

Chemistry A

Advanced GCE A2 H434

Advanced Subsidiary GCE AS H034

Examiners' Reports

January 2011

H034/H434/R/11J

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This report on the Examination provides information on the performance of candidates which it is hoped will be useful to teachers in their preparation of candidates for future examinations. It is intended to be constructive and informative and to promote better understanding of the specification content, of the operation of the scheme of assessment and of the application of assessment criteria.

Reports should be read in conjunction with the published question papers and mark schemes for the Examination.

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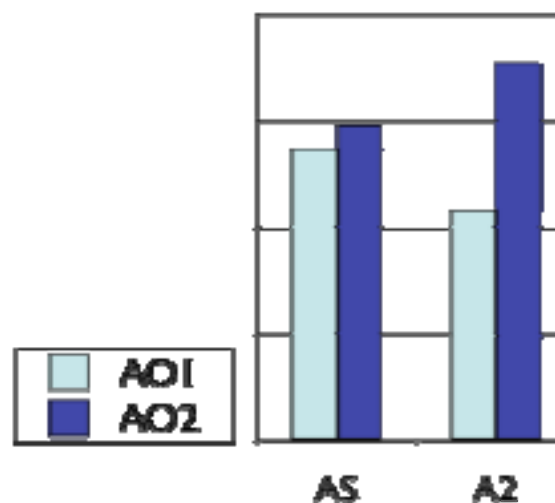
Chief Examiner's report

General comments

One aspect of the new revised specification is that candidates are required to apply their knowledge and understanding to a much greater extent than in the old legacy specification. When devising examinations, two main assessment objectives, AO1 and AO2, need to be considered. The weightings for these objectives are shown in the specifications for *Chemistry A* and they comply with requirements in the Science Core Criteria that apply to approved Chemistry specifications offered by all the Awarding Bodies. An outline of AO1 and AO2 and their relative weightings for the AS and A2 units are summarised below.

- AO1: Recall Knowledge and understanding
- AO2: Application, Unfamiliar situations

The greater emphasis on AO2 means that rote recall of the course content is unlikely on its own to guarantee a good result. The assessment model also provides the opportunity for more demanding stretch & challenge questions that will help inform the new A* grade, assessed in the A2 units only. In order to deliver this range of grades with the application emphasis, the A2 examinations are significantly tougher than the AS examinations.



There is a marked increase in AO2 against AO1 compared with the old legacy specifications that predate the current specifications.

For the new A2 examinations, this places a much greater emphasis on application of knowledge and understanding than in the past and novel questions that require application of knowledge and understanding will be a feature of this examination. The real challenge for both teachers and their students lies in their preparation for this style of examination. The best candidates usually rise to the challenge but weaker candidates can struggle. It is particularly important that weak candidates answer what they can in the questions, even if they are unable to see the way forwards to a final solution.

Future papers will be set in a similar style with a mixture of questions assessing stock chemistry from the main course and questions that assess whether candidates are able to apply their knowledge and understanding. In preparing their students for future papers, teachers are advised to use more application-based problems rather than solely questions based on the specification content.

The following strategies could be adopted:

- Encourage students to do more than just memorising the course content and old mark schemes
- Work on understanding the principles
- Practise application-type questions
- Practise writing short, concise answers

Time should not be an issue for the completion of the A2 papers but candidates must have a strategy for making best use of what time is available.

Candidates should not write too much when responding to earlier questions. The wording in the question and the mark allocations provide some guidance here. At worst, an excessively long response can lead to contradictions of earlier correct points with loss of marks already gained. A good strategy for answering questions on any paper is to first identify, and complete, questions from all the paper that can be tackled quickly.

Questions for which an obvious strategy is not apparent can then be tackled first as these will naturally take more time to complete. It is essential that a candidate does not get bogged down trying to complete a difficult question when the majority of the paper has yet to be tackled. The worst-case scenario is that easier questions, and better mark-gatherers, are not reached with the obvious detrimental effect on total performance on the paper. Although papers often tier in difficulty with more difficult questions later on, it is inevitable that there will be some straightforward parts to all questions.

It is hoped that this report goes some way to communicate the vision of the papers set in the revised specification and to explain why the A2 papers especially are different in style and tougher for candidates from those in the old legacy specification.

F321: Atoms, Bonds and Groups

General comments

As was the case for last January, the entry was pleasingly high and the responses given by candidates suggested they had been well prepared in familiar areas of the specification. The entry was almost 26000 this January compared to 24000 last January.

The candidates found the paper a little harder than last January, but the spread of marks suggested that there was something for everyone on the paper.

This paper examined a wide range of knowledge and skills from within the specification and, in the main, the responses of many candidates were pleasing and showed that they had prepared well for the exam. In particular it was noticeable that when it came to questions that elicited standard definitions, many students had clearly taken the time to learn these comprehensively and so were able to obtain full marks. With questions that then moved away from these set responses there was more of a challenge and sometimes this revealed a lack of familiarity with certain types of chemical calculation that should improve as the course progresses. This was certainly true of **4b(iii)**, for example. Lying between these two types of questions was a number of examples, which undoubtedly looked familiar to the well-prepared candidate, such as the question surrounding the geometry of boron trifluoride and ammonia. What is so important in these cases is that candidates do not rush at an answer but rather make sure that they have actually answered the question with the required level of detail.

Once again, it was very noticeable that, if a question had appeared in a previous question paper, e.g. the definition of relative atomic mass, then most candidates scored well and, more pertinently, better than the last time the question was seen. Conversely, questions on previously untested areas of the specification proved to be more challenging. This suggests that a significant amount of exam preparation is from the use of past mark schemes. Centres should remind their candidates that slight changes in questions may render a previous year's answer to a similar question redundant.

Chemical literacy was often shaky for weaker candidates and it is disappointing to see formulae such as NaCl_2 and H_2NO_3 appearing.

Many candidates failed to satisfy the marking criteria because ambiguous and imprecise statements were made. Weaker candidates failed to recognise when responses were unrealistic, truncating values and rounding off inappropriately. Some scripts were difficult to read and a lack of organisation within the written response gave rise to errors. The use of bullet points may help such candidates.

