Advanced Higher Chemistry Investigation Guidance

Please note that this document is subdivided into two sections.

Make sure you read both parts carefully.

Section A – This should be read before you start your Investigation and consulted regularly as you carry out your Investigation.

Section B – This must be consulted as you write up your Investigation Report.

Section A

(a) Introduction

The Investigation is a piece of individual research undertaken to prove that you can

- research a chemistry topic by looking up textbooks, journals and using the worldwide web
- design and plan experiments
- carry out experiments safely and accurately
- evaluate procedures and results
- write a scientific report.

(b) Assessment

Your Investigation will be assessed both **externally** and **internally**.
The external assessment will be covered in Section B of this document.

Internal assessment
The Investigation is treated as a Unit of the course and as such, is internally assessed using a NAB which must be passed otherwise you will not be entitled to get the Course Award. The NAB has two Outcomes and each outcome has three performance criteria which you must pass.

Outcome 1: Develop a plan for an investigation
Performance criteria:
(a) A record is maintained in a regular manner.
(b) The aims of the investigation are clearly stated.
(c) Experimental procedures and apparatus are appropriate for the investigation.

Outcome 2: Collect and analyse information obtained from the investigation
Performance criteria:
(a) The collection of the experimental information is carried out with due accuracy.
(b) Relevant measurements and observations are recorded in an appropriate format.
(c) Recorded experimental information is analysed and presented in an appropriate format.

Before you start your Investigation and during the time you spend on your Investigation you must keep a record of work, commonly known as the "Daybook". You may be asked to submit your Daybook to the SQA in order to provide satisfactory evidence of your achieving the above Outcomes and Performance Criteria. **It is important that you get your supervisor to check your Daybook regularly and to take his/her advice.**

Your Daybook should contain

- a copy of the above Outcomes and Performance Criteria
- the aims of your Investigation. These may change during the Investigation and the changes and reasons should be recorded in your Daybook.
- a plan of the experiments you intend to undertake including the purpose of each experiment and a list of every piece of apparatus used in each experiment. The methods you select may not fit your proposed Investigation perfectly so make sure you note down any modifications and amendments.
- the theories behind the methods you have chosen as well as explanations of how these methods work. You need to consider how these meet the aims of your Investigation. You should include equations for any reactions as well as risk assessments for what you intend to do.
- a day to day plan listing the chemicals and apparatus required and used each day (showing both the quantity and concentration of solutions etc) with step-by-step procedures written in enough detail so that you can use this to write your final Investigation report. **Every day you are in the lab working on your Investigation you should note the date, what you did, any observations – expected and unexpected, any advice given and any websites, book references you used. References should be written in standard form as given at the end of this document.**
- some comments, advice etc written in by your supervisor as appropriate.

(c) Timescale

Right at the start of your Investigation, it is advisable to set up a **timescale** with start dates and deadlines for each phase of your Investigation, eg

Phase	Start Date	Tasks	Deadline Dates
Planning		Read this guide.	
		Decide on which Investigation you are to carry out.	
		Show supervisor your daybook with aims and outline of experiments you intend to carry out.	
		Prepare a risk assessment for these experiments and show your supervisor the completed Risk Assessment form.	
		Check and organise that the apparatus and chemicals will be available for you whenever you need them.	
Practical		Complete the experimental work in the time allocated. Allow time to carry out duplicates.	
Report		Hand in First Draft.	
		Hand in Final Report.	

Some advice on Practical work:

Practical work almost always takes longer than you anticipate. You should plan each day's work in advance and organise that all the equipment and chemicals you need are available for you.

Before each lab session

- You should have a clear plan written in your Daybook of exactly what you hope to achieve during the lab period.

During each lab session

The Daybook should be brought to every lab session

- You should enter the date in your Daybook, followed by **all** measurements and observations you make presented in an appropriate format. Your Daybook must contain a complete record of the work undertaken during each session in the lab.
- If you are uncertain about any procedure, ask a member of staff before continuing.
- It may be appropriate to briefly acknowledge help given by your supervisor (or other persons) in your Daybook at the relevant place.

