Qualification Accredited

OCR
Oxford Cambridge and RSA

A LEVEL

Delivery Guide

CHEMISTRY A

H032, H432
For first teaching in 2015

Theme: Amount of substance and the mole

Version 2

www.ocr.org.uk/chemistry

A LEVEL
CHEMISTRY A

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk.

Would you prefer a Word version?

Did you know that you can save this pdf as a Word file using Acrobat Professional?

Simply click on **File** > **Export to** and select **Microsoft Word**

(If you have opened this PDF in your browser you will need to save it first. Simply right click anywhere on the page and select ***Save as . . .*** to save the PDF. Then open the PDF in Acrobat Professional.)

If you do not have access to Acrobat Professional there are a number of **free** applications available that will also convert PDF to Word (search for *pdf to word* converter).

Curriculum content

Candidates should be able to demonstrate and apply their knowledge and understanding of: 2.1.3 Amount of substance.

The mole

a. explanation and use of the terms:
   (i) *amount of substance*
   (ii) *mole* (symbol 'mol'), as the unit for amount of substance
   (iii) the *Avogadro constant*, N_A (the number of particles per mole, 6.02×10^{23} mol^{-1})
   (iv) *molar mass* (mass per mole, units g mol^{-1}),
   (v) *molar gas volume* (gas volume per mole, units dm^3 mol^{-1})

Determination of formulae

b. use of the terms;
   (i) *empirical formula* (the simplest whole number ratio of atoms of each element present in a compound)
   (ii) *molecular formula* (the number and type of atoms of each element in a molecule)

c. calculations of empirical and molecular formulae, from composition by mass or percentage compositions by mass and relative molecular mass

d. the terms *anhydrous*, *hydrated* and *water of crystallisation* and calculation of the formula of a hydrated salt from given percentage composition, mass composition or based on experimental results
   M0.2, M2.2, M2.3, M2.4

Calculation of reacting masses, volumes of gases and mole concentrations

e. calculations, using amount of substance in mol, involving:
   (i) mass
   (ii) gas volume
   (iii) solution volume and concentration
   (f) the ideal gas equation:
   $pV = nRT$
   (g) use of stoichiometric relationships in calculations

In A level Chemistry, no concept can be more key, and more difficult to **really** understand, than amount of substance and its unit, the mole. It is one thing 'doing the mole', another 'understanding the mole'.

This guide looks at ways of helping students to acquire an understanding of 'Amount of substance', an abstract quantity described by IUPAC as: "*Amount of substance, symbol n, is a quantity that measures the size of an ensemble of entities.*" (www.iupac.org/publications/ci/2009/3102/1_mills.html.) It is perhaps unsurprising that many of us resort to the (incorrect) phrase of 'number of moles'.

Approaches to teaching the content

difficult to teach, with students needing to master so many basic skills (writing formulae, equations, the mole) so that their use become second nature.

Section 2.1.3 'Amount of substance' has three main parts

- The mole
- Determination of formulae;
- Calculation of reacting masses, volumes of gases and mole concentrations.

Working through these parts sequentially would make for very heavy going, for teachers and students alike; successful delivery often treats these three parts as a whole, teaching how amount of substance links

- first with mass,
- then with gas volumes and
- finally with mole concentrations.

This approach has the advantage that practical work can be integrated within the content teaching to help students to get to master this difficult concept, as well as allowing development of important practical skills and making the whole topic much more interesting.

The activities suggested in this guide focus on the relationships between amount of substance, the mole, the Avogadro constant and mass. The approach is aimed at helping students to understand how these terms are linked together. They also allow for introduction of the term molar mass as mass (in g) per mol.

Common misconceptions or difficulties students may have

1. What is 'amount of substance'?

Conceptually, use of mole, as the unit for amount of substance, is fundamental to all quantitative areas of chemistry. Historically 'the mole' was introduced into chemistry well before 'amount of substance', the very term for which the mole is the unit. The choice of 'amount' is unfortunate as it has a more general term in everyday life, adding to the conceptual difficulties.

