# GCE EXAMINERS' REPORTS

## CHEMISTRY
### GCE
### AS/Advanced

## SUMMER 2023

**Introduction**

Our Principal examiners' reports offer valuable feedback on the recent assessment series. They are written by our Principal Examiners and Principal Moderators after the completion of marking and moderation, and detail how candidates have performed.

This report offers an overall summary of candidates' performance, including the assessment objectives/skills/topics/themes being tested, and highlights the characteristics of successful performance and where performance could be improved. It goes on to look in detail at each question/section of each unit, pinpointing aspects that proved challenging to some candidates and suggesting some reasons as to why that might be.[i]

The information found in this report can provide invaluable insight for practitioners to support their teaching and learning activity. We would also encourage practitioners to share this document – in its entirety or in part – with their learners to help with exam preparation, to understand how to avoid pitfalls and to add to their revision toolbox.

**Further support**

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| **Executive summary** | **Page** |
|---|---|

**Unit**

**Subject Officer's Executive Summary**

Candidate performance in this series was in line with what was expected. AS candidates found Unit 2 more challenging that Unit 1 and for A2 candidates the Unit 4 paper was the best answered.

Providing Advance Information for candidates made no difference to performance on the written papers but it was very helpful for leaners and centres in the case of the practical unit.

Weaknesses outlined below by the Principal Examiners are similar to those noted each year. Simple recall is often poor across all units and improved exam technique would benefit many candidates. It is noted that this year's A2 cohort had no experience of GCSE examinations due to the pandemic. Knowledge and understanding of practical methods also suggests a lack of hands-on experience of some key practical skills and techniques.

| Areas for improvement | Classroom resources | Brief description of resource |
|---|---|---|
| **Recall of key knowledge** | Resource WJEC Educational Resources Website | **Knowledge organisers** include key facts for all specification topics summarised in one/two page presentation |
| **Exam technique** | Resource WJEC Educational Resources Website | **Exam walk-through** presentations based on the summer 2019 papers; focus on key information given in questions, command words, approaches to answering particular types of questions and much more |

**CHEMISTRY**

**General Certificate of Education**

**Summer 2023**

**Advanced Subsidiary/Advanced**

**UNIT 1 – THE LANGUAGE OF CHEMISTRY, STRUCTURE OF MATTER AND SIMPLE REACTIONS**

## Overview of the Unit

This year candidates from year 13 sat the paper as well as year 12, consequently the number of entries was up from around 3100 to 3650. The mean mark was 29.5 – down 6.4 marks from last year and down 2.5 from the 2019 figure.

It was pleasing to note that good knowledge of electron configuration, balancing equations and oxidation numbers was shown by many candidates. Most candidates also showed a fair knowledge of radioactivity, ionic bonding and shapes of molecules. However, as noted in previous reports, the examiners were disappointed with the standard of many of the answers given, especially the QER question (Q7a). Too many marks are still lost for basic recall e.g. Q2 (solid structures), Q9(c)(i) (Le Chatelier's principle), Q10(c) (metallic bonding). Once again writing ionic equations proved to be demanding for most candidates with Q11(a)(v) being extremely poorly answered. This year the redox question (Q7(b)(ii) was also poorly answered.

A significant number of candidates performed well in some familiar calculation questions e.g. Q6 (atom economy), Q9(b)(i) (moles), Q9(d) (pH). However, calculations that were slightly different were poorly answered e.g. Q8(b) ($pV = nRT$), Q10(e) (% isotopic abundance), Q11(a)(vi) (titration calculation). This shows that candidates' understanding of numerical concepts is still lacking in depth. Many also have difficulty in converting from one unit of measurement to another and rearranging the subject of a formula.

As with previous series, this paper tested candidates' knowledge and understanding of practical work including the ability to refine practical procedures. This paper had a range of practical procedures, some of which proved to be unfamiliar to most candidates e.g. Q11(a)(iii) (diluting solutions), Q11(b)(i) (gravimetric analysis). Practical work is a very important aspect of chemistry, but it seems that during the past few years candidates' experience has been limited. As a result their understanding of basic practical procedures has suffered.

## Comments on individual questions/sections

## SECTION A

This section was fairly well answered, with the mean mark being around 5.5 out of 10.

Questions 3, 5 and 6 were well answered. Although the other questions involved simple recall, questions 1, 2 and 4(a) were only fairly well answered and question 4(b) was poorly answered.

In Q1 just over half the candidates gained both marks. The main error was to give the incorrect number of lone pairs.

In Q2 around half knew that calcium's bonding was metallic, but only a very small percentage stated that solid iodine contains both covalent bonding and van der Waals forces.

While around a half knew that the arrow had to go up from n=1 to n=$\infty$ in Q4(a), only about one in five knew that the arrow went from n=3 to n=2 in Q4(b). The most common error in Q4(a) was to draw the arrow pointing downwards. In Q4(b) the commonest errors were to draw a line from n=2 to n=1 or from n=$\infty$ to n=2.