After each lab session

In your Daybook

- you should analyse the results obtained during the lab session
- note down any conclusions or findings
- note down what you will do in your next practical session. This may be repeating what you have already done or making modifications as a result of what you have found out.

Remember what you write in your Daybook will be the basis of your Investigation report. It is important that you write your results etc into your Daybook in such a manner that you will find it easy to follow and understand when you write your report.

Section B - Writing the Investigation Report

External assessment

For external assessment purposes, you are required to write and submit a Report on your Investigation to SQA. A total of 25 marks (20% of the total marks) are allocated to the Investigation Report. Following the guidelines in this document should allow you to score a high mark in this part of the course.

The Investigation Report **must** have a logical structure and **must** include the following:

- **Title page**
- **Contents page**
- **Summary/Abstract which must include the aims stated clearly and the main findings**
- **Underlying chemistry**
- **Experimental Procedures**
- **Results**
- **Conclusion(s)**
- **Evaluation**
- **References**

All the pages must be numbered throughout the report.

The Report must be clear and concise and should be easy to read and understand. It should be written in the past tense and the passive voice used. This is particularly important in the Experimental Procedures section.

The Report should be about 2000 – 2500 words in length, excluding graphs, tables etc.

Note that a **hypothesis is not required** and **should not** be included in your report.

A total of 25 marks are awarded for the Investigation Report and these marks are broken down into the following categories.

1 Presentation (3 marks)
2 Underlying chemistry (4 marks)
3 Experimental procedures (6 marks)
4 Results (5 marks)
5 Conclusion(s) (2 marks)
6 Evaluation (5 marks)

These categories are expanded on below and also on the final page of this document.

Title page

The title page should include an appropriate title for the Investigation, your name and candidate number and the name and number of the centre you attend.

Contents page

The contents page must list the sections within the Investigation along with their corresponding page numbers. It is **essential** that all pages throughout the Report are numbered.

Summary (or Abstract)

The Summary must contain a clear statement of the main aims(s) **and** overall finding(s)/ conclusion(s) of the Investigation. The Summary must be brief and **must immediately follow the contents page**. If the aim of your Investigation is to determine the actual quantity/mass of a substance then the main findings **must** include the **values** obtained, eg if the mass of vitamin C in a fruit or fruit juice, or the acidity in wines is to be determined, then the values **must** be stated in the main findings **and** in the conclusions later on in your report.

Underlying Chemistry

This section must include a concise account of the **chemical theory** underlying the **experimental procedures** used in your Investigation. **Diagrams, structural formulae, balanced chemical equations**, etc must be included as appropriate. This part is worth 4 marks and you should try to include relevant theory from work done at Higher or Advanced Higher here.

Examples include:
Your Investigation may involve the extraction of a substance using an organic solvent and a separating funnel. It may be appropriate to discuss partition coefficients here.
or
Your investigation may involve titrations and it may be appropriate to discuss choice of indicator here taking into account the pH ranges of different acid/base indicators.
or
Your investigation may involve experimental techniques such as chromatography or colorimetry and it would be appropriate to discuss the chemical theory behind these techniques here.

It is best to do this section in your own words to show that you understand the chemistry involved.
Downloading directly from the internet or copying directly from books may suggest to the marker that you have not understood the chemistry involved and may be considered as plagiarism. It is always best to put things into your own words.

Experimental Procedures

This section must contain an account of the experimental procedures carried out in your Investigation. The procedures must be clearly described and in sufficient detail to allow someone else to repeat the Investigation without reference to any other source.

It would be appropriate in this section to include labelled diagrams or labelled photographs of assembled apparatus.