Candidates are advised to write with clarity. There is much evidence of poor handwriting by candidates – if a response cannot be read then it cannot be given marks. Candidates are asked to use black ink. Sometimes thick felt-tip pens are being used and the script becomes difficult to read as the line width is so thick. Also, such ink 'bleeds' through onto the reverse of the page and makes the pages very difficult to read.

Candidates are also advised to make '*dot-and-cross*' diagrams large enough to show clearly the dots and crosses. Very small diagrams are difficult to interpret.

It is essential that candidates check they have answered all the questions.

Comments on individual questions

Question 1

Question 1 was, by design, the easiest question on the paper. The intention to make candidates feel at ease was realised as most scored well on the first few sub-questions.

(a) Almost every candidate scored this opening mark by correctly associating the difference between the isotopes with their different number of neutrons. Only the weakest students confused neutrons with protons while a handful of others incorrectly calculated the number of neutrons in each isotope.

(b) Overall, marks here were an improvement on previous years with three marks being awarded to the vast majority. Candidates had clearly learned this common definition very well. One does sometimes wonder if the phrase '*weighted mean*' is clearly understood as variants such as '*weighed mean*' were relatively often seen.

(c) The calculation of relative atomic mass has become very straightforward to candidates, with only the weakest failing to complete the calculation. Most candidates were able to assemble the correct mathematical sum needed to calculate the answer but the correct outcome to the mathematical operation was not always achieved.

Candidates should be encouraged to check that the final answer, being an average, is a number which lies between the masses of the isotopes given. This simple check may make some aware that they have made a simple transcription or calculator error.

However, the most common error was rounding to 85.55.

(d) A significant minority left this question blank, possibly because it was the shape of the 5s orbital being asked for rather than the generic 's' orbital'. A few described the shape as dumb-bell. Weaker candidates gave a circle as their response and credit was not given for this 2-D shape.

(e) In **(i)**, the equation for this ionisation energy was generally well known. Missing or indecipherable or incorrect state symbols were the common errors seen. There was a considerable improvement compared to when this question has been asked previously. In particular, there appeared to be far fewer answers that gave an equation showing the ionisation of the metal atom to the two-plus ion.

In **(ii)** the increased number of protons / nuclear charge in the nucleus of Sr was picked up by most candidates. A high number correctly stated that there was increased nuclear attraction acting upon the outermost electrons for the third mark. Some candidates erroneously believe greater attraction is caused by an increase in the number of electrons in the outer shell. The relevance that the first electron was being removed from the same shell was often missed, or indeed contradicted by statements such as Sr has a bigger atomic radius than Rb. As ever, candidates do need to be aware that (nuclear) 'charge' is not (nuclear) 'attraction' and that (electrons) 'pulled closer' is not the same as (electrons) 'pulled more'. Candidates need to be aware that 'more energy required' is just a restatement of the ionisation values quoted in the question. Weak use of English often left it in doubt which element was being referred to. It may be that use of bullet points would help candidates. This may also help to prevent candidates writing at length and simply restating the same points using a different form of words.

Part **(iii)** proved more difficult than was envisaged. The question was an alternative to the typical question for successive ionisation energies and only the best candidates seemed to recognise this. Some candidates answered the question 'why is the second ionisation energy greater than the first ionisation energy?' using greater proton to electron ratio in their answer, without appreciating that the comparison was between second ionisation energies of Rb and Sr. It was a common misconception that when there is one electron 'left' in the shell it is easier to remove than when the shell is full without appreciation of the full shell being 'closer to the

nucleus'. Ionisation energy can be a difficult topic for some and a significant minority of responses contained contradictions. In fact, very few candidates discussed removal of the second electron from a rubidium (or strontium) ion, naming the element instead. Similarly candidates referred to the atomic radius (or even radii of the atom) rather than ionic radius in their explanations.

Question 2

(a) Parts **(i)** and **(ii)** were generally well answered and minimal rounding was seen. Errors included incorrect powers of ten or transcription errors.

In **(ii)**, the expected response of **a(ii)** divided by **a(i)** was frequently seen but others opted to instead divide **a(i)** by **a(ii)**, not realising that 0.5 would not be a viable answer for H_xA . Equally worryingly were responses such as 2000 based upon incorrect answers in **a(i)** and **a(ii)**.

(b) In **(i)**, despite being specification learning outcome: 1.1.3b 'state the formula of nitric acid', it was disappointing to see how many could not recall this formula. The answer could have been determined by considering the charge of the nitrate ion seen in the formula of copper(II) nitrate, but many were unable to write the formula of copper(II) nitrate despite it appearing in the question. Many used copper instead of copper(II) oxide. Hydrogen gas was produced, rather than water, even when copper(II) oxide was used.

In **(ii)**, ionic bonding was explained by nearly all, although the needless mentioning of metals and non-metals suggested a big influence from GCSE days.

In **(iii)**, it may have been that it was 'copper' appearing in the name of the solution which convinced weaker candidates that it was delocalised electrons which were responsible for conductivity. Mobility/movement was almost universally mentioned. Very few wrote about free ions or the anonymously named 'mobile charge carriers'.

In **(iv)**, calculating oxidation numbers still proves difficult for many. An answer of +10 was often seen arising from candidates who had failed to note the presence of two nitrogen atoms.

(c) Most candidates failed to score here. Few candidates seemed familiar with the concept of water of crystallisation and its representation. Many got to $6H_2O$ but could not put the dot formula together properly or give the copper nitrate part, despite the formula of copper(II) nitrate being given in the question. Many wrong answers had the nitrate group without brackets. CuN_2O_6 was another common error as well as CuN . Quite a few were attempting to write a balanced equation.

Question 3

(a) This question has largely been seen before. It is a standard description and is a specification learning outcome. Although many had learnt this response by heart and scored both marks, others became confused with the first part; common errors were omission of 'electrons' or 'atom' but covalent bond was seen in most cases.