**SECTION B**

Feedback on this section refers to the following themes

- important concepts (ionisation energy, bonding/solid structures and equilibrium)
- mathematical skills
- practical methods

**Ionisation energy**
This was tested in Q8(c) and all three parts were poorly answered. Although details about first ionisation energies are usually well known, details about successive ionisation energies are not. Many candidates failed to gain a mark with only around 1 in 5 scoring a mark in part (i) and 1 in 4 in both sections of part (ii).

In part (i) a number of candidates got confused between the variation in first ionisation energies across a period and successive ionisation energies. Another common error was to think that the electrons were removed from the inner shell first.

In many cases in part (ii) the marks were lost for an inability to express ideas clearly, rather than a lack of knowledge. In part I, many simply stated that 'the outer electron is closer to the nucleus' without giving a reason. In part II, most stated that 'the $4^{th}$/$12^{th}$ electron is removed from a new shell' without adding 'nearer to the nucleus'. Candidates who said 'extra stability due to a full outer shell of electrons' gained no credit.

**Bonding/solid structures**
As expected, a whole range of answers was seen in the QER question (Q7(a)) about intermolecular bonding. Only a small minority of candidates obtained a higher band mark with around half scoring in the lower band. A significant minority did not attempt the question.

Candidates scoring in the higher band covered most of the indicative content with no incorrect chemistry. For these candidates, the main weakness was not comparing Group 4 and Group 7 hydrides.

Candidates scoring in the middle band gave partial answers for both groups or trends for both groups and an explanation for one. However, the answer often contained some incorrect chemistry. For these, the main error was not getting the trend for Group 7 hydrides correct.

Candidates scoring in the lower band often gave answers that were very confused. Sometimes they gave the trends for both groups or a trend and explanation for one. Other times they just gave a trend for one group or stated that HF was the anomaly, but often most of the answer was incorrect.

The dot and cross diagram in Q8(a) was a slightly more complex example and just over half the candidates gained both marks. Some lost a mark for giving incorrect charges on the ions, but a significant number showed covalent bonding rather than ionic bonding and so failed to gain a mark.

Q9(e) tested the candidates understanding of polar covalent compounds. Only around a third managed to score any marks. Most stated that it was not purely covalent because it formed a coordinate bond or it formed hydrogen bonds.

Q10(c) was about conducting electricity and although around three-quarters gained at least one mark, only around a quarter gained all three. Most candidates knew that metals conducted electricity due to delocalised electrons. A significant number also knew the conditions required for both metals and ionic bonds to conduct. Fewer knew that ions carried electricity in ionic compounds. The main errors highlighted both a poor use of terminology and misconceptions. Most thought that ionic compounds conducted due to free electrons. Some referred to van der Waals forces and molecules when discussing ionic bonding and others thought that metals did not conduct when molten.

**Equilibrium**

This was tested in Q9(c) and all parts were generally poorly answered although in many cases the marks were lost for an inability to express ideas clearly, rather than a lack of knowledge.

Part (i) was a simple recall of Le Chatelier's principle, yet only around half gave an appropriate answer. Many candidates failed to refer to the position of equilibrium shifting, simply stating that the 'system' shifted.

In part (ii) the first mark was for using information in the diagram and the second for applying the principle. Only around a quarter gained both marks. Many candidates did not use the diagram while others thought that ammonia was a product not a reactant and so lost the first mark. Many could not apply Le Chatelier's principle, giving answers that were too vague, such as 'backward reaction is endothermic so forward reaction is exothermic'. A few lost a mark for referring to the 'endothermic side' instead of the 'endothermic direction', but most lost a mark for not explaining why the endothermic direction was favoured by failing to refer to equilibrium.

In part (ii) the first mark was for drawing a curve on the diagram and the second for explaining the shape of the curve. Only around a third managed to gain both marks. More candidates gained the first mark. The main reason for losing this mark was to draw the curve finishing above or below the original curve. The main reason for losing the second mark was for only explaining why the curve was steeper and not why the same number of moles of ammonia were used. A typical answer was 'a catalyst reduces the activation energy and increasing the rate, so the curve is steeper'.

**Mathematical skills**

The question on pH (Q9(d)) was well answered and atom economy (Q6), empirical formula (Q7(c)), half-life (Q8(d)(ii)), using moles/mass/concentration (Q9(b)) were fairly well done. The main errors were multiplying by 0.78 in Q6, omitting the hydrogen in Q7(c), incorrectly converting from g to mg in Q8(d)(ii) and calculating the wrong $M_r$ in Q9(b).

Q8(b) using pV = nRT tested the candidates' abilities to change the subject of a formula and to convert from one unit to another. Around two-fifths scored all four marks but around a similar number failed to score any marks. As expected, the main error was a failure to convert $m^3$ to $cm^3$ but surprisingly converting kPa to Pa proved challenging for a significant minority. Almost all candidates who attempted the calculation converted °C to K. A significant number lost marks for failing to rearrange the equation correctly.

In Q10(b) candidates had to use stoichiometry and molar volume and this proved difficult. Only around two-thirds gained at least 1 mark, with fewer than one in five gaining all 3 marks. Most candidates calculated the moles of barium nitrate but only a quarter of these used the equation correctly to calculate the total moles of gas formed. Some candidates forgot about the oxygen that formed, but most ignored the equation and assumed that the moles of gas were the same as the moles barium nitrate. A significant number used pV = nRT instead of molar volume and lost marks by using incorrect units.

