LEVEL 3 CERTIFICATE / EXTENDED CERTIFICATE

APPLIED SCIENCE

ASC6C: Organic chemistry
Report on the Examination

1775 (1776 & 1777)
June 2019

Version: 1.0

Further copies of this Report are available from aqa.org.uk

General

ASC6c is designed to introduce learners to preparative organic chemistry and its importance in a range of contexts, from pharmaceuticals to flavours and fragrances. The importance of yield, rates and purity of compounds together with their characterisation using spectroscopic techniques are also studied. Key roles played by structure and isomerism in the uses and applications of organic compounds are also considered.

Given the wide range of compounds, structures, formulae and isomeric forms that will be considered, various performance criteria within PO1 can be met with concise reports (eg a "revision guide", posters, PowerPoint slides or similar formats). The important point is that these fully represent the Unit Content, but contain primarily just factual content and suitable examples: ie a source of reference or "aide memoir".

For the initial, introductory POs, most, but not all, of the earlier presentation issues have been rectified. Suitable coverage of all the expected areas of structure, bonding and isomerism remains an issue for some.

The ability to research and use relevant material, images, structures, formulae and data varied considerably. ICT skills did unexpectedly let some learners down in terms of both content and also presentation.

The choice of preparations is the centres'. Aspirin and ethyl ethanoate were the most commonly seen preparations and limonene the most common extraction. These are good choices, although one solid and one liquid provide the widest coverage of techniques and the opportunity to carry out both a melting point and a boiling point. There are other alternatives of course, but the extraction of the active ingredient from tablets is neither preparative nor acceptable.

Learners completed the practical preparations relatively well, especially as there were techniques new to them and based on some demanding experimental approaches. However, purifications were not always done as well, as subsequent criteria for purity testified (as did yields in excess of 100%).

Most work seen in portfolios was word processed and there has been a gradual improvement regarding the incorporation of diagrams, formulae, equations, and structures into learners' work. However, some still revert to hand drawn versions which were often inaccurate and poorly or incorrectly drawn.

For diagrams of apparatus and equipment, images from the Internet (properly referenced) are best practice. Spectra will be downloaded or copies of spectra actually obtained by learners from their own products.

PO1: Identify molecular structure, functional groups and isomerism

P1

As with all content in this unit, the scientific principles and examples must be targeted only at organic compounds.

Inorganic examples gain no credit. Their inclusion is an indication of a weak approach to the Unit and lack of knowledge. This follows through to types of bonding and intermolecular forces in some cases, which are not relevant to the criterion.

Presentation varied enormously. In a significant number of cases, approaches could have been more logical, with greater use of headings and sub-headings. In some cases, information is rather randomly presented and related key points are difficult to find.

The key elements of this criterion are:

- Bonding, strong C-C bonds, ability to multiple bond, catenation
- Use of the terms aliphatic, alicyclic, aromatic, arene, saturated and unsaturated, applied correctly to a range of examples
- Structures and nomenclature for common functional groups, with a range of examples
- Examples of structural, displayed and skeletal formulae

P2, M1, D1

P2 was well researched and presented by many learners, although referencing was weak in the majority of cases.

It is important that all three techniques – IR, NMR, MS – are considered and at similar levels of detail. The basic research needed for P2 would be demonstrated by an outline of each of the three techniques and a (researched) spectrum for a named compound to illustrate typical output, again in each case. This then leads into M1 where descriptions of how spectra are obtained are needed, followed by an outline of the associated scientific principles. More able students again did this very well, usually following the pattern of:

- Diagram of the basic construction of each spectrometer
- Explanation of the type of sample used and how the spectrometer works
- An outline description of how the spectral “peaks” are produced

To then access D1, the spectra previously included for P2 (or additional alternatives) can be used. At Distinction level, this needs to be detailed in all three cases, with peaks assigned and linked to structural features of the compounds involved.

Good approaches considered each of the three techniques in turn, covering P2, M1, D1 before moving on to the next technique.

P3, M2, D2

P3 was often met, but weakly in a large number of cases. The key features expected are:

- A group of compounds with a common use or application is selected
    - Eg *flavours, fragrances, liquid crystals, biofuels, painkillers, dyes (Spec. p126) but there are many more.* This is not a functional group (nor alkanes), as uses would not be common to all
    - The choice made should allow access to M2, D2
- Common uses or applications of the members of the group are outlined
- Structures are outlined

M2 requires two of the group to be chosen, and for the specified aspects of P1 to be applied in detail to these two.

