APPLIED GENERAL L3
APPLIED SCIENCE

ASC/U (2/5/6a,b&c): Applied Experimental Techniques
Report on the Examination

1775 (1776 & 1777)
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ASC2

General

Summer 2022 was the first Summer Series entry opportunity for the Certificate Units since 2019.

Some centres had clearly taken advantage of the Reports on the Examination published in the January 2020 and 2021 series and, if necessary, had adjusted their approaches and marking to good effect. In addition, some centre assessors will have taken advantage of the Teacher Online Standardisation Materials (TOLS) available online via eAQA, although it did appear likely that others may not have accessed these useful materials. All centres are reminded of the requirement for internal standardisation (Specification p136) and use of TOLS materials would contribute to that.

There were many examples of good quality work in the samples submitted for moderation in summer 2022, and most centres had a clear understanding of the requirements of the specification and the performance outcomes. In most centres, it was also clearly understood that the approaches adopted by learners should reflect fully the demands and expectations of a Level 3 qualification. However, some centres had underestimated the depth and breadth of the portfolio evidence expected, and were too generous in their assessments. As a result, some fell out of tolerance and marks were regressed.

ASC2 provides opportunities for research, experimental work, risk assessment, analysis of results, drawing conclusions and evaluating outcomes, as well as exploring links to industry and commercial applications. It covers elements of biology, chemistry and physics and some centres deliver the course via three subject specialists. Others do not have this opportunity, and this is understood. Whichever delivery approach is adopted, effective internal standardisation and/or moderation processes to ensure validity of assessments must be in place.

Submission of coursework samples is variable, and, whilst many centres get this absolutely right, others fall short of the standards expected. Centres are reminded of the following:

- The deadline for marks submissions via MMS is May 15th
- The sample should be posted to the moderator promptly
- Portfolios should be hole punched and treasury tagged (top left): <u>NB no poly-pockets,folders or staples</u>
- Only one copy of the Assessment Brief is needed
- The USF must be completed (centre name, number, candidate name, number, candidate and teacher signatures, UAR (Unit assessment record), total marks, confirmation and evidence of internal standardisation)
- Outcomes of internal standardisation and moderation must be consistent with the marks submitted via eSUBs
- Pages should be numbered
- Work should be printed, portrait format, correctly sequenced
- Any previous versions, drafts etc must be removed before submission
- Marks awarded on the UAR must be identical to the marks submitted to AQA by the centre via MMS and the UAR total is consistent with the number of “ticks” in the grid
- A completed Witness Confirmation is enclosed with each portfolio submitted.

Examples of good practice seen at moderation included the following:

- Researched content from the internet is reworded to demonstrate the student's own knowledge and understanding
- Any direct cut and paste (prose) content is suitably annotated by the assessor and not given credit
- All sources are referenced
- Experimental work is carried out individually wherever possible (eg titrations, determination of resistivity)
- Where any pair or group work is necessary, it must be confirmed that each individual has played a full part in all the experimental work and his/her own results are clearly identified. This ensures each individual can follow the standard procedure and record their own results, providing clear evidence in all six relevant Pass POs
- SPs have all been fully trialled by the centre so that learners achieve data consistent with Level 3 expectations
- No centre issued templates or scaffolding are used in portfolios e.g. for recording results or carrying out calculations
- Hand drawn lines of best fit to support learner understanding are evident (for instance in M2, P6, M9).

PO1: Demonstrate applied experimental techniques in biology

P1, M1, D1

The most common issue encountered is still that these three grading criteria all require both respiration and photosynthesis to be considered. It should also be remembered that M1 cannot be awarded if P1 is not met.

- P1 requires an outline of <u>uses of physiological measurements</u> of respiration (eg peak flow and lung capacity), and photosynthesis (eg uses of measurements for improving yields and productivity)
- M1 requires explanations of the scientific principles behind respiration and photosynthesis (see Unit content p46, 47 in the Specification)
- D1 must be suitably detailed for Distinction level, and should cover both respiration and photosynthesis and how they are applied in a medical or commercial context
- Good portfolios usually include very detailed applications of peak flow, lung capacity and blood pressure in medical contexts and the use of BMR by sports physiologists
- Photosynthesis is usually linked to commercial applications in agriculture and horticulture and manipulation of factors in the context of improving crop yields and rates of growth
- Good approaches make use of graphs, tables and images in D1 to support and demonstrate the points made.

PO1a and PO1b

P2 requires a standard procedure, issued by the centre, to be followed, and this must measure the effect of one factor on rate of respiration. M2 needs formulas / calculations / graphical representations to be used in explaining the data recorded as part of P2. D2 involves the evaluation of the results and the SP used.

Varying temperature is the most common approach seen and most centres have now adjusted their procedures to allow a suitable range of data to be recorded. Centres should remember that, where ethical constraints restrict the range of temperatures to be used, it follows that M2 is likely to not be met.

Typical high scoring portfolios include the following:

- Measure rate of respiration of yeast (sometimes seeds/beans) at 5 or 6 different temperatures
- The temperatures chosen span the optimum value and the pattern of results and optimum are as would be expected
- Rates are calculated (eg by volume of gas/time) and a graph of rate v temperature is drawn
- The shape of the graph is explained with reference to, for instance, reaction kinetics, collision rate, activation energy, enzyme action, active sites and denaturing
- The results are evaluated and anomalies and errors identified; methodology is evaluated.

P3 requires a standard procedure to investigate the Hill (light dependent) reaction and all results to be recorded. No calculations or conclusions are expected. M3 requires the same SP as used for P3 to be adapted for three different limiting factors (most commonly light intensity, wavelength of light, carbon dioxide (for instance via varying concentrations of sodium hydrogen carbonate), herbicides).

For M3:

- Learners state the modifications required in each of the three cases and/or include a new, adapted standard procedure
- The science behind how the adaptations work is explained (eg applying the inverse square law for light intensity diminishing with increased distance; explaining how wavelength of light relates to the colours in the visible spectrum).

PO2: Demonstrate applied experimental techniques in chemistry

P4, M4

Volumetric analysis and colorimetry are outlined in terms of their basic principles and uses for P4.

M4 then requires explanations of the underlying science of the two techniques with specific reference to standard solutions, choice of indicators, and the Beer-Lambert Law.

The following details should be evident in portfolios:

Volumetric analysis

- The reaction, equation and stoichiometry (molar ratio)
- Choice of indicator, justification and explanation in terms of pH titration curves and end points
- The importance of using a standard solution, examples and uses.