In Q10(e) candidates had to use algebraic skills to calculate the percentage abundance of an isotope. The vast majority did not realise that if the percentage abundance of one isotope is x the percentage abundance of the other isotope must be 100 – x. Consequently, this was poorly answered and fewer than one in five scored any marks. Some gained the marks by using trial and error.

Q11(a)(vi) was a titration calculation and proved to be extremely challenging. There were four distinct steps, the answer had to be given to 3 sig figs and it was towards the end of the paper. Over half failed to score a mark with many candidates not attempting the question. Only around one in five scored 3 or 4 marks. There were many common errors:

- using 25.00 instead of 26.40 $cm^3$ as the titre
- not multiplying by 5 to get the moles of the undiluted sample
- not multiplying the moles by 40 to change to $dm^3$
- not multiplying by 35.5 to give the mass
- not giving the final answer to 3 significant figures

Although Q11(b)(ii) was a straightforward volumetric calculation only around 1 in 5 candidates scored all 3 marks and around 60% failed to score a mark. Again, many candidates did not answer the question. They may have run out of time. The main error seen was calculating the wrong $M_r$ of $BaSO_4$. Only a few failed to convert $dm^3$ to $cm^3$ for the volume.

**Practical methods**

Candidates need to be able to recall certain practical procedures and understand why certain steps are taken. Also, if a result is different to the expected or an aspect is changed, they should be able to give the reason for the difference or describe the effect of any change. Finally, they have to be able to refine these procedures if necessary. These skills were partly tested in Q10(a) but mainly in Q11.

In Q10(a) both parts (i) and (ii) were very poorly answered. The main improvements given in part (i) were 'do repeat readings' or 'make sure the mass of each carbonate is the same'. In part (ii) 'removal stops addition of more $CO_2$ to the limewater' was a popular incorrect answer. In part (iv), most candidates knew that using a second Bunsen burner does not increase the temperature.

Q11(a)(i) was easily the best answered in this section. Over two-thirds knew why the burette was rinsed with silver nitrate. The candidates who said ‘to react with any $Cl^-$ ions in the burette’ gained no credit since this would cause a precipitate and block the burette.

However, in part (ii), only a minority knew why the seawater was diluted. A number just stated that the concentration of the seawater not the chloride ions was too high. Others thought that this would increase the titre to give a better chance of seeing the colour change and/or reducing the percentage error.

Part (iii) proved to be one of the most demanding parts of the whole paper with just under three-quarters of candidates failing to score a mark. Most answers did not give any details of how the dilution took place. A typical answer was ‘dilute the seawater with 5 times the amount of water’. Some did identify appropriate apparatus to gain marks, but only a minority gave actual volumes to show that the seawater had been diluted by a factor of five.

Part (iv) was well answered. The vast majority of candidates knew what action needed to be taken and most could explain why. Some gave two actions without any explanation and so lost a mark.

Unfortunately, in part (b)(i) most candidates did not know what was meant by gravimetric analysis and consequently over two-thirds failed to score any marks. Many described a titration. Others referred to simply heating the mixture and allowing it to cool to form a precipitate, while a minority referred to using a mass spectrometer. For those who gave credible answers, the main errors were:

- not ensuring that the reaction was complete / adding an excess of barium nitrate
- not washing the precipitate
- not heating the precipitate to constant mass / subtracting mass of filter paper from final mass

## CHEMISTRY

## General Certificate of Education

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## Advanced Subsidiary/Advanced

## UNIT 2 – ENERGY, RATE AND CHEMISTRY OF CARBON COMPOUNDS

### Overview of the Unit

Based on available evidence from exam analysis and feedback from examiners, the paper proved to be accessible for most candidates, with all questions being attempted by most candidates.

Candidates had generally prepared well for the exam, although too many candidates still lacked the knowledge to answer basic recall questions. This is evident in Q3, Q5 and Q13(b)(i) which were done particularly poorly.

Candidates continue to perform well on the organic analysis question (Q11(a)), although the lack of an empirical formula calculation at the beginning seemed to confuse a significant number.

Finally, there were a number of candidates who did not take enough care to read the questions properly, leading to completely irrelevant answers to certain questions. This was well common in Q8, Q9(a)(ii) and Q 10(a)(v).

### Comments on individual questions/sections

### SECTION A

Q.1 This question was not well answered with a little over half of candidates gaining the mark. Most incorrect answers gave the incorrect number of hydrogen atoms.

Q.2 Approximately three-quarters of candidates answered this question correctly. The most common errors included missing oxygen from the reactants, missing water from the products and giving hydrogen as a product.

Q.3 Just under a quarter of candidates answered this question correctly. The most common error was nickel (which is a catalyst, not a reagent).

Q.4 Approximately three-quarters of candidates answered this question correctly. The most common error for this question was a diagram missing a double bond.

Q.5 This question was answered well with most candidates obtaining at least one mark and many gaining both. The most common error was the loss of the second mark by not indicating the position of the bromine atom or giving the incorrect isomer.