(b) This question was designed to be one of the easiest on the paper but was quite poorly answered by many. Candidates did not seem to realise the relevance of the data in the table. Better students answered this correctly.

(c) In **(i)**, the shape of SF_6 has not been asked before but the majority of the candidates were aware of the answer, although many inaccurate spellings of octahedral were seen.

In **(ii)**, the 'dot-and-cross' diagrams were generally well drawn, the omission of fluorine lone pairs being the common error. There was a significant number of 'shape' rather than 'dot-and-cross' diagrams. Weaker candidates omitted to state that it was electron pairs repelling which was responsible for shape. Where this was given, candidates often omitted how many and what type

of electron pairs were responsible. Weaker candidates generally do not appreciate the difference between a rule of thumb (2.5° reduction for each lone pair) and an explanation for the reduction. Better candidates scored all five marks here.

In (iii), very few candidates recognised the significance of symmetry in the BF_3 molecule and the cancelling of dipoles was extremely rarely seen. Many misread the question and tried to explain why the bonds were polar.

Question 4

(a) The question asked candidates to state one use of calcium hydroxide in agriculture. Once again the expected response was from the specification (1.3.2f), i.e. the neutralising of acidic soils. Frequently seen incorrect responses were fertilisers or weedkillers, clearly given without thinking about the chemical nature of calcium hydroxide. Worse still were 'toothpaste' and 'cleaning agents'. The chemical nature of calcium hydroxide being too strongly alkaline to support living organisms was seldom seen.

(b) In (i), most scored the mark here. Centres are reminded to encourage candidates to use the *Data Sheet* for A_r data. Candidates should also be encouraged to give numerical answers to the same number of significant figures as the data given in the question.

In (ii), most scored the mark here. For those who did know the relationship between moles and gas volume, the main reason for losing the mark was the use of 24000.

Part (iii) distinguished well amongst the top end of the cohort. A high proportion of candidates were able to calculate a concentration of hydroxide ions but based upon the number of moles of OH^- ions formed from $\text{Ca}(\text{OH})_2$ being identical to the number of moles of $\text{Ca}(\text{OH})_2$ present. They then multiplied $1000/250$ by 0.00131 rather than by 0.00262. Other routes to the incorrect answer were often rather obscure, sometimes involving the relative formula mass of $\text{Ca}(\text{OH})_2$, and sometimes involving the answers to the two preceding calculations.

(c) Part (i) was a difficult question, based around the mole concept. Only better candidates were aware that the higher A_r of Ba would result in fewer moles of Ba being present. The majority of answers were based on linking a greater volume of gas to a more reactive metal or Ba being impure (which was an answer to a similarly worded but different question seen in 2009 – one reason why revision by use of mark schemes should be treated with caution).

Part (ii) was well answered. Candidates were asked for what differences would be observed, so simply stating that Ba would be more reactive did not receive credit.

Question 5

(a) In (i), the key terms were known to many but not used well. The most common mistake was to state that temporary dipoles were 'induced' rather than 'produced' by uneven electron distribution. Others omitted to explain the formation of induced dipoles on the adjacent molecules. Some gave a description of van der Waals' forces in action rather than describing how they arise. Some lacked the literacy skills to write a clear answer. Once again, bullet pointed answers may have helped candidates.

In (ii), most candidates appreciated the reason for the trend in boiling points but frequently misstated the trend. Fewer candidates than in previous years believed that covalent bonds were being broken during boiling. Some confused boiling points with ionisation energies and gave answers in terms of distance/shielding/nuclear charge, etc. A few tried to link the trend in boiling point with reactivity. The final marking point proved more elusive and only the best candidates made clear the link between the boiling point and the energy needed to overcome the intermolecular forces.

(b) Often candidates considered it sufficient to state that astatine was in the same group as the other halogens but the majority went that necessary step further and discussed electron configurations.

(c) In **(i)**, candidates are advised to read questions carefully. Clearly, the organic solvent was added to the test-tube after the reaction had occurred. Many simply stated the colours of all halogens in cyclohexane. Responses that the solvent would not change colour with bromine and sodium chloride were incorrect (although if candidates suggested it remained orange, credit was given for identifying the correct end colour). Some candidates did not identify that one reaction did not take place and gave equations and colours for all possible combinations of displacement reactions. Many responses were confused and contradictory. Once again, the use of bullet points would have helped. Many good candidates scored four marks but did not secure the fifth and sixth marks for explaining the trend in reactivity, despite being in one of the bullet points in the question. It was rare to see a statement that chlorine will gain electrons most easily. Many candidates used the term 'attract' rather than gain or capture electrons in the formation of a chloride ion.

In **(ii)**, the response 'chlorine is toxic' was not rewarded as no chlorine was produced. Very few identified 'bromine is toxic' as the relevant hazard.

(d) A small but significant number of candidates did not attempt parts **5(d)** and **5(e)**.

In **(i)**, as fluorine only forms compounds with an oxidation state of -1 , HF was formed. Many did identify HF as the unknown product – but then failed to balance the equation correctly.

In **(ii)**, most scored one mark for identifying that oxygen had been oxidised. Pleasingly, despite having incorrect (or no) products in **d(i)**, many identified that if oxygen had been oxidised then fluorine must have been reduced and so must have attained an oxidation number of -1 . Some candidates opted to explain redox in terms of electron loss or gain instead of oxidation number changes.

(e) In **(i)**, most candidates were able give the expected electron configuration.

In **(ii)**, many candidates answered this part correctly but a significant number struggled and gave a range of unrealistic formulae.

F322: Chains, Energy and Resources

General comments

The number of candidates taking this unit showed a small increase from the corresponding series in January 2010. A significant proportion of these candidates were re-taking the component.

The average mark for the examination was 58 and candidates were awarded marks that covered the mark range from 0 to 90. Statistics show that all of the questions and the paper as a whole differentiated well. It allowed candidates of all abilities to demonstrate positive achievement. Candidates appeared to have sufficient time to complete the examination paper.