In this section, you should explain what you did and you may wish to address such issues as

- any modifications you have made to a procedure in the light of your experience as you did the experiments. For example, you may have had to dilute a solution to get better titration results. In this and in similar situations you should give the original raw results, where, practicable as well as the results after the modification. It will not count as a modification if you are carrying out the procedure wrongly to begin with and the modification involves carrying out the procedure the way it should have been done to begin with. For example, measuring out a volume for titration using a measuring cylinder then changing to using a pipette when you should have been using a pipette to begin with.
- the need for controls. For example you may have made up a solution of known concentration to check the accuracy of one or more techniques.
- duplicating each experiment to improve the reliability of your results. While repeating titrations to get concordant results is good experimental practice, this does not count as doing an experiment in duplicate. However, if titrations are being carried out to determine a quantity of substance in an actual product, eg if the mass of vitamin C in fruit or fruit juice, or the acidity in a bottle of wine is to be determined, then you should start with **two samples** from the same fruit or fruit juice or bottle of wine so that you can carry out the procedures in duplicate.

In describing procedures, it is very helpful to list all the equipment and chemicals used to show that the correct equipment has been used to give measurements of appropriate accuracy. For example, in a quantitative dilution of a standard solution, a standard flask must be seen to have been used rather than say, a measuring cylinder.

In giving quantitative data, you must quote these values to the correct number of decimal places appropriate to the equipment used. For example, if you use a balance reading to two decimal places, then masses must be quoted to two decimal places, eg 5·00 g and not 5 g.

The experimental procedures should describe accurately **what was done** in each experiment but **must not be written as a set of instructions**.

The **procedures must be written in the past tense and the passive voice must be used**.
For example,

'25·0 cm^3 of 0.105 mol l^{-1} sodium hydroxide solution was pipetted into a conical flask'

but **not**

'Pipette 25·0 cm^3 of 0.105 mol l^{-1} sodium hydroxide solution into a conical flask'

nor

'I pipetted 25·0 cm^3 of 0.105 mol l^{-1} sodium hydroxide solution into a conical flask'.

Results

In the Results section, you must provide **all raw data** as well as processed or derived data. Raw data are the readings you actually record in the course of the Investigation. For example, in titrations, **the raw data are the initial and final burette readings not the titre volumes**. The titre volumes are processed data. Make sure you are reading the burette correctly. For each titration, the initial reading on the burette is likely to be a low value and the final volume will be a higher value and the titre volume is the difference between the two readings.

Likewise if you are using a weighing bottle when measuring out the mass of reactant, you should record all the masses. If you tare the balance to zero when weighing you should state this in your report so that the marker appreciates that you have done so and will not be looking for raw results but just the mass of reactant used.

Raw and processed data must be presented in a clear and concise manner with appropriate use of tables, graphs, diagrams and calculations.

Tables must have appropriate headings and units must be specified.

Graphs must be supported with tables of raw and/or processed data, ie a graph on its own is not sufficient – the data from which it has been derived must also be presented.
When drawing a graph, you must ensure that

- scales are chosen so that the plotted points are widely spread
- each axis is labelled with the name of the quantity and the correct unit
- data are plotted accurately
- a best-fit straight line or curve is drawn – not 'join the dots'.

Where Excel or other software packages are used to present graphs, it is important that axes are adapted to suit the data in order that the results are presented in the most appropriate way.

Calculations must be clearly structured. Where the same type of calculation is repeated for different raw data, then only one sample calculation need be set out in detail, but the raw data must always be given. When calculating gram formula masses of compounds you should check the correct formula of the substance to see if it contains molecules of water of crystallisation. For example, anhydrous $CuSO_4$ has a different gram formula mass compared to $CuSO_4.5H_2O$ and you must be aware of the correct formula of the compound used.

Raw data may also include melting point data, chromatograms or diagrams or photographs of chromatograms. In chromatography the distances travelled by the spots would be raw data but the calculated R_f values would be processed results.

