

Qualification
Accredited

AS AND A LEVEL

Delivery Guide

CHEMISTRY A

H032/H432

For first teaching in 2015

Theme: Identifying Unknowns

Version 2

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.

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3.1.4 Qualitative analysis

(a) qualitative analysis of ions on a test-tube scale; processes and techniques needed to identify the following ions in an unknown compound:

(i) anions:

- CO_3^{2-} , by reaction with $\text{H}^+(\text{aq})$ forming $\text{CO}_2(\text{g})$ (see 2.1.4 c)
- SO_4^{2-} , by precipitation with $\text{Ba}^{2+}(\text{aq})$ Cl^- , Br^- , I^- (see 3.1.3 g)

(ii) cations: NH_4^+ , by reaction with warm $\text{NaOH}(\text{aq})$ forming NH_3 .

4.2.4 Analytical techniques

(a) infrared (IR) radiation causes covalent bonds to vibrate more and absorb energy

(b) absorption of infrared radiation by atmospheric gases containing $\text{C}=\text{O}$, $\text{O}-\text{H}$ and $\text{C}-\text{H}$ bonds (e.g. H_2O , CO_2 and CH_4), the suspected link to global warming and resulting changes to energy usage

(c) use of an infrared spectrum of an organic compound to identify:

- (i) an alcohol from an absorption peak of the $\text{O}-\text{H}$ bond
- (ii) an aldehyde or ketone from an absorption peak of the $\text{C}=\text{O}$ bond
- (iii) a carboxylic acid from an absorption peak of the $\text{C}=\text{O}$ bond and a broad absorption peak of the $\text{O}-\text{H}$ bond

(d) interpretations and predictions of an infrared spectrum of familiar or unfamiliar substances using supplied data

(e) use of infrared spectroscopy to monitor gases causing air pollution (e.g. CO and NO from car emissions) and in modern breathalysers to measure ethanol in the breath

(f) use of a mass spectrum of an organic compound to identify the molecular ion peak and hence to determine molecular mass

(g) analysis of fragmentation peaks in a mass spectrum to identify parts of structures

Approaches to teaching the content

Qualitative analysis is essentially a practical skill and can be introduced by simple test tube experiments. For example, an unlabelled sample could be tested alongside the chloride, bromide and iodide when students investigate the reactions between halides and silver nitrate (*specification section 3.1.3g*).

Spectroscopy will probably involve looking at spectra of simple compounds with emphasis on pattern recognition. There is no need to explain the practical basis of these techniques (especially as the modern manifestations of these techniques bear little resemblance to textbook descriptions).

Common misconceptions or difficulties students may have

Analytical techniques involve moving from the particular to the general and concentrating on relevant observations, whether in test tubes or copies of spectra. Many students take time to adjust to ideas of pattern recognition.

Students often struggle with the precise description of changes of state, for example mistaking a suspension/precipitate for a 'cloudy solution' or suggesting that 'the solution goes white'. They also have difficulty moving from these macroscale observations to generalisations at the particle level.

Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course.

Qualitative inorganic analysis provides students with opportunities to develop their skills of observation and interpretation. They have to distinguish changes of state, describe them precisely and deduce the likely identity of products. The topic provides opportunities to practise writing balanced chemical and ionic equations and to revise the reactions of acids and alkalis in terms of H^+ and OH^- ions.

The interpretation of IR and mass spectra will be set in the context of Organic Chemistry. Students will have to draw displayed formulae, showing all bonds, in order to suggest sensible identities for fragments formed during mass spectrometry, while the interpretation of IR spectra generates familiarity with different functional groups.

[Learner Resource 1: Writing Ionic Equations](#)

The Learner Resource provides practice at identifying which ions are involved in each reaction and at eliminating 'spectator ions' from the ionic equation. It includes precipitation reactions and the reaction of a carbonate with an acid.

A reaction to form silver chloride

Royal Society of Chemistry: Chemical Misconceptions

<http://www.rsc.org/learn-chemistry/resource/res00001096/precipitation>

This resource is intended for students aged 14-16 but parts would be useful at AS Level. The first two pages of the student worksheet use simple models to explain the processes going on when a precipitate forms. The final page, the production of lead iodide, is a good way of testing whether students are able to apply these ideas.

Assessment for Learning: Spectroscopy

Royal Society of Chemistry: Starters for Ten

<https://edu.rsc.org/resources/analysis-starters-16andndash18/4010279.article>

These activities can be projected onto a white board and used as a quick check of understanding. Starters 10.1.3 and 10.2 are on MS and IR spectroscopy respectively. The answers and a suggested mark scheme are provided so students can check their own work.