A significant proportion of the candidates found the questions that involved recall of conditions, processes and definitions very difficult. Many candidates were not able to use basic chemical terminology with accuracy and precision. Candidates generally performed well in calculation questions but were sometimes let down by incorrect use of significant figures.

Comments on individual questions

Question 1

This question focused on aspects of the chemistry of cyclohexane and cyclohexene. This was the most accessible question in the examination paper.

(a) Many candidates appreciated that fractional distillation depends on the difference in boiling point. Candidates often referred to intermolecular forces when the mark scheme required specific mention of van der Waals' forces and how they change with either increasing chain length or molecular size.

(b) Almost all candidates were able to deduce the general formula of C_nH_{2n} in **(i)**. Many candidates could construct the equation in **(ii)** and the equations given included skeletal, displayed or molecular formulae, all of which were accepted in the mark scheme. The idea that cyclohexane gives more efficient combustion was quite well known and a significant proportion of candidates referred to increasing the octane rating.

(c) In **(i)**, many candidates appreciated that cyclohexane contains carbon and hydrogen atoms together with a double bond. However, the mark scheme required specific reference to only hydrogen and carbon and to a carbon–carbon double bond, and many candidates did not include this level of detail.

Candidates found **(ii)** very demanding and often referred to the toxic nature of chlorine or the danger of radicals, neither of which were given credit in the mark scheme. Only a very small proportion of candidates referred to multi-substitution or the formation of dichlorocyclohexanes. It was insufficient to state that there was more than one product.

In **(ii)**, very often candidates realised that the hydroxide ion had a lone pair but many candidates did not refer to the able to donate an electron pair which was required in the mark scheme.

In **(iv)**, more candidates could identify compound **B** than could identify compound **A**.

In **(v)**, candidates needed to take more care when drawing the electrophilic addition mechanism. Common errors included:

- (a)** drawing a curly arrow from a carbon atom rather than from the double bond;
- (b)** showing the heterolytic fission of Br_2 by having the curly arrow starting from a bromine atom;
- (c)** failing to draw the positive charge on the carbocation;

(d) not starting the curly arrow from the bromide ion from either a lone pair or the negative sign.

Other misconceptions included giving the bromide ion a partial charge rather than a full negative charge and missing the hydrogen atom attached to the positive carbon atom in the carbocation.

Question 2

This question focused on the formation of the ester butyl ethanoate.

(a) Many candidates could draw the correct skeletal formula. The most common error was to draw propyl ethanoate rather than butyl ethanoate although some candidates were not able to draw the ester functional group.

(b) Almost all candidates could show how to calculate the atom economy.

(c) In (i), a significant proportion of candidates could not recall the conditions for esterification. A small proportion of candidates referred to reagents that would lead to oxidation or included high pressure as one of the conditions.

In (ii), candidates found the percentage yield calculation much more demanding than the atom economy calculation in (b). The majority of candidates used an approach based on the actual and theoretical moles. A significant proportion of candidates could not correctly round up the numbers they calculated.

(d) Although many candidates could appreciate the difference between percentage yield and atom economy, only a small proportion of candidates actually answered the question set. A significant proportion of candidates did not link low atom economy and high percentage yield with their explanations. Good answers for low atom economy referred to a lot of undesired products being formed rather than just more undesired product is formed. Good answers for high percentage yield stated that the actual mass of product was very close to the predicted mass.

(e) The mark scheme required a comparative answer such as **process 1** used fewer stages than **process 2** or **process 1** had a higher atom economy. Many candidates did not give comparative answers and merely gave information about **process 1**.

Question 3

This question focused on enthalpy change of reaction and bond enthalpy.

(a) The definition for enthalpy change of reaction was not well known and candidates were more likely to define bond enthalpy or enthalpy change of formation. Other candidates gave imprecise definitions about the enthalpy change when one mole of a reactant reacts or one mole of a product is formed. The best answers clearly linked the enthalpy change with the molar amounts as shown in the equation.

(b) In (i), candidates were often able to calculate the correct energy change as 2.31 kJ. Candidates who used 4.18 as the specific heat capacity were given full credit in this question. Some candidates did not convert the answer from J into kJ and others used the wrong temperature change or the wrong mass.

In (ii), a very large proportion of candidates were able to calculate the amount in moles as 0.20, although a very small proportion of candidates did not use the relative atomic mass of sulfur as 32.1 as shown in the *Data Sheet*.

In (iii), only a very small proportion of candidates were able to complete the calculation and get the correct answer of +23 kJ mol⁻¹. The mark scheme allowed +12 kJ mol⁻¹ as an alternative answer which is not the enthalpy change of reaction but is the enthalpy change per mole of NH₄SCN. A large proportion of candidates did not state the sign of the enthalpy change which

was specifically asked for in the question, and a similarly large proportion of candidates did not quote the answer to two decimal places, asked for in the question. Candidates that showed their working out throughout **(b)** had the opportunity to be awarded error carried forward marks for incorrect answers in **(i)** and **(ii)**.

(c) In **(i)**, the definition for bond enthalpy was not well known. Candidates often referred to the enthalpy change to break a bond in a mole of a compound or substance rather than the enthalpy change when one mole of bonds was broken. The mark scheme did not require any reference to the correct states. A common misconception was to refer to the enthalpy released or to refer to bonds being formed rather than broken.

In **(ii)**, many candidates could explain the formation of π bonds by the overlap of p orbitals, often illustrating their answers with labelled diagrams.

In **(iii)**, some candidates restated the question rather than explaining that the π bond was weaker than the σ bond.

In **(iv)**, most candidates obtained at least one mark and many obtained the correct answer of $+79 \text{ kJ mol}^{-1}$. There was no requirement to put the positive sign with this answer. A small proportion of candidates were awarded an error carried forward mark following incorrect calculation of the enthalpy changes involved in bond forming and bond breaking.

In **(v)**, only a very small proportion of candidates realised that the average bond enthalpy values given in table may not be the actual bond enthalpy values in the compounds given. The most common incorrect answers were that the conditions were not standard or that there was heat loss.