Moles, mass and number

In 2018, IUPAC redefined the mole as containing contains exactly $6.022\,140\,76 \times 10^{23}$ elementary entities: https://iupac.org/new-definition-mole-arrived/. We will accept both the classical (carbon-12 based) and revised (Avogadro constant based) definitions of the mole in examinations.

Surveys have shown that most students think that the mole and mass are the same thing. This is reinforced by use of phrases such as '1 mole is 12 g of carbon', '1 mole is the relative atomic mass in grammes' or '1 mol = 12 g C' in teaching and in textbooks equating amount of substance to mass, portion of substance, number of particles (Avogadro's number) or number of moles. All these phrases reinforce the idea that amount of substance is a measure of mass or a number.

Careful use of language is needed: '1 mole of carbon atoms has a mass of 12 g'. Here amount (1 mole) of substance (carbon atoms) has a mass of 12 g.

www.rsc.org/eic/2013/10/education-research-mole-demystify-definition

Use of 'molar mass' helps

The incorrect relationship: moles = mass/RAM is still used. As 'RAM' has no units, the relationship immediately communicates that moles and mass are the same thing.

Far better to always use the term molar mass, *M* and the relationship:

$n = m/M$ for amount (in mol) = mass (in g)/molar mass (in g mol^{-1})

The specification includes the terms molar mass (and molar gas volume) for this purpose. It is useful to place the substance as a formula after *n*, eg *n*(C); $n(CaCO_3)$

For the example above, when *n*(C) = 1 mol, *m* = 12 g and
$M = 12$ g mol^{-1}.

But *n*(C) ≠ 12 g.

Language in exams

Examination questions are set where candidates are asked to work out 'the amount, in mol, …….'. It is hoped that this approach will help to promote the use of this accurate language rather than the standard 'how many moles ……' which is then just a number and has no units. Number of moles of C atoms in 12 g of C = 1 (with no unit).

This is all very subtle but inaccurate language can reinforce misconceptions.

2. Moles of what?

Another difficulty with language is that the type of particles must always be communicated, e.g. 1 mol of hydrogen is ambiguous and could refer to H atoms or H_2 molecules. Best advice is to always encourage use of a formula: 1 mol of H_2 is unambiguous. Similarly *n*(H) and $n(H_2)$ are unambiguous.

Conceptual links to other areas of the specification

Understanding of amount of substance and the mole is used so often in chemistry that it is difficult to link to any specific topics later in the course. It is important at this stage for students to be able to use amount of substance and mole confidently and to be able to use the concept as a matter of course when the need arises.

Teacher reference

The Learning And Teaching Of The Concepts Amount Of Substance And Mole: A Review Of The Literature.

(Chemistry Education: Research And Practice)

http://pubs.rsc.org/en/Content/ArticleLanding/2002/RP/B2RP90023H#!divAbstract

Research document outlining problems encountered in learning and teaching of amount of substance and the mole. Heavy going but certainly makes you think about careful language when teaching this concept.

Activities

The theme for this delivery guide focuses on gaining an understanding of amount of substance and the mole and there are opportunities for delivery via a variety of contexts. The links provide a range of ideas and develop the topic further by linking amount of substance to gas volumes.

Activities

The majority of the activities suggested are very much 'hands-on' with students doing things, rather than formal 'chalk and talk' sessions, allowing students to learn by doing and problem-solving.

The OCR activities are ideas that have worked well with large classes. The activities have other benefits including developing practical skills, use of IT, use of powers on calculators and working together. They also allow the teacher to quickly identify the quantitative abilities of students and finding out how much they have carried forwards from GCSE.

In many external links, you will find that the phrase 'amount of substance' and 'amount of' have been rarely used with 'number of moles', or variants widespread. This is inevitable but it is hoped that this guide will help to promote more careful use of language and increased usage of 'amount of substance' over time.