Inorganic analysis is essentially a practical activity. It will form part of the practical assessment at A Level so students must practise making the correct observations as well as being able to interpret their results.

Spectroscopy is likely to be taught by reference to printed spectra but these can be placed in various contexts throughout the Organic Chemistry course. For example, when studying the conversion of an alcohol to a halogenoalkane students could compare the spectra of the reactant and product. They could look at the spectra of both possible products when discussing the oxidation of primary alcohols. When a new compound is encountered, students could use its mass spectrum and percentage composition to calculate the molecular formula. (Relevant spectra can be downloaded from the internet. See below for links to some online sources.)

Students may be able to experience practical IR spectroscopy by visiting local HE institutions or through the Royal Society of Chemistry's 'Spectroscopy in a Suitcase' scheme (<https://edu.rsc.org/resources/spectroscopy-in-a-suitcase-resource-packs/280.article#sias>).

Testing for Negative Ions

Royal Society of Chemistry: Learn Chemistry

<http://www.rsc.org/learn-chemistry/resource/res00000758/testing-for-negative-ions>

(This includes a test for nitrate ions which is not on the specification!)

Simple test-tube reactions allow students to discover the expected observations when testing for anions. To fulfil the requirements of the specification, students will have to be taught to test for carbonates first and only proceed to test for halide or sulfate ions when carbonate has been eliminated.

Basis of IR spectroscopy

Demonstration

This is an illustration of bond vibration at characteristic frequencies.

Hang some 100g masses from a spring. The spring will oscillate at a steady frequency which changes when masses are added or removed. This is an analogy for the difference in natural frequency of vibration of covalent bonds when atoms of different masses are present, for example C-H and O-H bonds. Adding a second spring in parallel to the first also changes the frequency, analogous to the difference between C-O and C=O bonds.

Infra Red Spectroscopy

The topic can be introduced by issuing students with spectra for some simple molecules. They work together to draw displayed formulae for the compounds and try to identify how the differences in structure are related to the presence of additional peaks on the spectrum. Students often mis-identify C-H peaks as O-H groups. This activity will help them to realise that almost all organic spectra contain a C-H stretch so they will have to look for a further peak in this part of the spectrum to identify an O-H. PowerPoint slides for this sort of activity can be found at

<http://www.tes.co.uk/teaching-resource/Using-Infra-Red-Spectroscopy-6260419/>

Chemistry of Climate Change

Royal Society of Chemistry

<https://www.stem.org.uk/resources/elibrary/resource/33885/chemistry-climate-change-14-16>

This booklet contains a wealth of internet links and information for teachers.

Student worksheet CA1 is a good introduction to the science of the greenhouse effect. It deals with the black-body emission spectra of the sun and the earth and absorption of IR radiation by atmospheric gases such as CO₂ and water vapour. Details about changes in dipole moment associated with bond vibrations are not on the specification but help to link IR spectroscopy with aspects of covalent bonding.

Modelling Climate Change

Science Enhancement Programme

<http://www.nationalstemcentre.org.uk/elibrary/resource/1905/modelling-climate-change>

This resource concentrates on the steady-state between incoming and outgoing radiation. It is mainly aimed at 14-16 year olds but parts can be used at AS Level, for example the modelling spreadsheet MCC_EnergyBalance. Students can download and use this to model the effect on global temperatures of changes in the amount of energy absorbed by the atmosphere.

Learner resource 2: Mass spectrometry of molecules

This is an introductory task intended for group work. Students work through example spectra to identify the molecular and (M+1) peaks and suggest identities for some fragments. Although the principles of mass spectrometry are not on the specification students have to realise that only charged particles will be separated and detected.

Online sources of spectra

<http://science.cleapss.org.uk/Resource-Info/L202-Spectra.aspx>

Schools which are members of CLEAPSS can download booklet L202, which provides some background information about spectroscopy together with IR, mass and NMR spectra for 40 common compounds. A smaller range of spectra can be downloaded from <http://rod.beavon.org.uk/spectra.htm>

Online databases

National Institute for Science and Technology (U.S.)

<http://webbook.nist.gov/chemistry>

National Institute of Advanced Industrial Science and Technology (Japan)

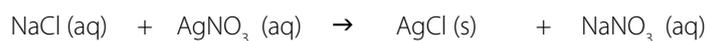
http://sdbs.db.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi

These are searchable databases which can provide spectra for a wide variety of compounds.