Question 4

This question focused on catalysts.

(a) In **(i)**, many candidates were able to construct the first equation but a smaller number could do the second equation. In the second equation, a common misconception was to include another molecule of ClO on the left-hand side or ClO₂ on the right-hand side.

In **(ii)**, many candidates could not write the overall equation and often $\text{O}_3 \rightarrow \text{O}_2 + \text{O}$ was quoted instead.

(b) The stages that take place in the catalytic converter were well known by candidates and the term *adsorbed* was understood by many candidates. The mark most likely to be missed out was that the bonds within the reactants were weakened. Only a small proportion of candidates used *absorbed* rather than *adsorbed*.

(c) Most candidates attempted to draw both the Boltzmann distribution and the enthalpy profile diagram. A significant proportion of candidates did not use the correct labels for one or both of the two diagrams. Many candidates appreciated that the activation energy was lowered; this was often drawn in both diagrams and stated in the written part of the candidate's answer. In the same way, many candidates appreciated that the catalyst had a different pathway and showed this both in writing and on the enthalpy profile diagram. A small proportion of candidates labelled the activation energy at the top of the curve rather than as a vertical line. A common misconception was to draw two Boltzmann distributions rather than one. These candidates appeared to have confused to effect of temperature with the effect of a catalyst on the Boltzmann distribution. Typically, candidates were awarded more marks from the diagrams than from their written work. Candidates did not always appreciate that there were more successful collisions and that more molecules had kinetic energy above that of the activation energy.

(d) A significant proportion of candidates gave the characteristics of a catalyst rather than answering the question set. Instead of focusing on the advantages of using catalysts in industry, they focused more on speeding up the rate of reaction and lowering the activation energy. The most common marks scored related to using less energy and burning less fossil fuel. Some candidates used the idea of better atom economy and the production of less toxic waste. Only a small proportion of candidates referred to the use of enzymes to improve specificity.

Question 5

This question focused on the chemical properties of halogenated compounds.

(a) In **(i)**, almost all the candidates could construct the balanced equation, the most common errors were the use of the wrong halogen or the wrong chain length for the halogenoalkane. In **(ii)**, candidates were often not awarded full marks because of a lack of care when drawing the mechanism. Typically, the partial charges on the C–Br bond were drawn correctly but the curly arrow representing the heterolytic fission of this bond often started from the carbon atom rather than the bond. The most common misconception was to give the ammonia molecule a charge, either NH_3^- or NH_3^+ . Other candidates did not start the curly arrow from the lone pair of an ammonia molecule. The product Br^- was well known by the candidates.

(b) Candidates found this part very demanding and very few candidates were able to get full marks for the question. Although candidates referred to the information in the table they did not always use it clearly. For example, it was insufficient just to state that iodobutane reacted faster at high temperature; the candidate needs to use the information in the table to show that it reacts faster at 60 °C than at 50 °C. Candidates were often imprecise with the use of chemical terms. For example, many candidates used the term *halogen* when referring to a halogenoalkane and then stated that iodine, rather than iodobutane, was the most reactive. Although many candidates realised that bond enthalpy was a key factor, they did not always refer to the C–Hal bond. A significant proportion of candidates gave answers that referred to van der Waals' forces and boiling points.

(c) In **(i)**, only a small proportion of candidates were awarded full marks. Although candidates could draw the monomer and the polymer they often could not put the '*n*' in the correct place. A significant proportion of the candidates gave the incorrect monomer, some being chloroethene but most being trifluoroethene rather than tetrafluoroethene.

In **(ii)**, candidates often referred to radicals being produced or products that destroyed the ozone layer rather than the formation of poisonous products.

Question 6

This question focused on mass spectrometry and infra-red spectroscopy.

(a) In **(i)**, many candidates were able to deduce that the value of *x* was 1 by using the molecular ion peak at 58.

In **(ii)**, a large variety of structures could be credited, for example, propanal, propanone, cyclopropanol and prop-2-en-1-ol.

In **(iii)**, many candidates gave C_2H_5^+ or CHO^+ but a small proportion of candidates forgot the charge on the ion or included a negative charge.

(b) Many candidates referred to the presence of a peak at 55.8 rather than peaks around 56.

(c) Candidates found **(i)** very demanding and did not appreciate that the number of peaks will correspond to the number of different isotopes.

Candidates found **(ii)** much more easy than **(i)** and gave answers that related to different relative proportion of isotopes. A significant proportion of candidates did not attempt these two questions.

(d) In **(i)**, candidates often described the lack of absorbance around 1640–1750 and 3200–3550 cm^{-1} , but those that quoted the range of 2500–3550 cm^{-1} were not given credit since this applied to a carboxylic acid rather than an alcohol. Other candidates referred to the presence of an absorbance around 2900 cm^{-1} as due to a C–H bond stretch but they were only credited if they referred to the lack of any other characteristic infrared absorptions. In **(ii)**, many candidates were able to identify the presence of the carboxyl group using the characteristic C=O and O–H absorbances in a carboxylic acid. References to C–O absorbance were ignored.

Question 7

This question focused on biofuels and was the most demanding on the examination paper.

(a) The manufacture of ethanol was not well known and a significant proportion of the candidates did not attempt the question. Candidates often gave yeast and a correct temperature for one mark but did not refer to the use of distillation to obtain the ethanol. Only a small proportion of candidates were able to write equation for fermentation.

(b) In **(i)**, almost all candidates realised that the products of the combustion of biodiesel are CO_2 and H_2O but a much smaller proportion of candidates could balance the equation. Often candidates gave $22\frac{1}{2}\text{O}_2$ rather than $21\frac{1}{2}\text{O}_2$, presumably because they had forgotten the oxygen atoms in the biodiesel.

In **(ii)**, although some candidates realised that there was an energy requirement in the manufacture of biodiesel, the mark scheme required a comment also that carbon dioxide would be emitted into the atmosphere. A common misconception was that biodiesel is not carbon-neutral because carbon monoxide is produced.