You must also take care with significant figures in presenting and processing data. In calculations, for example, it is appropriate that intermediate results carry one or two extra digits beyond the last significant one, but the raw data and final results must be quoted with the correct number of significant figures. For example, an initial burette reading must be quoted as 0·0 cm^3 or 3·0 cm^3 rather than 0 cm^3 or 3 cm^3.

The number of significant figures in the final calculated result depends on the apparatus used and the accuracy of the measurements taken. This is usually the same as the lowest number of significant figures in any measurement used to determine the final result. It should be noted that the number of significant figures is not the same as the number of figures after the decimal point. For example, the value 20.6 has 3 significant figures as has 1.40×10^{-5} but 0.06 and 1×10^{-5} have only one significant figure.

Observations, eg indicator colour changes, precipitates forming, gases forming, colours of solutions or precipitates, shapes and colours of crystals formed etc, must be recorded.

If you have prepared a solid or liquid product as part of your Investigation it would be a good idea to calculate the theoretical yield had there been 100 % conversion of the reactant(s). The percentage yield can then be calculated.

Conclusion(s)

The conclusion(s) must be under a separate heading and must relate back to the aim(s) of the Investigation. There must be a conclusion for each aim. If the aim of your Investigation was to determine the actual quantity/mass of a substance then the conclusion **must** include the **values** obtained, eg if the aim of the Investigation was to determine or measure the saponification value of an oil or oils, then the saponification values you determined **must be given** in your conclusion.

You may wish to write a conclusion after each experiment but these conclusions must all be tied in together under the "Conclusion(s)" heading near the end of your report.
The conclusions must be based solely on the experimental results obtained and must be valid from these results.

Evaluation

The Evaluation must be under a separate heading at the end of your report after your Conclusions. You may wish to write an evaluation after each experiment but these must all be tied in together under the "Evaluation" heading at the end of your report.

In the **evaluation of the procedures** you should address such points as

- accuracy of measurements
- the main sources of error and how these were or could have been reduced
- how close the results of control experiments were to the known values
- precision of procedures ie how close were the results in duplicate experiments
- modifications made or could have been made to improve the procedures in your Investigation
- any procedures that were attempted but did not work

In the **evaluation of the results** you may

- discuss the differences between the calculated values from control experiments and known quantities used and estimate the error in your other experimental results based on these differences
- discuss what effect the errors you identified in the procedures and apparatus had on the final calculated results

- discuss how close your calculated results were to accepted values
- carry out uncertainty calculations to determine the error or percentage error in calculated results.

For example, if you have two concordant titration values, 20.10 cm^3 and 20.20 cm^3, the average of these concordant values is 20.15 cm^3. You will use 20.15 cm^3 in your calculation of the final processed result. However you may also use 20.10 and 20.20 to see by how much your final calculated processed result would differ had these values been used. This will give you some idea of the uncertainty in the final processed result.

References

A reference is any piece of material to which a writer 'refers' in the text. More specifically, it is an entry at the end of the Report giving information about the source of the material 'referred to'. Such an entry allows the reader of the Report to consult the original work if necessary and is also an acknowledgement of the work of other authors.

You are most likely to cite references in the Underlying Chemistry and in the Experimental Procedures sections of your Report since these are the sections in which you are most likely to refer to journals, books and websites. You would be expected to consult these before you start to get ideas and information and also during the experimental work.

In your Investigation Report there must be a minimum of three references and these must be correctly cited in the text and listed correctly at the end. In your Chemical Investigation the only acceptable method of citing and listing references is shown below. The acceptable method of referencing is:

Books
Listed at back of report as:
Author(s), (surname followed by initials) (Year of publication) *Title*, Publisher, Place of publication, Page number(s).
eg Aldridge, S (1998) *Magic Molecules: how drugs work*, Cambridge University Press, Cambridge, p134.