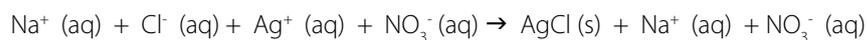
Many chemicals are ionic, ie they consist of oppositely-charged ions. When these compounds are dissolved in water the ions separate and can be treated individually. For example, solid sodium chloride, NaCl, consists of Na⁺ ions and Cl⁻ ions, held together in a lattice by electrostatic attraction. Sodium chloride *solution* contains aqueous Na⁺ and aqueous Cl⁻ ions which move around completely separately from each other. When sodium chloride solution reacts with silver nitrate solution it is really only the Cl⁻ ions which react with Ag⁺. The other ions are 'spectators'. An ionic equation includes only the ions which actually take part in the reaction.

Example

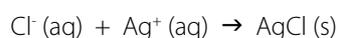
sodium chloride(aq) + silver nitrate(aq) → silver chloride(s) + sodium nitrate(aq)



The chemicals **which are in solution** are represented as their ions:



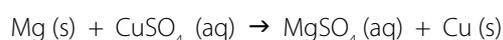
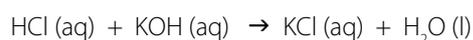
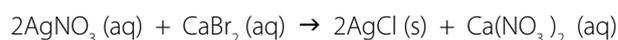
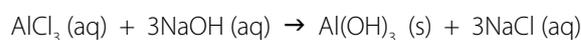
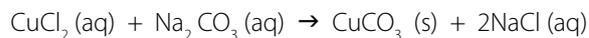
The **aqueous ions** which appear on both sides are then deleted to leave:



This equation shows that exactly the same reaction will occur between silver nitrate solution and any soluble chloride. This is the basis of the test for chloride ions.

Questions

Write ionic equations for the following reactions (the equations must balance in terms of charges and atoms):



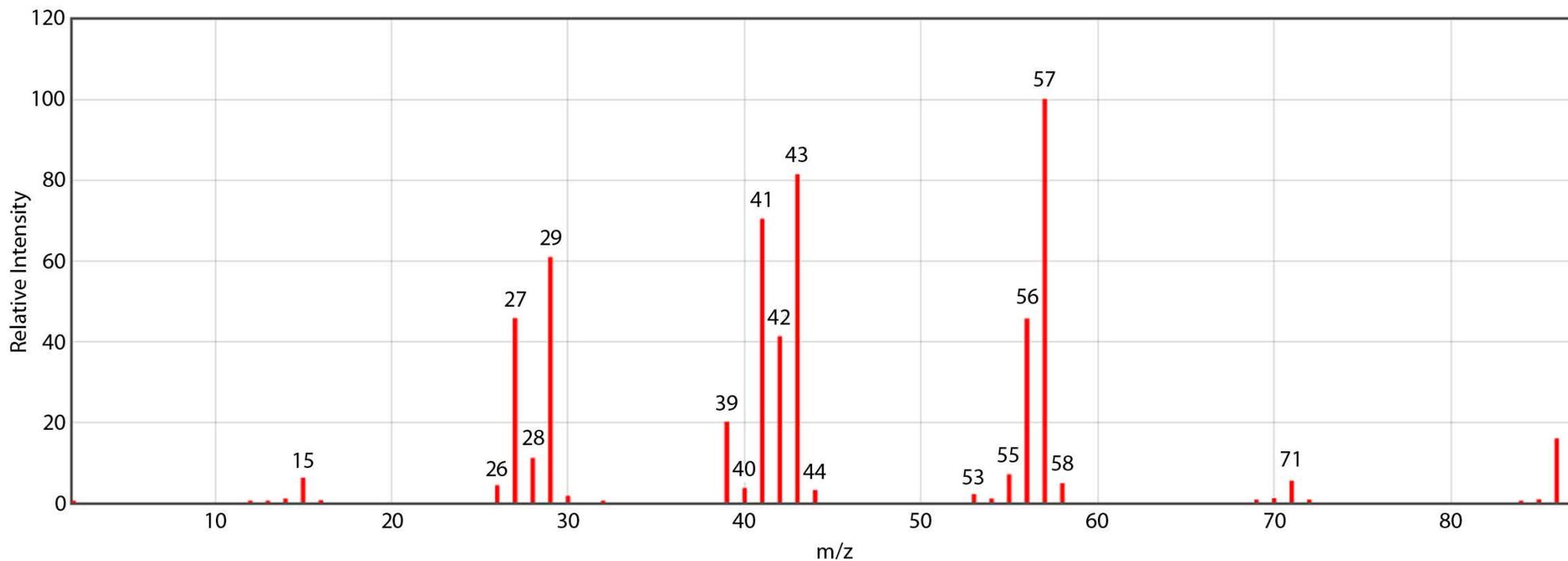
Write an ionic equation for the reaction of sodium carbonate solution with aqueous nitric acid.