(c) Candidates often appreciated that biodiesel was renewable but did not always suggest that this would result in less fossil fuels being used. The disadvantages of biodiesel in terms of using land that could be used for food were well known.

(d) Although a significant proportion of candidates referred to hydrogenation and realised that a nickel catalyst was needed, there were other candidates that referred to polymerisation instead. A small number of candidates confused hydration with hydrogenation. A significant proportion of the candidates did not attempt this question.

(e) In **(i)**, most candidates could draw the *Z*-isomer.

In **(ii)**, candidates found it more difficult to explain why there are *E* and *Z* isomers. Candidates realised that there was no rotation about the double bond but were not able to clearly describe that both carbon atoms of the double bond had two different groups attached to them.

F324: Rings, Polymers and Analysis

General comments

This was the third examination session for F324 in the new OCR A level Chemistry A specification.

Overall, candidates responded very well to the demands of this paper and it was particularly pleasing to see some good answers to challenging questions. Much of the examination was accessible to the average candidate and there was plenty of opportunity for those with flair to display their ability, particularly in the later questions. The paper discriminated extremely well with raw marks ranging from virtually full marks down to zero.

There was some evidence that some candidates had run out of time and were not able to complete the paper. This ranged from very brief answers to the later questions to blank spaces left in earlier questions. Some candidates appeared to have spent too long on earlier parts of the paper writing responses beyond what was required for the marks available with the result that they then had to rush later parts. The lesson here is that candidates should pace themselves carefully throughout the paper, always allowing time to attempt the later questions adequately (some good guidance on technique is included in the Chief Examiner's report).

Although many candidates drew excellent, clear and unambiguous organic structures, other candidates were very careless. For example, it was sometimes unclear where bonds started and finished, and sticks, which could have been bonds or methyl groups, were used in some structures. Connectivity was only tested in question **4b(ii)**; otherwise some candidates would have lost many marks.

Each of the questions had some parts that were accessible to all but the weakest candidates. There were also sections on the paper which challenged the most able, allowing these candidates to demonstrate their deeper understanding of the subject.

Comments on individual questions

Question 1

This question gave most candidates a gentle introduction to the paper with the majority scoring well over half the available marks.

(a) Almost every candidate got off to a good start with this question with very few being unable to make a good attempt at this standard mechanism. Candidates knew the mechanism but were sometimes careless in their description. The most common error was the absence of the proton on the product side, closely followed by the curly arrow in the intermediate originating from the H atom rather than the bond. The horseshoe in the intermediate varied enormously in size and shape as did the position of the + charge. Sometimes the horseshoe was not facing the carbon atom with the H and NO₂. Only in a few instances was the methyl group missing at the start, although more often it failed to appear in the product. In most responses, the 4-nitro compound was produced. Many candidates wrote equations for the formation of the electrophile NO₂⁺ and the regeneration of sulfuric acid.

(b) This was generally well answered with the majority of candidates gaining two marks. The most common errors were to draw a reflection of one of the isomers already given or to substitute an NO₂ group onto the methyl group. Many candidates labelled the positions of the nitro groups in the isomers as an aid to identifying which isomers were missing.

(c) This question differentiated well. Nearly all candidates scored marks but few earned full marks. Most achieved the mark for **Isomer 3** although a few gave a choice of **Isomers 1, 2, 3** etc., thereby losing the mark. It proved far easier to draw a correct structure for 3,5-diaminomethylbenzene than it was to name the compound correctly. The equation proved difficult to balance with candidates forgetting either the four O atoms from the nitro groups or the four H atoms needed to replace them. Significant numbers of candidates mentioned tin as a catalyst. Marks were lost on the organic acid in the second stage; either by writing incorrectly the formula for propanedioic acid, by missing the H atoms on the middle carbon, or by naming the compound incorrectly. Finally, instead of polyamides, there were many polypeptides and a few polyamines; some others simply repeated the information in the question that the compound was a condensation polymer.

Question 2

Esters were the common theme in this question, first covering some environmental aspects of the use of esters in biodiesel, then proceeding to some quite challenging aspects of esterification.

(a) Many candidates did not manage to gain the relatively easy mark here because they omitted the 1,2,3 needed for the name. Others gave the numbers but then omitted the **triol** part of the name.

(b) Most candidates gave ethanol or methanol as a suitable alcohol for making biodiesel but did not go on to link this to renewability or any of the acceptable alternatives in the mark scheme. Surprisingly few candidates linked the use of excess ROH to equilibrium. Many suggestions involved the breaking of all bonds or all ester links. Candidates did not seem to realise that biodiesel is made up of esters of fatty acids despite this fact being in the stem of the question.

(c) The equation for the formation of ethyl propanoate from a carboxylic acid and an alcohol was well written although too many omitted the water molecule. Far fewer candidates could write an equation using an acid anhydride. The problem was often the formula of the anhydride itself.

(d) Many candidates made a creditable attempt at the structures of **A**, **B** and **C**. Certainly the most likely place to lose a mark was with the cyclic ester. Many candidates chose to give two repeating units for the polyester. Candidates need to be clear that if they show carbon atoms as C, then hydrogen atoms need to be shown as H. Correctly drawn skeletal formulae were, of course, accepted.

Question 3

Candidates found this question as a whole easier than Questions 1 and 2. It was possibly the most straightforward of all the questions and candidates of all abilities scored highly on this question.

(a) The oxidation of the aldehyde was well known with most candidates scoring all three marks. A small number of candidates thought the reaction was a substitution reaction and included Ag in their product.

(b) This mechanism, being relatively new to the specification, was more testing and it was pleasing to see a good number of candidates demonstrating a sound understanding of mechanisms in organic chemistry. However, the nucleophile H^- was not known by a significant number of candidates who used H^+ or NaBH_4 directly. The dipole was usually included in the $\text{C}=\text{O}$ bond but carelessly drawn arrows sometimes cost candidates this mark. The most common error was to omit the \ominus sign from the intermediate (or indeed use a δ^- sign); the curly arrow from the $\text{O}-\text{H}$ bond to the O was also sometimes omitted. The product was well known, although it was disappointing to see a small number of candidates using trivalent carbon atoms.

