S. (2013) Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education Chemistry Education Research and Practice, 14, 156-168

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