- Structures
- Skeletal formulas
- Functional groups identified
- Correct IUPAC nomenclature if possible (although complexity may prevent this)
- Use of correct scientific terminology

D2 requires learners to explain why the structure and/or functional groups make them suitable for the specified use. Learners aspiring to high marks need to be aware of D2 requirements when choosing the group.
Learners should be able to:

- Identify the links between the use, the properties and the structure
- Explain how the structure affects the property.
    - For example:
        - Consideration of structures of NSAIDs and COX-2 inhibitors
        - Structures of fragrances/flavours and nasal and tongue receptors
        - Structures of dyes and effect on light absorption from the visible spectrum

P4, M3 and P5, M4, and D3

The portfolio content regarding isomerism is split into two sections in order that optical isomerism can be treated separately and its importance in biochemical systems developed in more detail. D3 can follow on from either P4/M3 or P5/M4 depending on the compound chosen, and this is acceptable. However, some learners did not target the required content well, and included too few examples of isomers, gave incorrect structures, and even inorganic examples.

P4, M3

Good portfolios were based on:

- a systematic approach which included
    - an outline of each type of isomerism (Spec. p120) which included chain, functional group, position, geometric (cis/trans).
- correct structures (often downloaded images)
- correct examples for each type of isomerism

To go on and access M3, a more detailed explanation is needed in terms of bonding and structure, including, for each type of isomerism:

- Detailed examples for each
    - Explanations relating to straight chain and branch chain molecules
    - Rearrangement of atoms bonding to produce a different functional group
    - Bonding of functional groups at different positions
    - Restricted rotation around carbon-carbon double bonds

P5, M4
Most portfolios seen met the requirements for P5, although examples linked to biochemical systems were not a strong point for some learners. This followed through to M4, which also demonstrated weak understanding of what was required.

P5
This requires an outline of optical isomerism demonstrating an understanding of:

- Asymmetric carbon, chiral centre
- Optical isomers (enantiomers)
- Optical activity
- Racemic mixture

M4
Often, good portfolios incorporated discussions of the importance of the three dimensional structure of enantiomers and their relationship as non-superimposable mirror images into their work for P5, although it is more properly assessed here in M4.

It was clear from the stronger portfolios that learners had an understanding of the importance of stereoisomerism in biochemical systems and how this is related to enzyme action and active sites. Such portfolios demonstrated knowledge and understanding of:

- Importance of stereoisomerism in biological systems
- A range of optically active compounds
    - For instance amino acids, sugars, proteins, enzymes
- The nature of enzymes' active sites
- Why only one enantiomer may be active
- Examples, 3-dimensional structures
    - For instance lactic acid, alanine, glucose, limonene

D3

Thalidomide was again a common choice and there is much information available to research. It does fit the criteria well, but a full description, as befits a Distinction criterion, is necessary. The best examples had clearly been based on several sources and the combination of relevant content from each of them led to higher level accounts.

Other examples that would fit the descriptor well, and for which there is easily accessed information include:

- Naproxen (where one isomer is toxic and the other is a NSAID)
- Various flavours and fragrances where enantiomers have different smells, tastes
- Aspartame sweetener (which has potential side-effects for one isomer) – a complex example.

PO2: Understand reactions of functional groups

P6, M5

P6 in some cases, portfolio content fell short of that expected. It should provide evidence as follows:

- For each of five functional groups, one example of a reaction is provided
- Reagents, conditions, observations are given in each case
- Equations are provided for the reactions
- Changes that occur to the functional groups are explained.

On occasion:

- Five different functional groups were not considered
- Equations and explanations were missing.

It is important that the choice of five reactions in P6 contains at least two which would fit M5. Typically these include:

- Alkenes reacting with aqueous bromine
- Aldehydes reacting with Benedicts, Fehlings or Tollens
- Alcohols reacting with carboxylic acids to give esters.

PO3: Prepare organic compounds

P7, M6

P7 was again completed well by some learners; however, others did not complete all of the requirements for this section. Some did not include all four “preparative techniques” listed in the Unit content (p122), and yet more did not consider “purification techniques” (also p122). Others described all four, but did not give an example for each, and yet more had the wrong diagrams alongside the technique being described.

Diagrams/images of apparatus, a short explanation and an example of a preparation or extraction that uses each technique are required for:

- Reflux
- Distillation
- Fractional distillation
- Steam/water distillation.

And for purification:

- Filtration under reduced pressure, recrystallization
- Washing and separation of immiscible liquids.

M6 needs a similar approach (diagrams, short explanations) and reference to the effects of impurities. As with P7, this is not difficult, but omissions of some of the required content were not uncommon.