Colorimetric analysis
- The visible spectrum
- How a simple colorimeter is constructed and how it works
- Choice of filter or wavelength of incident light used, absorption curves and lambda max
- Absorbance (NB not transmission)
- The Beer Lambert Law and graphical representation
- Calibration and the nature of the abs v concentration graph
- Uses.

PO2a

Key content and outcomes that scored well for PO2a, volumetric analysis, covered the following:

- For P5, learners followed a suitable SP to:
  - Prepare a standard solution (for example sodium carbonate or sodium hydrogen carbonate) NB The choice of standard is important and inappropriate choices (eg NaOH) cannot be credited
  - Carry out a titration (for example against hydrochloric acid of unknown concentration)
  - Achieve titres of suitable values, typically 20 – 25 cm^3
  - Record all results to include mass of standard weighed out, volume of volumetric flask, volume pipetted, initial and final burette readings (to +/- 0.05).

Note: a completed Witness Confirmation and RA is needed to support the practical work.

- For M5, learners calculated:
  - The concentration of the standard solution from the mass they weighed out and the volume of the volumetric flask
  - The unknown concentration.

- For D3, learners researched titrimetric methods used in industry with particular reference to:
  - Use of auto-pipettes, auto-titrators, electronic end-point detection
  - The accuracy and precision of recording of the results that follows
  - The use of primary standards explained with suitable examples.

PO2b

Key content and outcomes that scored well for PO2b covered the following:

- For P6, learners followed a suitable SP to:
  - Use solution dilutions of a standard solution (eg copper (II) sulphate)
  - Prepare a suitable range of known concentrations
  - Select a suitable filter or choose a suitable wavelength
  - Correctly zero the colorimeter
  - Record absorbance values for all standards and the unknown
  - Plot a calibration graph
  - Use the calibration graph to determine the unknown concentration.

- For M6, learners:
  - Explained the choice of filter or wavelength in relation to the colour of the unknown and the visible spectrum (and in the best portfolios, by referring to a graph of abs readings v filter colour and determining λmax)
  - Described any anomalies in the data recorded
  - Referred to the Beer-Lambert Law and compared the expected line (straight line through the origin) with that achieved.

- For D4, learners:
  - Evaluated the outcome of the analysis of the data
  - Systematically considered all the stages in the procedures, the apparatus used and any errors or lack of precision that may have resulted
  - Considered the data recorded (solution dilutions, colorimeter readings) and its reliability through repeats, and precision of recording
  - Compared the outcome with the expected value and accounted for any discrepancies.

PO3: Demonstrate applied experimental techniques in physics

P7 and M7 were surprisingly weak in some submissions, with resistivity in particular being often poorly understood by learners and lacking an explanation of its definition. SHC was usually better described/defined. Both, however, were poorly explained “in relation to material properties”. It is essential to get P7 correct as, if weak, it usually followed that M7 was not met. M7 needs to concentrate on (researched) values of resistivity and SHC, and how these determine uses of a range of materials in industry.

The following details should be evident in portfolios:

Resistivity

- The meaning and definition of resistivity and how resistivity relates to resistance
- How resistivity determines uses of materials
- How values of resistivity are linked to uses for a range of materials with high and low values
- How values of resistivity are linked to the uses of semi-conductors.

Specific Heat Capacity

- The meaning and definition of SHC
- Why different materials have different values
- How high and low values of SHC are linked to uses of materials
- Suitable examples including water.

PO3a

Key content and outcomes that scored well for PO3a covered the following:

- For P8, learners:
    - Followed a SP to measure resistivity
    - Recorded all results including the length and diameter of the wire
    - Used suitably precise equipment
    - Repeated readings at least three times.
- For M8, learners:
    - Calculated cross sectional area and resistance, and hence resistivity
    - Compared their results with (researched) industry standard values
    - Identified whether their result was in agreement with the industry standard
    - Identified and accounted for any anomalous readings and reasons why any differences arose.
- For D5, learners:
    - Researched industry standard methods of measuring resistivity such as 4 point probes
    - Described these methods, usually with diagrammatic support
    - Linked these methods to reduction of errors such as contact resistance
    - Considered the improved accuracy and precision of recorded data that result.

PO3b

Key content and outcomes that scored well for PO3b covered the following:

- For P9, learners:
    - Followed a SP to measure the SHC of one material (usually a solid)
    - Recorded all results.
- For M9, learners:
    - Plotted a graph of temperature <u>change</u> v time (or energy supplied)
    - Calculated % errors in the measurements made and plotted error bars (for temperature change only) on the graph (Note: uncertainties in readings are acceptable in place of error bars)
    - Drew the line of best fit (NB this is often not a straight line throughout, especially at low and at high temperatures)
    - Calculate SHC
    - Explain the graph in terms of heat transfer (heat gain v heat loss and how this may vary as temperature increases; Newton's Law of cooling will be relevant here).
- For D6, learners:
    - Explain how the SP (NB that used previously in P9) could be adapted to measure the SHC for a material in a different phase (typically, a liquid)
    - Diagrams, adapted SPs, due regard for heat losses / insulation / materials used for apparatus, measurements recorded, are typically all part of good responses.

PO4: Understand safety procedure and risk assessment when undertaking scientific practical work

P10 tended to be either well done or very poorly done in respect of the Risk Assessments seen. This remains an area that needs to be addressed by a number of centres and it does, of course, tend to affect the likelihood of equally weak RAs being submitted for the Extended Certificate units.

P10 has three outcomes which are assessed:

- The safe use of a range of practical equipment and materials (across all six experiments) is normally met, but <u>does need supporting evidence from the centre</u> via a Witness Confirmation for each learner
- The ability to identify hazards is judged from the learner written RAs cross-checked against the experiments carried out
- The ability to produce risk assessments for one experiment from each of PO1, PO2, PO3 and these need to be suitably identified in the portfolio. [NB The remaining three RAs can be centre issued, and copies of each included in the sample.] All 6 RAs need to be evident.

Centres should note that a missing learner RA will lead to P10 not being available for credit

The production of meaningful risk assessments remains an area which needs attention in a number of centres, some across all three science areas, some in one or two.

- The approach to RAs needs to be coordinated across the three science areas
- RAs should start with identification of materials (chemicals, micro-organisms, other materials and apparatus) including, for chemicals, relevant states and concentrations. Apparatus should also be included, but “glassware” can only be one entry as can “mains electrical equipment”.
- Learners must make it clear that they understand the difference between hazard and risk and assign these to the next two columns. The nature of the hazard should correctly reflect the state/concentration of the chemicals
- A numerical approach to risk should not be undertaken
- Further column entries should then consider control measures and PPE, disposal if relevant, and action on spillage/emergency or similar points.

NB: RAs written in prose are not suitable and will not gain credit.