Q.6 More than half of all candidates gained the mark for this question. The most common incorrect answers were 160, 0.6, 100 and –100.

Q.7 Almost three-quarters of candidates answered this question correctly. The most common errors included omitting the Z and incorrectly naming this as the E isomer.

**SECTION B**

Q.8 It was clear that most candidates had some understanding of biofuels with many candidates obtaining at least 3 marks. Many identified these fuels as renewable and more ‘carbon-neutral’ and also showed an awareness of the disadvantages associated with using land to grow crops for biofuels. A minority of candidates were able to gain higher marks, usually by explaining how biofuels are not truly carbon-neutral due to factors such as transportation and energy needed for fermentation. A small minority gained no marks as they seemed to think that biofuels and fossil fuels were the same, indicating a fundamental misunderstanding of this topic.

Q.9 (a) (i) Changes in concentration and time had to be worked out here. No credit was awarded for an answer of 0.83 calculated from values read off where the tangent meets the curve. A few candidates who had no idea what to do.

(ii) Few candidates answered this question correctly as they omitted the fact that the rate of reaction was proportional to the concentration. Many misread the question and described the relationship shown on the graph (concentration against time).

(b) Over half of candidates were able to gain at least one mark in this question. This was almost always by measuring the change in colour over time (colorimetry). Many failed to gain the second mark as they did not describe measurements being taken over time.

(c) Many candidates answered this question correctly. Those who did not tried to use the numbers provided but clearly had no idea of the correct approach.

Q.10 (a) (i) Almost all candidates gained this mark. The most common incorrect answer was a measuring cylinder.

(ii) Few candidates gained the mark for this question. Many incorrectly talked about more energy being released or more collisions happening but with no explanation as to why.

(iii) Few candidates gained the marks for this question. The most common correct statement was that the acid has been fully neutralised.

(iv) Most candidates gained the mark for this question. Of those who did not, most either did not draw the lines long enough to intersect or drew the line on the left back to 0,20.

(v) Many candidates gained at least one mark for this question, with many of those gaining both marks. Of those who did not gain two marks most made the mistake of writing the maximum temperature instead of the temperature increase.

(vi) Approximately half of all candidates gained at least one mark for this question. The most common error was not adding the volumes of the two solutions to find the total volume of the solution being heated.

(vii) Almost all candidates obtained at least one mark on this question, with two marks being most common. There were several common mistakes made in this question including using 25 as the mass in the calculation of moles of methanoic acid, neglecting to divide the number of moles by 10 due to dilution and failing to convert joules to kilojoules.

(b) Many candidates obtained the mark for explaining the comparative strengths of the two acids. Very few candidates gained the mark for saying that more hydrogen ions are available in the stronger acid.

(c) (i) Most candidates scored 0 or 2 marks. Those who could write the correct formula for the salt and recall that water and carbon dioxide are formed could usually balance the equation and give state symbols. The most common error in writing the formula for copper(II) methanoate.

(ii) Almost all candidates obtained at least one mark on this question for reference to effervescence. Far fewer referred to the solid disappearing or a blue solution forming.

Q.11 (a) Most candidates gained between three and five marks by correctly analysing the data provided and identifying features of the unknown compound. Many gained six marks or more. A significant number of candidates correctly identified the compound but did not obtain all eight marks due to missing certain key points e.g. the conclusion drawn from the reaction with acidified potassium dichromate. Some candidates expected to have to work out an empirical formula as has often been required in previous similar questions.

(b) Less than a quarter of all candidates gained any marks for this question. Those who gained one mark did so for drawing three peaks. A minority of candidates were able to gain the second mark for correctly labelling each peak with the correct ratio of hydrogens in each environment.

Q.12 (a) (i) Most candidates gained one or two marks for this question. Those who gained two marks mostly omitted the first step of hydrolysis using aqueous sodium hydroxide.

(ii) Many candidates gained the first mark by identifying the halogen as chlorine. Around half of those gained the second mark by proving this using some kind of simple calculation.

(b) (i) This question differentiated well resulting in a mean mark of 2 out of 4. Approximately half of candidates gave a very good answer missing either the partial charges or the lone pair on the hydroxide ion. Those who did not know the details of the mechanism often gained a mark for the partial charges on 1-chloropropane or the correct products.

(ii) The majority of candidates answered this question correctly.

(c) (i) About one in three candidates gained this mark but a good number did not attempt it.

(ii) About one in six did not attempt this question and the mean mark was less than 1 out of 2. Many gave structures without a double bond. Some drew the E and Z isomers of the same alkene for which they scored only one mark.

**Question 13**

Q.13 (a) (i) This was quite well answered by many candidates and differentiated well. Many gained two or three marks. The most common error was not including a lone pair of electrons on the oxygen atoms.

(ii) This was a difficult question and fewer than one in 12 gave an answer which referred to interference with the formation of the ice lattice.

(b) (i) Around half of candidates answered this question correctly. Of those who did not get this mark, most omitted the acidic conditions or simply had no idea what the reagent was.

(ii) Few candidates gained any marks for this question. The most common mistake was the omission of water as a product of this reaction.