Content for M6 should demonstrate:

- How m.pts are measured (diagram or image, short explanation)
- How impurities affect melting points (depression of values and increased range)
- How b.pts are measured (diagram, short explanation)
- How impurities affect boiling points (elevation of values).

P8, M7, D4

P8
There were some very good RAs in evidence, demonstrating good understanding of how to arrange the content, which headings to use, and complete and correct content.

Some learners, however, had not learnt lessons from ASC2 and its subsequent feedback. A significant number still do not understand the difference between hazard and risk, and they do not complete RAs appropriately or use the correct table headings.

A template with the following would be sufficient if completed accurately. CLEAPSS hazards being available would help learners enormously.

- Name of material (including state, concentration where relevant), apparatus, etc
- Hazard identified (eg “corrosive” or “flammable”)
- Risk identified (a numerical approach is not needed)
- PPE, control measures
- Action on spillage, emergency, and disposal.

Note that “glassware” should be a single entry, as should “mains electrical equipment”.

M7 should consider reasons why the method chosen is appropriate. Areas to consider include:

- Availability of reactants
- Timescale for the experiment, rate of reaction, use of catalysts, elevated temperature
- Yield, equilibrium
- Purity of the compound / purification procedures.

D4 is based on research and it is important that the industrial scale production is identified and described. Comparisons with the method used in the centre’s laboratory can then be made in terms of the reaction, the conditions, scale, rates, purification, and automation as relevant.

P9, M8, D5

These three potential criteria are all related to characterisation: identification and purity.

P9
This was done well in most centres, although some learners did not set out the calculations well or explain the stages. The following were expected and generally present.

- Masses of reactants and of the purified product
- Calculation of % yield for each compound prepared
- Boiling point or melting point for each compound (NB Melting point is usually quoted as a range).

In some cases, for instance the preparation of ethyl ethanoate or cyclohexene, the boiling point was not actually determined and a distillation temperature or range was quoted instead. This should be rectified in future submissions.

M8:

M8 requires a comparison of values obtained with:

- Literature values for melting/boiling points
- Expected % yields (from research*).

*These are not necessarily easy to find, but a realisation that most reactions have a yield <<100% is important. Reactions may not go to completion in the timescale of the experiment, or they are reversible. Purity is important and purification stages will also inevitably reduce yields. Typical yields for esterifications may be in the range 50-70% for instance, perhaps lower. How/why a number of learners managed to get yields >100% is uncertain, although it does suggest that technique is an issue.

The comparison of values in M8 is taken further in M9 where overall conclusions regarding the methodologies used in the preparations are drawn (see below).

D5 links back to D1, and is based on a researched spectrum for one of the compounds made. Characterisation here effectively means “identification” in the first instance, and then considering purity subsequently.

The spectrum has to be described in terms of the “peaks” present and how they can be assigned and related to specific aspects of the structure of the compound.

- Researched tables of data (for example absorption frequencies or chemical shifts) and explanations relating to the fingerprint region (for infrared spectra)
- Assigning major peaks in the mass spectrum to structural features of the compound
- Identifying the groups responsible for the peaks and splitting in the NMR spectrum.

This is then extended:

- What peaks would be present if common impurities are present?
    - Solvent
    - Water
    - Side products
    - Unreacted starting materials.

P10, M9, D6

P10 requires two reports: one for each preparation. These were generally present.

Looking back at previous POs, the following should have been the minimum covered previously:

- Standard procedure
- Equipment/apparatus used
- Outcomes (yield, m.pt / b.pt.).

M9 follows on from M8 and conclusions should be drawn relating to the methods of preparation used. The best conclusions were reached for a systematic consideration of the expected outcomes for each of the two preparations and included consideration of:

- Whether the methods used produce good yields
- The evidence to support the comments on yields
- Whether the compounds were produced in a pure state
- The evidence to support the comments on purity.

D6 can then cover the possible improvements that could be made to increase yield or purity. This was by no means the most well considered PO and there were many areas which may have been considered. Learners will need centre guidance as to the type of content expected, but, at the same time, remind learners that only some areas listed below may be applicable for any given preparation or extraction:

- Reaction (reflux) time
- Steam distillation times
- Loss of product during reflux or distillation
- Excess reagents to improve yields
- Catalysts
- Reversible reactions
- Alternative reagents
- Purification stages, loss of product, removal of impurities
- Drying stages
- Alternative processes.

Overall:

- Some excellent portfolios were seen
- Excellent research, thorough understanding of the criteria, and careful practical work led to high marks
- Some portfolios did not appear to reflect the 60glh expectation for the unit
- Some areas were rushed and incomplete
- Presentation was an issue for some.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.