Write an ionic equation for the reaction between solid copper (2) oxide and dilute hydrochloric acid.

Mass spectrometry may be considered to consist of three basic processes:

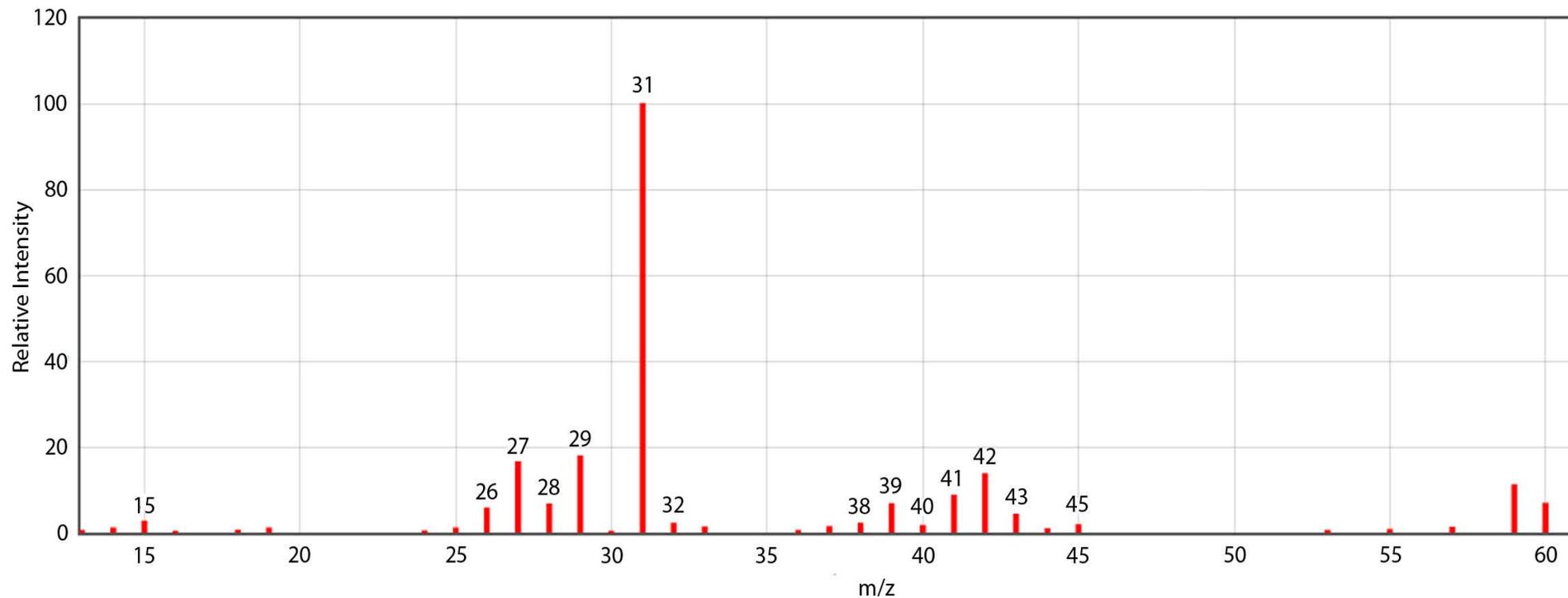
- Atoms or molecules are bombarded with a stream of high-energy electrons producing positive ions which are accelerated by an electric field.
- The positive ions are separated according to their mass-to-charge (m/z) ratio.
- Ions with a particular mass-to-charge ratio are detected by a device which is capable of recording the number of ions striking it.