(iii) Most candidates gained at least one mark in this question. Common errors included drawing distillation instead of reflux, labelling water in and out the wrong way around (water should go in at the bottom of the condenser), blocking the top of the condenser with a bung or thermometer and omitting the jacket of water around the condenser.

(iv) Very few candidates obtained the mark for this question. Many gave a correct formula but did not include the positive charge.

(v) Many candidates gained one or two marks through simple moles calculations. Few gained more marks than this. A common error was to attempt to calculate the moles of ethanedioic acid using the mass of the hydrated ethanedioic acid.

(vi) I. Few candidates gained any marks from this question. Few correctly drew the structure of the ester and those that did often omitted water from the equation, neglected to balance the equation or only converted one of the two acid groups to an ester.

II. Many candidates answered this correctly with a significant number providing the correct answer despite being unable to draw the ester group in the previous part-question.

**CHEMISTRY**

**General Certificate of Education**

**Summer 2023**

**Advanced**

**UNIT 3 – PHYSICAL AND INORGANIC CHEMISTRY**

**Overview of the Unit**

Overall Unit 3 this year appeared slightly more accessible to candidates with the mean mark increasing by 5 marks since 2022. There was a balance of questions that were accessible to most or almost all candidates and those that were more challenging, with the number of challenging part-questions increasing later in the paper. Almost all candidates attempted every part question, with only a couple of part questions attempted by fewer than 95% of candidates. In general candidates performed better on short, factual questions and found longer questions which required linking ideas or calculations more challenging.

In the inorganic chemistry areas of work, candidates were able to recall physical and chemical properties well but found applying ideas of chemical analysis and tests more challenging. In the physical chemistry areas, candidates were often able to calculate values in familiar question types such as calculating an enthalpy change or the minimum temperature for a reaction. Where candidates had to combine calculations, such as volume of gas produced and pH, or make decisions on an appropriate calculation, such as in listing acids in order of strength, more struggled to reach a correct answer.

Practical methods are examined in all units of the A level course and in this unit these questions had some of the poorest answers.

**Comments on individual questions/sections**

**SECTION A**

Many questions in this section were answered well, with recall of factual knowledge such as in questions 1, 5, and 6 leading to correct answers for many candidates. The common errors in the other questions were as follows.

2. The question stated that silver chloride was insoluble, so it was disappointing to see some candidates coming to conclusions that indicated that it was soluble. Some combined the values in various ways but did not explain how the value obtained was linked to solubility. They wrote the value obtained and that 'therefore the silver chloride is insoluble' without indicating whether it was the sign or size of the value that showed this.

3. Weaker answers linked the colours seen with the incorrect ions. Some linked purple with potassium and others stated this was linked to an 'iodine ion' rather an 'iodide ion'.

4. Most understood the need for pairs of electrons and electron-deficiency to form a coordinate bond but weaker answers did not identify the location of the electron pair on chlorine, or identify it as a lone pair. It was common to see reference to the $AlCl_3$ as electron deficient rather than the Al being electron deficient.

7. It was not uncommon to see candidates describing bonding and/or structure here rather than properties. Some candidates discussed only boron nitride but reference to both substances was required.

**SECTION B**

Q.8 (a) A common error was to use a volume of 25 $cm^3$ to obtain a value that was ten times greater than the correct answer.

(b) The equations challenged many candidates with some unable to recall the correct equation for the dichromate and others unable to combine this with the iodine/iodide half-equation given in the question. It was particularly disappointing to see answers that gave the reverse of the half-equation in the stem without any reference to dichromate. The calculations were generally well done, although the reacting ratio was not always applied correctly.

(c) This was a very poorly answered question. Most stated the colour change was orange to green rather than orange to yellow. Some candidates thought that the reaction was not redox as only oxidation or only reduction occurred which showed a significant misunderstanding of redox reactions.

(d) These calculations were well answered in general. The most common errors in part (i) involved the incorrect use of the enthalpy change of the overall reaction. In part (ii) a few candidates did not convert between kJ and J correctly.

Q.9 (a) This QER question gave candidates the opportunity to discuss the various reasons for the existence of multiple oxidation states. Some failed to refer to the specific compounds listed and this limited the marks awarded. Most recalled the inert pair effect and were able to apply this to the oxidation states in Group 4. The discussion of octet expansion in Group 5 was done well by many candidates but others attempted to use the inert pair effect to explain the chemistry of $NCl_3$ and $PCl_5$. Responses relating to the oxidation states of manganese were often vague and did not refer to ionisation energies.

(b) Most could write the rate equation but the question on choice of sampling interval was answered poorly. Some thought that the 5 minutes overall would not be enough time whilst others thought that 30 seconds did not give enough time for analysis to occur, showing a lack of understanding of the idea of quenching.

(c) The reason for choosing a wavelength in colorimetry was not well known. Many limited their discussions to the wavelengths absorbed by the reactants only and not the need for a difference absorption by reactants and products.

The use of a graph to find activation energy was beyond most candidates. Many attempted to rearrange the Arrhenius equation given in the question. Those that could make the link between the equation as written and $y = mx + c$ gained better marks. It was not uncommon for candidates to struggle when calculating the gradient of the line due to the $10^{-3}$ on the $x$-axis.