(c) The addition reactions of safranal were well known with the vast majority of candidates scoring three marks. Almost all candidates opted for bromine. Bromination of both or either of the two carbon–carbon double bonds was acceptable. A small number of candidates used an addition reaction but then placed one of the added Br atoms onto the wrong carbon atom.

Question 4

Overall, candidates found the start of this question challenging, but the question then became more accessible, finishing with an easy four marks in the final part.

(a) Less than half the candidates gave an acceptable equation in this part. The most common reason for not gaining the mark was to have no chlorine in the products. Another error was $\text{H}_2\text{NCH}(\text{CH}_3)\text{COO}^-$ on the right without a balancing H^+ . Many started with one NH_3 on the left and then gave both the amino acid and an NH_4^+ ion in the products. Very few candidates thought to neutralise both acidic products with the excess ammonia. However, correctly balanced equations with acidic products were accepted.

Correct answers to the second part were rare.

(b) Whilst there were many good answers to the first part, some candidates gave a structural rather than skeletal formula. A number drew the intermediate nitrile.

The optical isomers were well answered by the majority of candidates. The most common reason for not scoring both marks was incorrect bond linkages from the central carbon to one or more of the surrounding groups. This connectivity was only assessed in this part of the question. A small minority of candidates did not draw a 3-D structure. Methods of drawing the three-dimensional nature of the bonds varied from the excellent to the improbable to the impossible. Centres would be advised to draw 3-D diagrams in the simple style shown in the mark scheme.

(c) This was very well-answered by the majority of candidates. Few did not score all four points and in most of these cases candidates had either not fully read the question, giving only a partial answer, or they had given the same point twice, worded slightly differently. The answers were largely the points given in the specification.

Question 5

Overall, this question was tackled well.

(a) There were many quite comprehensive answers, at times spoilt by the use of the word absorption instead of adsorption. On occasions, answers referred to an adsorption in the mobile phase instead of an affinity for the stationary phase. The R_f values mostly ranged between 0.1–0.3 with only the occasional answer being outside this range. A number of candidates reversed the expression for calculating the R_f value and ended up with a number greater than 1. A large number of candidates appreciated that the size of the spots, particularly spot **B** on the chromatogram, suggested that the rose oil may contain additional compounds with similar R_f values obscured by the extended spots.

(b) Most responses appreciated that gas chromatography separates the components in a mixture, but the use of mass spectrometry to identify these components was less well understood. Many answers repeated the question and stated that mass spectrometry identified the compounds in a mixture with no further explanation. Some candidates incorrectly used expressions such as splitting pattern when explaining how mass spectrometry identified the components. A number of responses mentioned that the mass spectrometer gives the molecular mass of each component and hence can identify the compound without appreciating that three of the compounds in the question had the same M_r .

Responses for the two compounds in spot **B**, contained permutations of all four compounds. Candidates that identified geraniol and nerol as the correct isomers often then gave either an incorrect reason, such as similar R_f values, or gave the very basic reason that they contain the same functional group. Three of the stereoisomers contained an alcohol group and therefore candidates needed to state that nerol and geraniol were stereoisomers (or *cis-trans* or *E/Z* isomers).

The definition of the term stereoisomers was often given incorrectly with candidates quoting that the isomers had the same molecular, rather than structural, formula. It was generally understood that the definition involved a different arrangement in space.

Various parts of the skeletal formula of citral were circled to illustrate the feature causing the stereoisomerism in citral, ranging from a circle around a specific carbon atom to a circle around all the double bonds.

Most candidates were able to identify two of the three chiral centres in menthol, however, all three correct chiral centres was less common.

(c) A surprising number of candidates did not notice that the M_r of myrcene was given in the question and incorrect values of the M_r frequently appeared in answers. Similarly, working out the M_r of menthol from a skeletal structure proved difficult for a large proportion of candidates. However, a pleasing number of candidates scored full marks on this part.

Question 6

Candidates coped well with most aspects of this question.

(a) Most candidates made an attempt at this question and there were many excellent answers. Candidates commonly used two approaches and both were credited in the mark scheme. Some candidates explained the splitting pattern of the three peaks in terms of the protons responsible for the peaks. Others explained the splitting in terms of the protons on the adjacent carbon atoms. From the responses, a number of candidates struggled with proton NMR spectroscopy, whilst others could not interpret the skeletal formula. Common misconceptions included peaks caused by the protons thought to be on the oxygen atoms, two triplets caused by the protons on carbons 4 and 6 and the prediction of a triplet caused by the protons on carbon 5.

(b) Again, most candidates attempted this question, but few worked their way through to a correct answer. Those who did usually used enough of the data to earn full marks. Carbon-13 NMR spectroscopy and mass spectrometry fragmentation patterns are both relatively new to the specification and some candidates struggled to interpret the data. However, most candidates realised that the M_r of the compound was 106 and the structure contained a benzene ring with two other carbons attached. Working out the four isomers proved more difficult and the elimination of three of them, using the number of carbon environments, was only achieved by a small percentage of candidates. A small but significant number of candidates thought that, because the molecular ion peak was at 106, then the M_r would be 105 or 107. This made the rest of the question very difficult.

F325: Equilibria, Energy and Elements

General comments

This was the first January series in which this paper has been available.

This examination was tackled by a diverse cohort, the majority of the ca. 2500 entries being large centres in excess of 100 candidates, taking this unit first in the A2 year. This route of assessment is perfectly viable and perhaps reflects the move towards later examination dates in January with more teaching weeks now being available from September (or even June of the previous year) to late January than from late January to June. The entry was supplemented with small numbers of candidates from many centres, presumably candidates completing their A levels last year but re-sitting in an attempt to improve their examination grades.

A feature of the candidate responses was that questions accessing recall were answered well, especially those questions on topics that have featured heavily in previous examinations in the old legacy specification. Consequently, the majority of candidates tackled questions well when they were more predictable, e.g., most of **Question 1** on rates and the explanation of buffers in **3(c)**.