ASC5

General

June 2022 was the first Summer submission opportunity for ASC5, Investigating Science, since June 2019. There have been some entries for January 2020, 2021 and 2022 and those centres will have received useful feedback on learner performance.

For this Summer 2022 submission, a range of investigation titles was evident, some more successful than others, and there was a mixture of centres submitting for the first time and others who had clearly had the opportunity to fine tune approaches after feedback from previous series.

Some centres had clearly made good use of the Student Worksheets: “ASC5 Investigations Task Overviews” (available on the AQA website). Teachers can print off the double-sided card for each investigation to produce a useful teaching aid which can be issued to learners to support them in the conduct of their investigation. There are ten different investigations represented and each provides advice and information on how to approach the various assessment criteria.

There are still issues apparent in a number of centres regarding the suitability of the selected investigative work at this level, and the following important points should be borne in mind.

- All aspects of the investigation should reflect the Level 3 nature of the Applied Science award
- ASC5, as with any other coursework unit, requires 60glh
- The suggested titles represented in the “ASC5 Task Overviews” on the AQA Website should be followed as written or other approaches agreed by an NEA Adviser
- If centres wish to develop their own Investigation, then they are advised to consult their NEA Adviser first
- Some suggested factors on the Task Overviews are more demanding and higher level than others: centres must prioritise accordingly
- Typically, a <u>minimum</u> of three factors, all at Level 3, could allow access to the higher level criteria if completed fully and to an appropriate standard
- Restricting the number of factors is very likely to prevent access to most of the higher criteria
- Adopting practical work with a low level of demand (<L3) and/or a restricted coverage of the relevant scientific principles will, similarly, prevent access to many of the Merit and Distinction criteria.

Some investigated fewer factors than documented, whilst others chose mainly low-level experimental approaches which were well below Level 3 standards. In both cases, credit was immediately limited to lower criteria.

Some of the more popular investigations seen this Summer include the following:

- “Electrochemical Cells” has proved to be successful in the past and provides opportunities for good Level 3 approaches and theory, eg application of the Nernst equation and redox potentials
- Whilst “Fermentation in the brewing industry” is a popular choice, it is also potentially one of the weaker investigations in terms of practical approaches. The entry in the Specification lists 5 factors to choose from (the Task Overview suggests 3, but this is then widened in terms of practical approaches and techniques when ethanol content (ABV via specific

gravity), colour and clarity are also included). At its simplest, submissions have investigated one factor, sometimes very inaccurately and with limited outcomes and marks available

- "Properties of shampoos" lists 5 factors, although there are others that would be suitable such as effect on hair dye and anti-microbial action for instance. Here, several factors are able to be brought up to L3 approaches such as a quantitative determination of viscosity using Stokes Law, applying pH using GCE level definition, formula, effect of dilution/temperature, buffer action, calibration of pH meters, etc., cleansing effectiveness via careful gravimetric work. Simplistic approaches to foaming and oil-emulsification will add breadth, but not depth
- "Output of a wind turbine" lists 3 factors and all should be investigated. This does require appropriate apparatus, and simplistic approaches that involve, for instance, cut out pieces of card and blue-tack are very likely to fail
- "Factors that affect reaction time" is another popular investigation, but not always for the right reasons. There are 4 factors listed in the Specification, and there are various real and virtual timers to trial. There are good links to background science in ASC4, although other sources and other relevant aspects of science should also be researched. Obtaining sufficient data in order to make valid conclusions is always a problem, and this has to be recognised and explained.

Alternative Investigations

Centres may choose their own investigations, but are strongly advised to contact their NEA Adviser well in advance of starting work. Full details of the intended investigation, likely aims, experimental methods/SPs, factors to vary, links to industry/commerce will be needed if an informed recommendation is to be made.

Centres should note that it is allowed for all students to follow the same investigation title (but they must work independently, carry out their own research, obtain and record their own results, analyse, manipulate, conclude and evaluate, etc.).

Good investigations were characterised by:

- Comprehensive portfolios created with a firm understanding of the depth of treatment expected
- Extensive research and use of secondary sources
- Wide ranging approaches to all elements of the investigation
- Good levels of scientific knowledge and understanding consistent with level 3
- Appropriate practical methods producing accurate and reliable data
- Sensible marking by assessors who clearly understand the need for content at an appropriate level
- Clear centre annotation identifying where performance outcomes had been met and awarded.

Weak investigations which struggled to meet even Pass criteria were characterised by:

- Insufficient factors being investigated (sometimes only one) and/or choosing low-level approaches well below Level 3 expectations
- A lack of evidence of contact with the centre's NEA Adviser
- << 60glh and/or < Level 3 (the two often went together)
- A portfolio of very few pages and very little content
- Limited and/or low-level research into scientific background
- Only one standard procedure identified, used or trialled (and sometimes issued, not researched)
- Restricted outcomes and levels of data recorded.

Learners would benefit from guidance on the following at the outset:

- The levels of science expected and the depth of knowledge and understanding that should be demonstrated
- Using practical techniques of suitable levels of demand and avoiding GCSE level work (or even below)
- How to access sources which are not predominantly based on GCSE work (or below).

With the right decisions, appropriate investigations can meet all the criteria at a good level. However, it is possible for two investigations with the same title to be met at Distinction level or at below Pass level depending on the decisions made and approaches adopted.

To an extent, some credit may normally be available if investigative processes and procedures have been followed, but some criteria cannot be met for low level approaches, weak science and restricted, inaccurate or unreliable data.

PO1: Prepare for a scientific investigation

P1, M1, D1

These criteria involve progressively more detailed research and explanations of scientific principles across the performance outcomes grid. The principles to be covered concern all aspects of the investigation including:

- The scientific area concerned, and the underlying theories and principles
- The science related to the relevant procedures, techniques, possible approaches
- The science relating to the variables/factors to be investigated and/or controlled
- The need for a particularly detailed account of principles which also have to be related to commercial and industrial uses (D1).

Although not necessarily a pre-requisite, some investigations will have direct, extensive links to other areas of the specification, for instance "reaction time" and ASC4, and this gives an idea of the level of theory that is appropriate. In this example, relevant parts of "*the structure and function* *of the nervous system and brain*" and "*nerve impulses*" from ASC4 would provide a good high level basis for some of the scientific principles behind the investigation. In addition, further areas, relating to the standard procedures and factors/variables investigated or controlled, would also need to be considered.

P2, M2, D2

These criteria are also connected and provide a sequence from Pass to Merit to Distinction.

- P2 requires a plan, aims and researched standard procedures/techniques (plural) to be followed
- M2 records results/data from trials of the SPs identified in P1 – leading on to changes made to the SPs to be adopted
- D2 then requires a justification of the final SPs chosen and the accuracy, reliability and validity shown.