This should be cited in the text as:
(Aldridge, 1998)
For example, "Most drugs work by interfering with the way in which either an enzyme or a receptor functions (Aldridge, 1998).", **ie only the surname(s) of the author(s) and the year of publication in brackets, and nothing else.**

Journals/Periodicals
Listed at back of report as
Author(s), (which must be surname followed by initials) (Year of publication in brackets) Title of article, *Name of Journal*, **Volume number** (Part number if appropriate), Page number(s).
eg Brown, TM, Cooksey, CJ and Dronsfield, AT (2001) Indigo – forever in blue jeans, *Education in Chemistry*, **38**(3), pp69-71.

This should be cited in the text as:
(Brown, Cooksey and Dronsfield, 2001)
For example, "The reduced form of indigo is soluble and colourless while the oxidised form is insoluble and blue (Brown, Cooksey and Dronsfield, 2001)", **ie only the surname(s) of the author(s) and the year of publication in brackets, and nothing else.**

Websites
The full URL and the date you accessed the material must be listed at the back of the report.
eg
URL:http://www.pdrhealth.com/drug_info/nmdrugprofiles/nutsupdrugs/mal_0292.shtml, visited November 2013.
or
http://www.pdrhealth.com/drug_info/nmdrugprofiles/nutsupdrugs/mal_0292.shtml, visited November 2013.
or
www.pdrhealth.com/drug_info/nmdrugprofiles/nutsupdrugs/mal_0292.shtml, visited November 2013.
would be correct but
URL:http://www.pdrhealth.com, visited November 2013 **is not acceptable**

This must be cited in the text as:
(pdrhealth.com)
For example, "Malic acid, also known as apple acid, hydroxybutanedioic acid and hydroxysuccinic acid, is a chiral molecule (pdrhealth.com)", is correct **but (www.pdrhealth.com)** and **(http://www.pdrhealth.com)** would **not** be acceptable. Dates **must not** be cited in the text.

The URL and the date visited must be listed at the back of the report **but should not be cited in the text.** The date visited must be cited at the back for **each website reference** and must not be given as a blanket statement such as all websites visited November 2013.

Note that you must have at least three **different** references in your report. Different pages from the same book counts as **one** reference only. Similarly, if you refer to the same website several times, this too counts as **one** reference only. You should also be careful when using a website such as Wikipedia since the information it holds may not always be accurate.
Note that

- you **must not** submit the same Investigation for both Advanced Higher Chemistry and Advanced Higher Biology or Advanced Higher Physics
- joint Investigations are not permitted
- where possible, you **should avoid** doing the same Investigation as anyone else in your centre
- "new" Investigation titles are always welcomed by markers.

AH Chemistry Investigation – summary of assessment scheme and mark allocation for the Course report.

Assessment category and assessment criteria	Marks
Presentation (3 marks)	
• Title page/contents page/pages numbered/at least 3 references listed and cited correctly	1
• Summary/abstract including aims and overall findings clearly stated	1
• Clear and concise report	1
Underlying Chemistry (4 marks)	
• Background chemistry/formulae/equations/theory behind techniques etc	4,3,2,1,0
Experimental Procedure (6 marks)	
• The procedures are appropriate to the aim(s) of the Investigation	1
• The procedures are clearly described and in sufficient detail to allow the Investigation to be repeated	1
• The procedures are at an appropriate level of demand for AH Chemistry	1
• Two or more techniques/modifications in the light of experience/control experiments	1
• Experiments duplicated	1
• Accuracy of measurements	1
Results (5 marks)	
• Raw data are recorded	1
• Raw and processed results are within the limits of accuracy of measurement	1
• Appropriate use of tables/graphs/diagrams/sample calculations	2
• Observations	1
Conclusion(s) (2 marks)	
• Relate(s) to the aim(s) of the Investigation	1
• Valid from the results of the experiments	1
Evaluation (5 marks)	
• Evaluation of the procedures including such points as accuracy of measurement/repeated experiments/control experiments/sources of error/modifications	2
• Evaluation of results including such points as effects of errors on final results/ results of control experiments/accepted values/uncertainty calculations	2
• Overall quality of the Investigation	1
Total marks	**(25)**