The spectrum below was obtained for a sample of hexane:



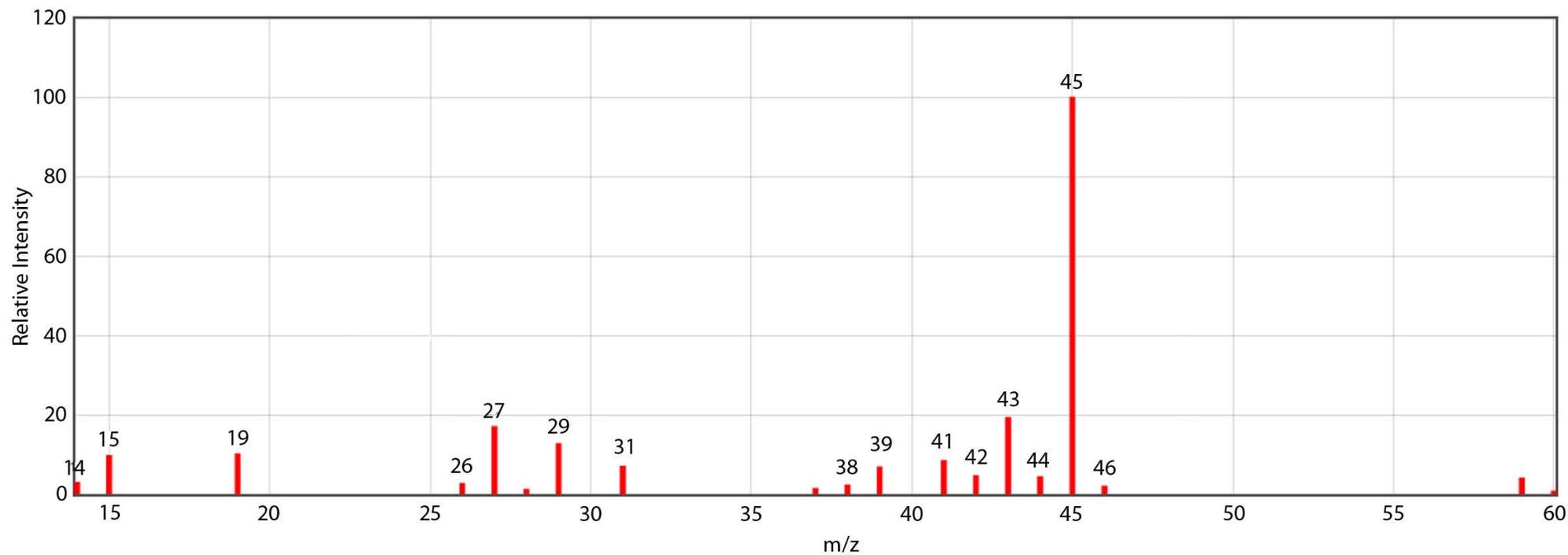
1. Draw the displayed structure of hexane. Show all the atoms and bonds.
2. One of the peaks on this spectrum corresponds to a hexane molecule with a single positive charge. This is called the *molecular ion* and its mass-to-charge ratio corresponds to the molecular mass of the compound. Find this peak and label it **M⁺**.
3. Another peak corresponds to particles which are heavier than the mass of the molecule. This is due to the presence of an atom of ¹³C (natural abundance 1.1%) in some hexane molecules. Label this peak (**M+1**).
4. The remaining peaks are for particles which are lighter than the whole molecule and correspond to fragments formed when covalent bonds are broken. The spectrum of hexane shows that fragments are much more common than intact molecular ions. Find the peak corresponding to fragments formed when molecular ions split in half and label this peak **C₃H₇⁺**. (Only charged particles will be detected so the charge must be shown on any fragments identified on the mass spectrum.)
5. The *base peak* is due to the most common fragment. In this spectrum it has a mass-to-charge ratio of 57. Suggest a formula for this fragment and label the peak. Make sure you include the charge.
6. Try to label the peaks at *m/z* 15 and 29. Include charges!

Mass spectrum of propan-1-ol:



7. Draw the structure of propan-1-ol and use it to help you label the peaks at m/z 60, 59, 31 and 29. Include charges!

Mass spectrum of propan-2-ol:



8. Draw the structure of propan-2-ol and suggest identities for the fragments causing some of the peaks in the spectrum.
9. Why are the spectra of these isomers so different?

Answers

- Hexane
2. M^+ peak at m/z 86
 3. $(M+1)$ at m/z 87
 4. $C_3H_7^+$ at m/z 43
 5. Base peak is $C_4H_9^+$
 6. CH_3^+ at m/z 15; $C_2H_5^+$ at m/z 29
- Propan-1-ol
7. M^+ peak at m/z 60
 $C_3H_7O^+$ at m/z 59
 CH_3O^+ at m/z 31
 $C_2H_5^+$ at m/z 29
- Propan-2-ol
9. Base peak at m/z 45 could be $C_2H_5O^+$ formed by loss of CH_3 .

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