Note: Whilst "practise techniques" are mentioned in the Unit content (p85) the main purpose is to "determine parameters". Trials are designed to identify the SPs to be used, and how variables are best controlled to give accurate, reliable data. Changes to the plan, including modifications of parameters – eg concentrations, times, etc as appropriate – need to be described.

In weaker portfolios, trials were usually very limited in scope as they were not aimed at trialling methodology and determining parameters. Subsequent modifications were not extensive, and often not present at all.

PO2: Carry out the investigation and record results

P3, M3
Over the whole entry, risk assessments were poor, and sometimes very weak indeed. This is surprising as these learners will have already completed risk assessments for ASC2.

Learner generated RAs are needed for P3 and Control Measures are assessed for M3. Control Measures are often incorporated into the RA template and this is acceptable.

RAs are best recorded on a standard template (lengthy prose style RAs are not acceptable). Column headings of Equipment and Materials, Hazard, Risk, Control Measures, PPE, Action on Spillage, are expected. Hazards and risks must be correct for the states and concentrations used and quoted in the RA.

P4
A teacher Observation Record is required for each student to support the criterion "correctly follow SPs to use a range of practical equipment and materials safely".

Other issues that can arise are that learners do not "use a range of equipment" or be working at Level 3.

It is important that the SPs are present in portfolios together with the associated results in order that P4 can be judged in the context of the practical work carried out.

P5, M4, D3

For P5, data must be recorded to correct levels of precision (significant figures/decimal places) with correct units and adhering to normal conventions. This was not always seen, and absent units and/or incorrect conventions result in P5 not being met.

- It is assumed that all data recorded are the learner's own unless otherwise annotated
- Learners and assessors must sign the USF to confirm that all work is the student's own
- If any secondary data from other learners are included, these should be tabulated separately and annotated accordingly.

M4 assesses effectiveness of methods used to collect data. This is measured on the quality of the recorded data, precision of recording, anomalies, repeatability/concordancy, etc.

Questions to ask:

- Are data complete / are sufficient data recorded?
- Are sample sizes adequate?
- Is the precision of recording appropriate?
- Are there any anomalies?
- Are the data repeatable, hence reliable?
- Are there any issues with accuracy?

D3 then considers the responses to these questions, and makes suggestions for improvements to the methodology and/or data collection.

PO3: Analyse results, draw conclusions and evaluation the investigation

P6, M5, D4

P6: Analysis of data could include suitable, simple calculations – eg means - and presentation of data using appropriate graphs and/or charts.

M5 Manipulation of data using appropriate methods usually incorporates mathematical changes, for instance calculating rates of fermentation, energy output from a wind turbine, viscosity using Stokes Law, time of fall in a ruler drop test. These modified outcomes can then be presented graphically in a more meaningful way.

IT is expected to be used at some stage in the process, either in the manipulation steps (eg spreadsheet calculations) and/or at the graphical representation stage. The use of IT does have to be appropriate, and should enhance the ways in which data are manipulated and presented, remembering also that some Excel graphs are too simplistic, often with inappropriate lines of best fit, to be useful.

A sometimes useful addition to manipulation of data would be the use of statistical methods, but this does have to be appropriate to the data set recorded and often this is not the case for ASC5.

D4 discusses the methods and formats used in the analysis in the context of the outcomes and their relevance to the original aims of the investigation. Justifications can also consider the analytical methods used and what further information or outcomes are derived as a result of applying those methods.

P7, M6
P7 identifies sources of error and anomalous data. These errors can be systematic or random. Good approaches, seen from learners, were to:

- Identify qualitative errors and consider the methodology used
- Identify quantitative errors (in the readings taken/data recorded)
- Identify % errors in readings recorded (and comment on their values).

M6 then:
- Explains these sources of error and how they arose including reasons for anomalous data
- Explains how these sources of error can be minimised.

P8, M7, D5
P8 and M7 were particularly weak areas for most learners.

For P8, conclusions should be related to the original aims set out in P2 and should be based on the data recorded and analysed in P6/M5.

In M7, these conclusions based on primary data are compared with equivalent information (data) gained from secondary sources, such as researched expected outcomes and literature values if available.

This was a weak aspect of many portfolios as students offered limited or no evidence of the comparison of conclusions drawn from primary data gathered by the learner, and those based on secondary data.

NB Using other learners' results as secondary data may well be of limited value, and should not be seen as a substitute for extensive research and recording of relevant secondary data from reliable sources.

D5, in many ways, ties together the explanations in M6 and the review of outcomes in M7. A full evaluation of the outcomes and qualitative and quantitative errors is an essential start point. The use of percentage errors can then lead to a comparison of the accuracy of the calculated outcomes with the overall error.

PO4: Present the findings of the investigation to a suitable audience

P9, M8, D6

P9:

- The report on the investigation is usually the portfolio and no separate mini-report is expected.
- The presentation:
    - Can be in various formats
    - Should be designed for a suitable (identified) audience
    - Should be appropriate for that audience
    - Should contain text and images
    - Should include results and a conclusion, which are clear and concise.

Some very poor PowerPoint presentations were again seen with slides that needed to be more focussed and concise. Improvements are expected for future submissions and many learners would benefit from guidance in the design and content of PowerPoint presentations.

M8 connects to M7 in terms of secondary data, but does cover its use in other POs such as P1, M1, and D1. M8 also has the additional expectation of use of correct scientific terminology throughout.

D1 assessed the relevant scientific principles and their relationship to industrial/commercial uses, and now D6 revisits these, but from the point of view of the relevance of the results and outcomes of the investigation to those industrial processes.

P10, M9

P10:

- Requires sources to have been used in research for PO1 and for secondary data for M7.
- Expects (just a basic version of) HRS to be used. For example, a numbered indication eg [12] in the body of the text and the reference listed in a footer or in a bibliography at the end.

M9

- Requires the usefulness of the references to be evaluated and the references themselves to be validated.

Validation can consider a whole range of checks and ideas depending on the nature of the source. Approaches may include:

- Type of publication, who published it and where
- Purpose of the publication
- Academic standing of the author
- Advertising / government / academic / commercial / industrial/ pressure group
  Peer review / editorial control / adopted textbook / book reviews / citations / cross referencing.

ASC6a

General

ASC6a remains a popular choice of Unit, although it does not necessarily reach the high standards seen in portfolios for the other options (ASC6b and 6c). Compared to ASC6b and ASC6c, there is more assessed practical work in this unit, and it could be this weighting that is seen as important and more suitable for the learners interests and abilities.