Activities

'How many atoms in my signature', OCR Lesson Element

https://www.ocr.org.uk/Images/170200-how-many-atoms-in-my-signature-activity-instructions.pdf

This first activity starts with a question: 'How many atoms are there in your signature?' This short activity allows students to be introduced to amount of substance, mole and the Avogadro constant using a problem-solving approach. The initial activity is extended by use of problem sheets. These allow students to develop an understanding of the link between, amount of substance in moles, mass in grammes, molar mass in g mol^{-1} and the Avogadro constant in mol^{-1}.

Working through molar relationships, OCR worksheets

The 'Moles of Atoms' and 'Moles of Molecules' worksheets allow students to develop an understanding of the relationships between amount of substance, mole, Avogadro constant and molar mass before any mathematical equations have been introduced.

Students will need to be introduced to the idea of molar mass as the mass per mole of a substance, the fact that the molar mass of an element's atoms is the same value as the relative atomic mass in g mol^{-1} before completing the two activity sheets. Apart from this both sheets can be handed out with no introduction as there are plenty of clues on the sheets and students will quickly work out what to do.

Note that all the examples on the 'Moles of Molecules' sheet are molecules so as not to get into the situation where ionic compounds are referred to as being composed of molecules – a big misconception in its own right.

Finally, introduce the important equation:

$$n = \frac{m}{M} \quad \text{meaning} \quad \text{amount of substance, } n \text{ (in mol)} = \frac{\text{mass, } m \text{ (in g)}}{\text{molar mass, } M \text{ (in g mol}^{-1}\text{)}}$$

It is good practice when referring to amount in mole to use n(NaCl) = …. rather than 'number of moles'. Only by using the term 'amount' will we get students to use the terms correctly.

Learner resource 1

Learner Resource 2

Mole Day activities

https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/mole-day.html

October 23rd is Mole Day. There are lots of resources available and it often corresponds with a time in the year when students are beginning to grasp the understanding of the mole. This link has a number of activities that could be used to complement the teaching of the mole.

How big is a mole?

'Not the animal, the other one.' - Daniel Dulek

http://ed.ted.com/lessons/daniel-dulek-how-big-is-a-mole-not-the-animal-the-other-one

This TEDEd Lesson covers the concept of the mole in chemistry. This cartoon introduces the Avogadro constant and the mole in an entertaining and engaging way.

Formula of magnesium sulfate, OCR Lesson Element

The activity is a practical investigative approach to formula determination. It can be used with minimal introduction for students to 'learn by discovery'.

The outcomes are underpinned by the links between amount of substance, mass, formulae, equations and stoichiometry.

Using the links on the right you can download the following:

LE Formula of Magnesium Sulfate TEACHER.pdf

LE Formula of Magnesium Sulfate STUDENT.docx

LE Formula of Magnesium Sulfate STUDENT.xlsx

RSC Starters for ten

https://edu.rsc.org/resources/starters-for-ten/954.article

The activities in section 1 of this resource cover all aspects of this topic. These are very useful to use with students and to boost their understanding of these topics. In includes activities on the Ideal Gas Equation which is new to the specification.

Carbonate rocks!

Royal Society of Chemistry:

https://edu.rsc.org/download?ac=12886

This activity links amount of substance to the context of an analytical geochemical laboratory. This activity links amount of substance with mass and provides an insight into how understanding of this concept can work in a real-life situation as a problem-based practical activity.

The change in mass when magnesium burns

Royal Society of Chemistry:

https://edu.rsc.org/resources/the-change-in-mass-when-magnesium-burns/718.article

This is a similar experiment to the provided OCR magnesium sulfate activity but with a different way of interpreting group results graphically. The experiment is essentially the well-established practical for determination of the empirical formula of magnesium oxide.

The volume of 1 mole of hydrogen gas

Royal Society of Chemistry:

https://edu.rsc.org/resources/the-volume-of-1-mole-of-hydrogen-gas/452.article

This is an interesting approach that links together amount of substance with mass, gas volumes and stoichiometry. This would complement well parts (e) and (f) of this section of the specification. The experiment could also be used to introduce an awareness of errors within a practical activity and could be used to question which measurements should be improved. The experiment could also be modified to allow gas collection using a gas syringe or in a measuring cylinder over water. Care is needed as some parts go beyond the specification (volume at STP) and use rounded atomic mass data. Also watch use of 'number of moles'.