Q.10 (a) Some candidates struggled with this question as they did not recognise the need to know an overall enthalpy and entropy change for the reactions. Many thought that the enthalpy of formation and the standard entropy of $F_2O$ and $Cl_2O$ were the only the values needed. They failed to show an understanding that the enthalpy of formation for the elements would have been zero but the entropy would not.

(b) This was well answered by almost all candidates.

(c) Many struggled to use the volume of gas to find the concentration of the acid, with common errors including missing the 2:1 stoichiometry, not using $m^3$ as the units for volume in $pV = nRT$ and mixing the volume of gas and volume of water in the calculations. Most could use their answer from part (i) to correctly calculate the pH and gained all three marks.

(d) Most could use the equilibrium constant to calculate a value for $K_c$, but many did not use the correct concentrations. It was common to see the initial values being used rather than the equilibrium values. Some candidates that calculated equilibrium values struggled with the initial values of water and $Cl_2O$ being different.

The electrochemistry in part III was well done but it was common for candidates to identify the ions incorrectly as $Tl^{3+}$ and $Fe^{3+}$ or write the full half-equations. Those candidates lost credit.

Q.11 (a) Almost all candidates gave the meaning of ‘weak’ but fewer included the idea of acid by referencing $H^+$ ions.

(b) This challenged many candidates as they had to decide on an appropriate method to identify the order of acid strength. Candidates could calculate $K_a$, $pK_a$ or pH values for all three acids to make the necessary comparison. Some tried to come up with an order by comparing values of different things e.g. a combination of pH and $pK_a$ values.

(c) Few candidates gained full marks here. It was common to see candidates calculate the pH of sodium hydroxide using $[OH^-]$ rather than $[H^+]$. In the buffer calculation many answers assumed the concentration ratio was 2:1 rather than 1:1. In explaining the buffer action many described a buffer rather than explaining how it works. It was not uncommon to see discussions around an equilibrium shifting to the left or right without the equilibrium being included (or based on an incorrect equilibrium featuring NaOH).

Q.12 (a) Most candidates gained the marks in this part.

(b) Almost all candidates gained at least one mark for this question. Most were able to use 0.020 mol of carbon dioxide to find the value of c although a few gave this figure as the value.

(c) A few candidates incorrectly identified the metal ions as $Fe^{2+}$. The candidates who did identify $Cr^{3+}$ did not always explain the observations in terms of its amphoteric behaviour. Many answers did not reference the white precipitate at all and so failed to gain the third mark.

(d) A good number of candidates gained three marks for finding that 0.018 mol of HCl had reacted with the hydroxide and carbonate ions. Far fewer were able to use this to find the value of d.

(e) It was disappointing to see that very few candidates could combine their answers to parts (a)-(d) to suggest a formula. Weaker answers suggested formulae that had different values from those calculated in the earlier answers. It was expected that getting a final formula with balanced charges and the correct number of atoms would be challenging and credit was awarded for suggested formulae meeting either of these criteria.

**CHEMISTRY**

**General Certificate of Education**

**Summer 2023**

**Advanced**

**UNIT 4 – ORGANIC CHEMISTRY AND ANALYSIS**

## Overview of the Unit

The Unit 4 paper allowed candidates to apply their organic chemistry knowledge to a variety of practical techniques and reactions in familiar and unfamiliar contexts and consider both chemical and physical properties.

Candidates exhibited skills in the balancing of complex organic equations, describing isomerism, chemical analysis and applying many of the basic mathematical knowledge developed earlier in the course, including in stoichiometric, molar and ideal gas calculations.

Questions required candidates to apply their knowledge of organic reactions, functional groups and spectroscopic data to identify unknown structures and functional groups. Some questions required detailed, written explanation where candidates could show the depth of their understanding, for example, of the mechanism for bromination of benzene.

## Comments on individual questions/sections

## SECTION A

Most candidates showed knowledge of some key ideas and reactions and scored some marks throughout Section A. Questions 3(b) and 7 were the most poorly answered.

## SECTION B

Section B highlighted several key points about examination technique. Candidates lost marks carelessly e.g. for not ensuring an equation was fully balanced or for missing out one or more atoms when drawing a structure. Simple checks should be done before moving on to the next question. Questions were often not read carefully enough and many candidates lost marks for errors in structures which were given on the paper.

Q.8 This question showed how difficult candidates find calculations such as solubility in unfamiliar situations. There was a lack of depth of knowledge stereoisomerism and of the relationship between solubility and trends in variation of intermolecular forces.

Q.9 This question on organic acids and their derivatives was generally well attempted by most. Many did well on the interpretation of data to identify unknown compounds in part (a). More marks were lost on recall questions requiring the naming of reagents or reaction types. Some candidates struggled to balance the equation in (b)(i) and fewer than half managed to complete the yield calculation in part (d).

Q.10 The QER question in part (a) was on a familiar mechanism allowing all candidates an opportunity to score some marks. A disappointingly small number included the detail required to attain a top band mark. Many scored in the middle band by making a good attempt at the mechanism and writing a brief description. The best answers were detailed, accurate and complete (including reference to the role of the catalyst and it's regeneration) and correctly used appropriate terminology such as electron deficient, electrophilic substitution, electrophile, halogen carrier and temporary dipole.