However, learnerss in some centres did find it difficult to present all the evidence, data, and outcomes of practical work systematically and in a clear, coherent order. As with previous years, it was often difficult for moderators to locate sufficient evidence that learners had actually carried out all the required practical work and/or had understood the purpose of that work. Results were occasionally hard to locate, and, in some cases, there were no results evident at all for some required experiments.

PO1 (P3), PO2, and most of PO3 are all based on practical activities, and clarity and full supporting evidence, descriptions, results/data, photographs, images, etc are all very important. Some learners did not produce a coherent set of results and parts of an overall experiment could sometimes be found separated into three different sections in different places in the portfolio.

Another issue noticed by moderators was that PO4, as in previous years, was often a weaker section than any other. In some cases, this appeared to be a time issue, and in others it was seemingly due to the independent nature of the expected approach, based almost solely on individual research. Overall, PO4 can generate 6 marks - or almost 25% of the overall marks available - and this is potentially a very significant contribution to overall scores.

For all practical work, an Observation Statement or Witness Confirmation is required to support learner achievement and to provide the evidence that s/he has followed the SP, applied the risk assessment, used aseptic technique, recorded results correctly, etc.

It is very important to note that the USF signatures of both the learner and the teacher confirm that the work submitted is the learner's own independent work. If there was a degree of pair or group work, this must be made clear.

PO1: Identify the main groups of microorganisms in terms of their structure

P1, M1
P1 and M1 were covered well by many learners. Content was based on independent research and sourced material was adapted well by the learners to target the criteria. The key content and approaches include:

- Consideration of characteristic structures and features for each of the three types of micro-organism
- Labelled diagrams
- Identification and functions of the key features
- Detailed coverage for all three types of micro-organism (akaryotes, prokaryotes and eukaryotes).

In some cases, source material was not reworded to demonstrate the learners' own knowledge and understanding, and this could not be awarded credit.

P2, M2, D1
P2 should describe methods used to identify micro-organisms to include:

- Gram staining
- Light microscopy
- Electron microscopy
- Colony characteristics.

Annotated diagrams and images from research will always add to the descriptions. Good portfolios described all four techniques well, whereas weaker attempts sometimes missed out a technique completely and/or included very little descriptive detail.

M2 continues from P2 and explains how all the techniques described there are used and how they provide information that allows identification of the structures of microorganisms. This includes:

- How differences in structure of bacteria enable them to be identified by Gram staining
- How colony characteristics (morphology) enable microorganisms to be identified
- How light microscopy and electron microscopy are used and how their usefulness is related to resolution and magnification and the structural features of microorganisms.

In each case, good explanations will be accompanied by relevant images.

D1 in the Unit Content requires a comparison of the different identification techniques listed in P2 and how they are used in biotechnological industries. It was clear that learners did not always know what was required here and often underestimated the levels of detail expected at Distinction level. Relevant industries and techniques may include the following, for instance, but there are many more which could be researched. High scoring portfolios typically included industries such as food and beverage, pharmaceuticals, water, environmental, forensics (for example) and which industries use which identification techniques and for what.

Some excellent examples of independent research seen then went on to consider if there were other relevant techniques, for example those based on electrophoresis, DNA sequencing and mass spectrometry.

P3 is an experimentally based criterion. The evidence expected consists of the following:

- Standard procedure and risk assessment for Gram Staining correctly followed
- Observation Record
- Individual learner results (eg photographic images)*
- Conclusions drawn, ie identification of the microorganisms.

*Note: Weaker portfolios often failed to include evidence of outcomes and thus did not complete the experiment (which is "to identify microorganisms").

PO2: Use aseptic techniques to safely cultivate micro-organisms

PO2 is, in many ways, a precursor to PO3 and it is important that learners organise and present their work logically and in an unambiguous sequence. It does need to be clear which techniques from P5 (in PO2) are carried forward and used for M5 (in PO3). Centres should be aware of this and advise learners accordingly.

P4, M3
P4: Risk assessments are prepared by each learner for the safe cultivation of microorganisms and should include:

- Preparation of sterile growth media
- Names of microorganisms used
- Cultivation of microorganisms
- Aseptic techniques
- Safe disposal.

Centres should note that, without specific identification of the microorganisms used and full risk assessments associated with them, the RA will be considered to have important omissions and P4 should not be awarded. Risk Assessments in general are still a weak area for learners in a range of centres. This follows through to the control measures which are assessed in M3.

M3: Explanations of control measures applied can be incorporated into the RA table or considered separately. M3 should not be considered for credit if P4 is not awarded.

P5, M4, D2
P5: There should be at least two different types of micro-organism used in P5 (Specification p101).

To award P5, the following are required:

- Three different cultivation techniques are used
- Standard procedure(s) for the preparation of the growth media are documented
- Standard procedures for all three techniques including incubation are documented
- Observations (images/photographs to support successful completion of the tasks) are included
- Evidence of following aseptic technique
- Observation record supporting the completion of all three techniques.

NB: “Use aseptic techniques” is a key part of P5 and part of the marking criterion statement.

M4: This requires an explanation of the principles behind the use of growth media and each of the three techniques. This remains a weak area for many learners.
It would be sensible for each cultivation technique to be treated as a separate experimental account to include all the following before moving on to the next technique:

- Standard procedure and results/images (for P5)
- All relevant material/evidence required for M4 and D2
- An explanation of the principles of the technique (for M4).

D2 requires the following:

- An evaluation of the following in each of the three cases, referring to the results obtained
    - The effectiveness of the aseptic techniques used in each case
    - The effectiveness of the cultivation techniques in each case
    - A consideration of the results obtained
    - Identification of errors or anomalies evident in the results
- Justified suggestions for improvement.

Evaluations and justifications are often a difficult area for many learners, and this is applicable to all the units, but especially so here where a logical, ordered approach across all three techniques and their results is necessary. Weaker portfolios were often not logical in their order and omissions of key information such as results were not uncommon.

PO3: Use practical techniques to investigate the factors that affect the growth of microorganisms

P6, M5, D3
10 different factors which promote or inhibit growth of microorganisms are listed in the Unit Content (page 97).

P6 requires a range to be described, and portfolios should include a minimum of 5 or 6 although able learners may go on to describe more. Insufficient factors or lack of detail may prevent credit for P6.

M5, D3:

- M5 requires evidence of practical work investigating <u>three</u> factors that affect growth
- The three factors are drawn from the range considered in P6
- D3 requires learners to draw conclusions about how the factors affect growth
- Conclusions must be consistent with the recorded results.

In order to then go on and provide evidence for other marking criteria in PO3, centres often combine the experiments investigating these three factors with other practical approaches. This avoids too many repeats of similar practical work.