Apply the mole concept to substances

IB Chemistry video review: Richard Thornley (YouTube)

www.youtube.com/watch?v=sM4ulTjsuA4

This is part of a whole series of videos to support IB Chemistry but the context is relevant to almost any chemistry course. The series is very well put together and very informative. This video introduces the Avogadro constant and demonstrates well the reason for units of mol^{-1}.

The whole series is available at www.youtube.com/user/richthornley

This is potentially a very useful site as an idea-bank for teachers and for use within lessons.

The Ideal Gas Equation

These videos from the Khan academy could be useful for students who need support or as flip learning activity.

https://www.khanacademy.org/science/chemistry/gases-and-kinetic-molecular-theory/ideal-gas-laws/v/ideal-gas-equation-pv-nrt

The Ideal Gas Equation Questions

This link has a number of questions and solutions which could be used to support students in developing experience of using this equation.

https://www.chemteam.info/GasLaw/Gas-Ideal-Prob1-10.html

Ideal Gas calculator

This link takes you to a website which allows students to input values and calculate using the Ideal Gas Equation. It could be a good starting point and an option to support students in becoming familiar with the equation.

http://www.calctool.org/CALC/chem/c_thermo/ideal_gas

Learner Resource 1

Learner resource 1 Moles of atoms

Refer to the Periodic Table to complete the table below.

Element	Symbol	Relative atomic mass, *Ar*	Mass of sample /g	Amount of substance / mol	Number of atoms
hydrogen		1	2	2	12.04×10^{23}
carbon				1	
sulfur				2	
oxygen				3	
calcium				0.5	
sodium			46		
potassium					6.02×10^{23}
magnesium					3.01×10^{23}
gallium			34.85		
strontium			21.9		
bromine					18.06×10^{23}
arsenic					1.204×10^{23}
molybdenum					2.408×10^{23}
lithium			34.5		
rubidium			8.55		
silicon			5.62		
scandium			9		
cobalt					36.12×10^{23}
chromium				0.2	
nitrogen				0.01	
uranium-238				8	
phosphorus			0.31		

Learner Resource 2

Learner resource 2 Moles of atoms

Refer to the Periodic Table to complete the table below.

Compound	Formula	Molar mass /g mol^{-1}	Mass of sample /g	Amount of substance / mol	Number of molecules
water	H_2O	18	18	1	6.02×10^{23}
ammonia	NH_3			1	
carbon dioxide				0.5	
carbon disulfide			7.62		
phosphine	PH_3		68		
methane	CH_4		64		
methanol	CH_3OH				3.01×10^{23}
dichlorine oxide	Cl_2O			3	
hydrogen fluoride					12.04×10^{23}
acetone	C_3H_6O		29		
hydrogen bromide					18.06×10^{23}
nitrogen trichloride				0.1	
ethane	C_2H_6			0.25	
ethanol				1.5	
benzene	C_6H_6		468		
phosphorus pentachloride	PCl_5			10	
octane	C_8H_{18}		348		
	PCl_3			0.2	
silane	SiH_4				6.02×10^{24}
glucose	$C_6H_{12}O_6$				6.02×10^{22}

Need to get in touch?

If you ever have any questions about OCR qualifications or services (including administration, logistics and teaching) please feel free to get in touch with our Customer Support Centre.

General qualifications
01223 553998
general.qualifications@ocr.org.uk

Vocational qualifications
02476 851509
vocational.qualifications@ocr.org.uk

For more information visit
- **ocr.org.uk/i-want-to/find-resources/**
- **ocr.org.uk**
- **/ocrexams**
- **/ocrexams**
- **/company/ocr**
- **/ocrexams**

We really value your feedback

Click to send us an autogenerated email about this resource. Add comments if you want to. Let us know how we can improve this resource or what else you need. Your email address will not be used or shared for any marketing purposes.

I like this **I dislike this**

OCR acknowledges the use of the following content: Page 2: Word icon, Plan–B/Shutterstock.com.