The majority of candidates succeeded to one degree or another to suggest a structure for the derivative of eugenol in part (b)(iii). On the other hand barely any marks were awarded for (b)(iv) where very few knew that esters are insoluble in water.

Q.11 Parts of this question based on amino acids were very well answered but one in particular was very poorly done. It was very surprising to see that fewer than one in 12 candidates could explain why aminoethanoic acid only forms one dipeptide. Good work was seen on the mass spectrum and IR question as well as on chromatography and light absorption. Calculating the energy associated with a given absorption was quite well done but scaling units using the appropriate multipliers was a challenge for some. Part (d) was well done by many.

Q.12 This question asked candidates to identify several organic reagents and conditions from various equations and reaction schemes. Many answers were simpler than candidates expected and involved reactions that they had all been familiar with from Unit 2, such as electrophilic addition in alkenes and the oxidation of alcohols to carboxylic acids. Unfortunately many could not apply their knowledge in the context of these more complex and unfamiliar molecules. It was surprising that in part (d), only two in five could name the molecule whilst far more succeeded in working out its $^{1}H$ NMR splitting pattern.

**CHEMISTRY**

**General Certificate of Education**

**Summer 2023**

**Advanced**

**UNIT 5 – EXPERIMENTAL TASK**

## Overview of the Unit

Candidates were given advance information stating that the Experimental Task would test their knowledge, understanding and skills through an acid-base titration and a qualitative inorganic analysis exercise. This allowed them to focus their preparation on relevant parts of the specification and proved to be useful.

The task incorporated a back titration and qualitative testing of s-block metal carbonates. Candidates exhibited skills in the accurate use of burettes, graduated pipettes and balances and subsequently presented their results appropriately in suitable table format. In addition, they had the opportunity to highlight their observation skills as they recorded results for flame and solubility tests.

Candidates were expected to use molar calculations, stoichiometry and molar mass values to determine the concentration of calcium ions present in a sample of water and therefore its hardness.

Analysis of the qualitative results highlighted the candidates' ability to compare solubility trends in Groups 1 & 2, along with characteristic flame tests, in order to identify the presence, or absence of metal ions.

Finally, candidates were given several questions that incorporated application and understanding of their final analysis to come to a conclusion as to the hardness of the water provided and the ion-exchange that may or may not have been successful.

## Comments on individual questions/sections

All candidates managed to apply their practical skills of titration techniques to collect and present results from which they could calculate the concentration of calcium ions in mg $dm^{-3}$. However, the quality in recording results varied considerably. Whilst a lot of candidates produced very good tables and scored highly, many lost marks for omitting units, recording to only one decimal place and working out mean values incorrectly. Accuracy marks varied considerably, but the majority of candidates scored marks for concordant results having carried out several titrations accurately. Most inaccurate results appear to have arisen due to errors in producing the original solution in the volumetric flask.

The molar analysis from the final mean titres was again varied. Some scored full marks, but most dropped some marks along the way from parts (i)-(v). There were many who did not understand the concept of a back titration and there was confusion as to the link between reacted and unreacted acid and the original acid used. Many did not use the correct stoichiometric ratio for the reaction between acid and carbonate ions.

During the qualitative analysis of the sample of ion-exchanged water, most candidates were able to link their observations accurately to the presence of sodium ions (or calcium ions for Test 2) from flame and solubility tests. However, not many managed to score the full four marks in part (vi). Whilst they could explain why the result identified that sodium ions were present and this meant that the ion-exchange had worked, they failed to consider what the alternative result with calcium would have been, e.g. the yellow-orange flame showed the presence of sodium ions, for one mark, was not backed up by explaining that had there been any calcium ions the flame would have been red-brick, to gain the second mark.

The last two questions were answered well with most candidates gaining these marks.

In part (vii) most explained that the nitric acid test only tested for carbonates and that ‘we already knew there was a carbonate present’. A number of other answers were accepted. However, marks were lost for statements that were not completely accurate. A mark was awarded for stating that the sulfate test may not be useful because neither sodium sulfate nor calcium sulfate would give a precipitate but no credit was given for ‘sulfate test is no good as all sulfates are soluble’. ‘The sulfate test is no good as all sulfates except for lead and barium are soluble’ is correct and was awarded the mark.

In part (viii) most realised that the charge of the calcium ions was twice that of the sodium ions, so two sodium ions were need for the ion-exchange to occur. Incorrect answers here tended to arise from candidates discussing the number of electrons lost when the ions formed which was irrelevant for this question.

## CHEMISTRY

## General Certificate of Education

## Summer 2023

## Advanced Subsidiary/Advanced

## UNIT 5 – PRACTICAL METHODS AND ANALYSIS TASK

### Overview of the Unit

The Advance Information published in February 2023 gave the following themes and topics as key areas of focus for revision and final preparation:
Organic functional groups
Inorganic reactions
Organic reactions
Rates of reaction
Equilibrium constants

This paper proved successful in that it differentiated well. Some marks were accessible to almost all candidates whilst others were gained only by the most able. This led to a good distribution of marks.