- NB Specification p102 gives examples of approaches to this practical work (but there are alternatives).

Approaches to this work should include:

- Use of a range of cultivation techniques (these can follow on from those used for P5)
- Use at least two types of microorganism if carrying on from P5
- Use a range of counting or measuring techniques which could include/be selected from:
    - measuring clear zones
    - viable counts
    - use of a haemocytometer
    - colorimetry

  - viral plaque assay
  - and also use serial dilutions (alternatively, serial dilutions can be used in a separate activity such as the haemocytometer based investigation)
- Standard procedures, RAs (centre issued)
- Observation records, evidence for completion of all 3 practicals including aseptic technique
- Recorded results, images, photographic evidence.

Portfolio evidence was again variable across a range of centres and some was particularly difficult to follow and had omissions. Learners need sufficient direction to ensure all the evidence required for award of the various marking criteria is present. Issues that arose include the following:

- Some results were absent or incomplete
- Insufficient range of values of factors investigated for M5, leading to poor explanations and conclusions in D3
- Graphs were produced based on minimal evidence
- Some results were identical across all learners, indicating group work, but there was no indication of individual contribution*.

* The Observation Record should record any use of group or pair work and the individual's contribution. Centres should note that the signatures on the USF confirm independent work.

P7, M6, D4
P7 requires the use of one suitable technique to count/measure microorganisms.

This was most commonly a haemocytometer and some good approaches and results were evident. There were some well-considered explanations of the use of haemocytometers in a small number of centres, with fully explained subsequent calculations.

However:
- Success rates varied with the learner's levels of understanding
- Explanations of the technique were sometimes very difficult to follow and had omissions
- Diagrammatic support was sometimes weak or absent or not applied well
- Calculations were not explained in full and did not show understanding.

Viable counts were also a popular choice of technique and worked well for a number of centres.

It is important that centres realise that measurement of clear zones is not a technique suitable for the award of P7 (measuring micro-organisms).

In addition to, and in combination with, serial dilutions, the following techniques may be used:

- Viable counts on plates (relatively common)
- Haemocytometer (direct counts) (a common approach)
- Colorimetry (to measure turbidity and so an indirect count) (rarely seen)

- Measurement of clear zones (common, suitable for M5, D3 but not P7)
- Viral plaque assay (rarely seen).

M6: Explanations of the technique used were often not sufficiently detailed, as indicated above, and were based on incomplete understanding of the processes involved. For counts of colonies, it would be appropriate to record all 'raw' data, rather than just state the number of live cells. P102 of the Specification indicates that the total count should include viable and non viable cells.

D4: (Evaluation of measuring and counting techniques and suggestions for improvement)

As with previous years, this was often left by learners until all the required elements of PO3 had been completed, and this included serial dilutions (P8) and calculations relating to the original sample (M7): this is entirely acceptable.

P8, M7
The evidence for P8 includes the SP for the serial dilution and any associated data. The Observation Record should confirm correct use of the SP and safe working.

PO4: Identify the use of microorganisms in biotechnological industries

PO4 requires independent learner research, suitably referenced, and (very importantly) targeting the relevant sections of the Unit Content and the PO grid. This appeared to be a weaker area for learners in a wide cross-section of centres, despite some promising earlier content for PO1, 2, 3.

The rather weak content seen in some portfolios, appeared to arise for a variety of reasons including:

- Time constraints
- Insufficient / incomplete research
- Lack of understanding of the specific requirements of the marking criteria
- Lack of appreciation of the relevant Unit Content for PO4.

P9, M8, D5
P9
Good responses to P9 included the following:

- descriptions of the main features of both batch and continuous processes
- both processes are related to biotechnological industries
- suitable diagrams and examples
- reference to the scientific basis of the processes to support the descriptions.

M8
This requires explanations of the benefits of industrial fermenters or bioreactors.
Again, suitable examples to exemplify the purpose and nature of the fermenters or bioreactors enable the benefits to be more easily highlighted and explained.

Typical benefits to be discussed might include:

- Scale
- Rates
- Costs including energy use.

These can be linked to examples taken from a range of industries (see Unit Content p97).

M8 then leads into D5 where the emphasis is on the comparison of two specific industrial processes or techniques. At Distinction level, the two selected processes should be researched in detail, and similarities and differences discussed. It is very important that the microorganisms used in these two processes should be identified and the part played in each case described (this was a weak area for many, despite being very straightforward)

P10, M9, D6

For P10, <u>two</u> different industries should be chosen from those listed in the Unit Content.

- Food production
- Environmental health
- Pharmaceuticals
- Forensic science
- Agriculture
- Alternative energies
- Waste water treatment.

Learners select <u>two</u> industries, research them in some detail, concentrating on:

- Naming the micro-organisms used in each case
- Describing the relevant industrial processes and techniques in each case.

This leads on directly to the content expected for M9.

For M9, the same industries and micro-organisms as identified in P10 are considered further.

For each of the two industries, good portfolios will have already named the micro-organisms and, if not already present in some detail, will consider the processes in full and the outcomes or products formed. The reasons why these processes benefit society can then be explained in detail. Weaker content would be too brief and not explain benefits in detail or at the levels expected for Merit.

D6 can be based on a different biotechnological industry from those used in P10 and M9, but it does have to use micro-organisms and genetic engineering, as stated in the marking criteria.

Some key points are:

- An evaluation is needed, not just a simple statement of the process
- The biotechnological industry must clearly identified
- The background of the process and the product/outcomes are described

- The roles played by genetic engineering and the micro-organism are described
- Pros, cons, advantages, disadvantages are considered, as are legal restrictions, public opinion and possible misconception.

Overall, ASC6a had a wide range of approaches and portfolio content.

Some excellent portfolios were again seen in 2022, with suitable high-level practical work which was not only complete but also logically ordered and presented. This followed through to the inclusion of good supporting evidence, data, images, etc for all experiments. High scores also reflected a consistent approach across all four POs and good levels of knowledge of the required content and approaches.

In the case of weaker scores, it was not always apparent whether all the required practical work had been completed, as the evidence of outcomes was limited or absent. In some cases, the experimental work may have been completed, but no results could be found. The levels of organisation of the portfolio and sequencing of content also tended to impact on the available credit. Weaker portfolios also demonstrated weaker research skills, content which was sometimes close to source, sometimes incomplete, and a general lack of understanding of the levels of content expected by the unit content and PO grid.

ASC6b

General

ASC6b was a popular choice of unit and some excellent portfolios were seen. As with previous series, the number of centres misinterpreting the Unit's practical requirements relating to radioactivity is diminishing, although there remain some instances where the Unit Content requirements were not fully understood.

Higher scoring portfolios were again based on extensive research of the medical applications of imaging, radiotherapy, tracers, optical fibres and lasers, coupled with a sound understanding of the underlying physics. The best work was supported by an appropriate range of:

- images
- graphs
- data
- decay equations
- mathematical relationships.

The ability to provide, explain, use equations, and apply quantitative support for the background theory also typified high scoring Distinction level portfolios.

PO1: Understand imaging techniques

P1, M1, D1
Key points:

- P1, M1, D1 are linked via the underlying theory behind imaging methods and are sequential
- ultrasound and X-rays were the most common choices for the imaging techniques
- other techniques listed in the Specification (p107) are acceptable
- diagrams that fully illustrate the apparatus used are used for both the techniques chosen
- typical images are included and described.

In the portfolios submitted, most learners achieved P1 via descriptions of the underlying theory behind two imaging methods. However, the weaker portfolios did not go on to provide good links between the theory and the way in which images are formed for M1. Suitable examples and appropriate images will always add to the descriptions.

D1 requires calculations to be performed. Relevant content includes:

- the use of $v = f\lambda$ to calculate and then compare properties of relevant wave forms
- using $E = hf$ to determine and compare photon energies
- the calculation of reflection coefficient between two media (and its implications).

Just quoting relevant equations without applying them or using them to generate quantitative support for the theory will not achieve D1.

P2, M2

P2 and M2 may follow on directly from P1, although it is acceptable to select different imaging techniques, one suitable and one unsuitable, for this section.

The content required includes the following information as a basis for discussion and explanation:

- the selected condition is described, including its nature and site in the body
- a suitable technique is identified
- an unsuitable technique is identified
- a comparison of the quality of the images for the two techniques
- potential dangers to the patient of the unsuitable technique
- lack of dangers for the suitable technique.

This criterion is another where suitable images, well explained, enhance the portfolio evidence.

PO2: Understand radiotherapy techniques and the use of radioactive tracers

P3, M3, D2

These three performance criteria are linked and sequential. If P3 is not met, M3 and D2 cannot be awarded, although this is likely to be the case anyway if the basic descriptions for P3 are not all present.

Typical successful approaches include the following:

P3:

- a sensible/suitable choice of two radiotherapy techniques (see Specification p108)
- one technique is implant based and one involves external therapy
- good levels of research are evident and lead to descriptions of the two techniques
- the disease linked with each technique is clearly stated
- diagrams are included and are used to enhance the descriptions of the techniques.

For P3, diagrams are specifically mentioned in the performance descriptor and whilst most portfolios tended to include diagrams, their links to descriptions of the techniques were not well made. Often, in weaker portfolios, the diagrams were not referred to nor used to enhance understanding.

M3 goes on to explain how each technique is used and should include for each radiotherapy technique:

- how the technique is used to treat the relevant specified disease
- how each chosen therapy is administered.

D2 then explains, compares and contrasts the invasive nature of the two therapies chosen.

P4, M4, D3

Again, it is important for learners to understand that these criteria are associated with each other and are sequential. Good portfolios often tended to deal with P4 and M4 together, identifying each property of the selected radio-isotope sequentially and explaining the importance of that property.

P4 and M4
For the isotope selected, good portfolios included:

- Name, symbol, mass number, atomic number
- Type of decay/radiation emitted
- Half life
- Technique used
- Medical context.

And for M4:
- Decay equation
- Part played by and the importance of the type of radiation emitted
- Half-life explained in the context of importance in radiotherapy
- Physical half-life and biological half-life explained.

And for D3, quantitative support (calculations) for the explanations:
- Time taken for activity to fall to a level unsuitable for further use
- Calculation of effective half life
- Photon energy.

P5, M5, D4
These criteria relate specifically to the use of radioisotopes as tracers.

Good portfolios were typified by:
- Extensive levels of research and a wide ranging consideration of types of tracer
- Examples of tracers and links to illnesses or conditions identified
- Good support from suitable images
- Consideration of P5 and M5 together for the range of examples selected. This worked very well and avoided rather disjointed reports which sometimes typified lower scoring examples.

P5:
- Outline of how tracers are used and associated medical contexts
- A suitable range of examples (radioisotopes identified, common applications outlined)
- Outline of organ affinity, need for short half life
- Type of radiation emitted and detection.

M5:
- Identify two isotopes used as tracers
- Describe the medical contexts in which they are used, purpose, type of illness, location in the body
- Identify properties, decay equations, half-lives, organ affinity

- Link properties to reasons why they are suitable for the use described.

D4 requires detailed research and <u>both</u> isotopes identified for M5 must be considered.

- Graphical data should include decay curves
- Determination or demonstration of half-life
- Values for physical half-life and biological half-life researched and evaluated via calculations of effective half-life.

P6, M6

These two marking criteria are a good example of where a detailed knowledge and understanding of the Unit Content is essential (see Specification p108). This then has to be backed up by detailed research. Some good examples of this were seen, although it was clear from some submissions that learners had not always been prepared well in this respect.

Relevant content in high scoring portfolios included:

- Consideration of the dangers of radioactivity, comparison of alpha, beta, gamma
- Precautions taken for **<u>both</u>** medical professionals and patients
- Scientific principles behind the precautions taken
- The effects of ionising radiation including:
    - The meaning of stochastic and non-stochastic
    - The meaning of somatic and heredity.

PO3: Demonstrate the ability to work with radioisotopes in the laboratory

P7, M7, D5

A small number of centres approached this unit without the means to carry out the determination of half-life. An alternative which covers the same principles in terms of the use of data, is to perform experiments on half value thickness (eg for Co-60). This has the advantage of also allowing coverage of the various required practical elements.

PO3 entitled "Demonstrate the ability to work with radioisotopes in the laboratory" and the following points would all be part of the experimental approach, and, importantly, confirmed on the Observation Record:

- safe working
- following procedures involving correct handling of radioisotopes
- correct precautions taken to ensure safety
- use of a Geiger counter
- measuring background radiation.

This evidence can be obtained via practical activities including:

- A full protactinium half-life determination or a HVT determination for instance for Co – 60
- A comparison of the penetration properties of alpha, beta, gamma radiation (Specification p109).

It is also worth noting that:

- Just using a simulation does not provide all the evidence required for P7
- Evidence for penetration for alpha, beta, gamma radiation is also required as part of M7
- If the full protactinium half-life determination or HVT are carried out, then these other experiments into penetration can, as the Assessment Amplification suggests p112, be done as a group, tutor demonstration or online.