Good attempts were made at most of the calculations, where many candidates set out their answers sufficiently clearly to be able to see what was being done at each stage, allowing partial credit to be given when final answers were incorrect.

There was no indication that candidates had a problem with the length of the paper, with answer spaces that were left blank being uncommon and tending to indicate a lack of knowledge and understanding rather than time constraints.

### Comments on individual questions/sections

Q.1 (a) Most candidates gained 1 mark here. Weaker candidates did not identify the amine group and very few went on to correctly label it as a primary amine.

(b) (i) This question clearly differentiated between those that had revised the organic functional group tests and those that had not. It was surprising to see that some A2 candidates were unable to score any marks for this question. The question required the candidates to name three reagents that would give a positive chemical test for both compounds **A** and **B** and give the correct observations for the positive test. Since both compounds had a carboxylic acid group, a primary amine and secondary alcohol there were a number of possible reagents to choose. After incorrectly deciding that compounds **A** and **B** contained a phenolic —OH group, a number of candidates stated that both **A** and **B** would produce a white precipitate with $Br_2$(aq) and a purple coloured solution with $FeCl_3$(aq). Other common errors included giving the incorrect formula of nitric(III) acid and not including 'acidified' when aqueous dichromate(VI) was chosen as a suitable reagent. All too often, weaker candidates incorrectly chose 2,4-DNPH, Tollens' reagent and Fehling's solution.

(ii) Many candidates were able to state a chemical test that would give a positive result for compound **B** but not for compound **A**. Even though some recognised the need to identify the phenolic —OH group, careless errors in observations were often seen. No credit was awarded for brown to colourless with bromine solution with no mention of a white precipitate or for purple precipitate with $FeCl_3$. A number of candidates incorrectly chose acidified dichromate(VI) as a reagent.

(c) This question was poorly answered. Acceptable structures included any combination from the acylation of the alcohol or amine group, or anhydride formation via reaction with either of the carboxylic acid groups. Reactions had to be shown at two sites.

(d) Many candidates only gained one mark for this question. The intention was that they should use molar gas volume but some chose to use $pV = nRT$ which takes more time and has more scope for mathematical error. Common errors included using an incorrect $M_r$ value for compound **A** (although the correct value was given in the stem of the question) and incorrectly calculating the number of moles of hydrogen as being equivalent to the number of moles of compound **A**. Those using $pV = nRT$ often forgot to change pressure into $Nm^{-2}$ or failed to convert $m^3$ to $cm^3$.

Q.2 (a) Some excellent answers were seen to this six-mark question as these candidates worked logically, identifying appropriate reagents and linked observations for all three chemical reactions. Again, it was disappointing to see that a significant minority of candidates were unable to identify reagents for any of the three types of chemical reactions. No marks were awarded for observations where the reagents were incorrect.

A number of candidates only gave the name of one reagent for each of the different reactions.

(b) Encouragingly, the majority of the candidates who correctly identified the reagents and observations for the ligand exchange were able to give the formula of the complex ion formed.

Q.3 (a) (i) The calculation of rate from a concentration-time graph has been asked in many examination papers over the years and this was well done by many. However, weaker candidates divided the given concentration by the time elapsed at that point on the graph. The first step in this type of question should always be to draw a tangent at that point.

(ii) Candidates that correctly calculated the rate in part (i) often drew a tangent at a different concentration, calculated the rate at this concentration and showed that when concentration was halved (or doubled), the rate halved or (doubled). Others showed that as the half-life is constant.

(b) Pleasingly, the majority of candidates were able to calculate the value of the rate constant and state its units. Candidates that did not score marks in part (a)(i) were also able to score marks using 'error carried forward'. The most common errors seen were incorrect rearrangement of the rate equation and incorrect units for *k*.

Q.4 (a) Whilst this question was challenging, the majority of candidates scored at least 1 mark. No structure was given for the calculation of $K_c$ so only a minority of candidates scored the full 3 marks. The vast majority were able to calculate the number of moles of NaOH in the mean titre and hence the number of moles of $NH_3$ in the 25 $cm^3$ of the organic layer. However, only a minority then went on to calculate the number of moles of $NH_3$ in the 100 $cm^3$ organic layer. Similarly, only a minority of candidates correctly calculated the number of moles of $NH_3$ in the aqueous layer by calculating the initial total moles of $NH_3$ added and then subtracting the number of moles of $NH_3$ in the organic layer.

(b) The most common incorrect answer referred to there being the same number of moles of $NH_3$ in both layers.

(c) A few candidates gained both marks by calculating that the volume of 0.1 mol $dm^{-3}$ HCl needed would be very large, and therefore a higher HCl concentration would be needed or that the aqueous layer should be diluted. Incorrect answers included the need to use an alternative indicator.

(d) A few candidates scored 1 mark for correctly calculating that 250 $cm^3$ of the 8.00 mol $dm^{-3}$ ammonia solution should be added to 1750 $cm^3$ of deionised water. Only very few referred to the use of a volumetric flask.

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[i] ***Please note that where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.***