M7 requires the results of the experiments to be related to the use of radioisotopes in medical treatments (radiotherapy and tracers).

This will include:
The importance of half-life (physical, biological, effective)

- Comparison of half-lives for a range of different radioisotopes and applications
- The importance of penetrating power and its effect on uses of different isotopes.

D5 involves a summary of advantages and disadvantages of using alpha, beta and gamma radioisotopes in medical treatments. Some very good comparisons were seen, with some selecting a tabulated presentation which often worked well and was very comprehensive and detailed.

PO4: Understand the medical uses of optical fibres and lasers

P8, M8
P8 was met by most learners and requires descriptions of how optical fibres are constructed and how they transmit light. This was generally well researched and descriptions and explanations appropriate. The inclusion of relevant diagrams and images, with appropriate reference made to them, always enhances the descriptions.

M8, similarly, was often well done, but there was a significant number whose reports were weaker as they tended to just state uses and not go on to explain how the optical fibres are actually used in treatments. Both diagnosis and treatment should be considered and a range of examples included. As with many criteria, clear references to supporting diagrams and images enhance the content.

P9
This experiment was generally very well done by learners.

Centres should remind learners that the following are also needed:

- Recorded results
- Evidence of correct tabulation, precision of recording and units
- Ray diagrams
- Clear and correct use of results, diagrams, calculations.

P10, M9, D6

P10
This is straightforward:

- Identify two medical conditions where laser light is used in treatment

- Do not include purely cosmetic uses as these are not acceptable.

M9 (NB: M9 will not be available if P10 is not met)

A full report will:
- cover both medical conditions from P10
- explain the nature of the conditions to be treated
- explain how the treatment is administered
- explain the scientific principles behind the treatment including the role played by the laser light in each treatment.

D6
A different medical condition (from those used in P10 and M9) can be identified for D6, but it does have to be medical, not cosmetic, as mentioned above.

- A careful choice is essential as the medical condition chosen must be able to be treated in two ways, one via laser, one not
- Both advantages and disadvantages of each treatment need to be considered for the specified condition.

Cataract surgery was a common choice, but there are others which fit the criteria equally well.

ASC6c

General

ASC6c is designed to introduce learners to preparative organic chemistry and its importance in a range of applied contexts. The importance of yield, rates and purity of compounds resulting from organic synthesis is expected to be understood, and this is alongside their characterisation using spectroscopic techniques. The 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 such as a "revision guide", posters, PowerPoint slides or similar formats. The important point is that these reports fully represent the unit content, but contain primarily just factual content and suitable examples: ie a source of reference or "aide memoir".

For PO1, the presentation issues previously reported have largely been rectified. However, suitable coverage of all the expected areas relating to spectroscopic techniques, structure, bonding and isomerism remain an issue for some. Centres should ensure that learners are all aware of the unit content, and that they organise their work accordingly.

As mentioned in previous reports, learners' ability to research and use (incorporate) relevant material, images, structures, formulae and data varied considerably. ICT skills are still an issue, and they did unexpectedly let some learners down in terms of both content and also presentation.

The choice of preparations is the centre's, and 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 m.pt and a b.pt.

The two practical preparations were completed well by most learners, but purification stages were sometimes more challenging.

As previously reported, most work seen in portfolios was word processed and many learners are now able to incorporate diagrams, formulae, equations, and structures into their work. However, there is a small minority who are reluctant to source diagrams that show correct structures of molecules, and/or employ hand drawn versions which are often inaccurate and poorly or incorrectly drawn.

For diagrams of apparatus and equipment, images from the Internet (properly referenced) remain the obvious way forward, and spectra, similarly, will be downloaded.

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, and, in many ways, their inclusion is an indication of a weak approach to the Unit and lack of knowledge. This follows through to types of bonding in some cases.

There were some very good attempts at P1 seen, but also a small number of others with omissions

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 as has been reported in the past.

It is important that all three techniques – IR, NMR, MS – are considered and at similar levels of detail. The basic research needed for P2 leads to an outline of each of the three techniques and a (researched) spectrum for a named compound that illustrates typical "output". This then leads into M1 where descriptions of how spectra are obtained are needed, followed by an outline of the associated scientific principles.

Good portfolios demonstrated content relating to the following:

- Diagram of the basic construction of each spectrometer with suitable annotation/labelling
- Explanation of the type of sample used and how each 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.

P3, M2, D2
P3 was often met, but very weakly in a significant number of cases. It is important that learners realise that the choice of "group of compounds" is very important and that the <u>group selected for P3 should allow access to M2 and D2</u>. Alkanes, for instance, could not be used in M2.

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 <u>not</u> a functional group as uses would not necessarily 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 <u>two</u> of the group to be chosen from P3, 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 and this is understood)
- 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, and this was not always the case.
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.

Learners did not always target the required content well, and included too few examples of isomers, gave incorrect structures, and, in some cases, included 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, positional 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 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
Good portfolios sometimes 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 good 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.

Good 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
In terms of assessment, D3 can follow on from either P4, M3 or P5, M4.
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 was unfortunately mis-read in some centres and 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 of the five cases
- Equations are provided for each of the five reactions
- Changes that occur to the functional groups are explained.

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 researched and completed well by some learners, but why others only completed some of the requirements is not understood. 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. To a large extent, P7 and M6 are based on learner research, but lab based teacher demonstrations would help learners understanding of the processes involved.

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. However, some learners had not learnt lessons from ASC2 and its subsequent feedback, and some still do not fully understand the difference between hazard and risk.

Making CLEAPSS hazcards available to learners could help. Asking students to consider the following would be sufficient if completed accurately:

- 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 for learners in a school laboratory setting. Areas to consider include:

- Availability of reactants
- Timescale for the experiment, rate of reaction, use of catalysts, elevated temperature
- Yield, equilibrium
- Purification procedures/purity of the product.

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 reaction 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).

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 the idea that learners understand that most reactions have a yield <<100% is important and should be clear in the portfolio. They can then go on to explain that 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 <u>one</u> of the compounds made.

Characterisation here means "identification" of the compound based on the spectrum in the first instance, followed by a consideration of purity, again based on the spectrum (and where extra peaks might be seen if purity is low).

It follows that the spectrum has to be described in terms of the main "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) or:
- Assigning major peaks in the mass spectrum to structural features of the compound or:
- 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 in all portfolios.

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.).

Note: these do not have to be repeated in a separate section.

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.

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, based on excellent research and a thorough understanding of the assessment criteria.

The theory and the practical work will have been new to most learners. However, many rose to the challenge and, with extensive research, some high level practical work and appropriate support from the centre, a good proportion of high marks was in evidence.

Mark Ranges and Award of Grades

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