Overall, candidates found this paper demanding with few scoring very high marks. The most challenging questions – **2(g)**, **3(e)** and **4b(ii)** elicited very few correct responses.

Candidates were often vague and muddled in the language that was used and questions on basic concepts were often poorly attempted. However, all except the weakest candidates generally showed skill on the calculation questions; indeed success with calculations in **3a(ii)**, **3b(ii)**, **5(b)** and **6a(ii)** was often better than ability to explain chemical phenomena, especially related to particles in **6(d)**. The grade boundaries were of course adjusted to reflect the difficulty of the examination and to guarantee a fair outcome for the candidates.

There was no real evidence that time had been an issue in the completion of this paper, although some candidates wrote too much in their responses to early questions; others seemed to get bogged down trying to complete what were obviously difficult parts to questions, with a detrimental effect on later questions. Advice on examination technique and strategy is provided in the Chief Examiner's report.

It is hoped that, with more papers becoming available, teachers and their candidates will become more familiar with the demands of this paper. Success though will not come from purely learning all the specification content and memorising mark schemes. Although this will help, application will also be tested using questions set in novel contexts.

Comments on individual questions

Question 1

This question gave most candidates a gentle introduction to the paper with the majority scoring well over 50% of the available marks.

(a) Almost every candidate got off to a good start with this question with the majority scoring 2 or 3 marks. Where a mark was lost, it was more likely the units or inability to rearrange the rate equation.

(b) Parts **(i)** and **(ii)** provided most candidates with two easy marks although some weaker students responded far too vaguely with responses such as 'increases' for **(i)** and 'decreases' for **(ii)**.

Candidates found part **(iii)** far more testing and less than half the candidates were able to arrive at 64 times faster. Some candidates partly answered the question with responses such as 4^2 and then $\times 4$. It was common though to see answers of 4, 16 and 20.

(c) Surprisingly, this part created far more problems for candidates than parts **(a)** and **(b)**. For **(i)**, candidates often answered in terms of a shift in equilibrium position. The expected response was that the rate would increase as increased pressure increases the concentration.

In **(ii)**, about a third of candidates incorrectly associated an increase in rate in **(i)** with an increase in the rate constant.

(d) Only the best candidates were able to give a correct mechanism in this part. One mark was awarded for a response that started the 1st step with $\text{H}_2 + 2\text{NO}_2$ as reactants. The second mark required rather more: assembling two equations that would together give the overall equation. Any reasonable (or even unreasonable) intermediates were acceptable provided that, when combined, the two steps gave the overall equation. The commonest intermediate seen was N_2O but other common intermediates included H_2O_2 , O_2 and O .

Question 2

As with **Question 1**, most candidates were able to score more than half the marks in this question although only the best were able to tackle part **2(g)**.

(a) Candidates had little problem in showing the required electron configurations. Some failed to score the second mark, the most common error being loss of 3d, rather than 4s, electrons.

(b) The majority were able to score the mark here with correct alternatives being 'catalyst' or 'coloured'. As the question asked for one property of the Fe^{2+} ion, variable oxidation states could not be credited, although the examiners were able to credit a response that implied that the Fe^{2+} ion could be changed into an ion with a different charge or oxidation state.

(c) Weaker candidates struggled with this part. It was common to see responses in which candidates attempted, often unsuccessfully, to work out the oxidation number of every species in the equation. It was not uncommon to see answers which were obviously incorrect using completely unrealistic oxidation numbers. In contrast, good candidates showed good understanding of oxidation numbers and seemed to arrive at the oxidation of iron and reduction of chromium with comparable ease. This part proved to be an excellent discriminator.

(d) Stability constants are new to this specification and most candidates made at least an attempt to show the required K_{stab} expression, although water was often incorrectly included in the expression. A substantial number of candidates used 'double brackets' to represent the concentrations of the complex ions and the examiners were able to credit this.

(e) In **(i)**, candidates were usually able to communicate the idea that oxygen is exchanged with another ligand when required. The examiners expected to see a statement that oxygen bonds to the Fe^{2+} ion in haemoglobin rather than just haemoglobin.

In **(ii)**, many candidates correctly stated that carbon monoxide forms a stronger bond in the complex which then has a greater stability constant than the complex with oxygen. Strangely, some candidates thought that the stability constant would be smaller and others omitted to refer to the stability constant at all (despite it being asked for in the question).

(f) Part **(i)** discriminated extremely well with weaker candidates often just stating that platinum was neutral as it had no charge. It was refreshing though to see many excellent explanations in terms of the 1- charge on the two Cl^- ions cancelling the 2+ charge on the platinum ion. Explanations in terms of oxidation numbers could also be credited. A common error was inclusion of a Cl_2^{2-} ion.

In **(ii)**, the majority of candidates scored two or three marks. The standard of 3-D diagrams was very good. When drawing 3-D diagrams, candidates should take care to show bonds going into the plane of the paper as dotted lines or dotted wedges. Many candidates used a 'cross' diagram, effectively looking down on the planar structure. This was, of course, far easier to draw and perfectly acceptable.

The answers to part **(iii)** were good, the majority describing that *cis*-platin bonds to DNA, preventing replication.

(g) This part was designed for candidates to apply their knowledge and understanding of platin to a new novel structure. This part was designed with stretch and challenge in mind and it was refreshing to see the excellent correct answers from the most able candidates. It should be noted that the question included many hints which, if followed, would have offered a better chance of success.

Question 3

Overall, candidates answered this question well with most scoring more than half the available marks. All candidates found part **(e)** extremely testing.

(a) In **(i)**, most candidates were able to construct the correct equation.

In **(ii)**, most candidates worked out that 3.175×10^{-3} mol of glycolic acid reacted. The critical next step was to identify from the titration curve that 22 cm^3 of NaOH was required for neutralisation and more than half the candidates obtained the correct final answer of $0.142 \text{ mol dm}^{-3}$. Strangely, some candidates instead chose 45 cm^3 , presumably as this represented the approximate total volume of NaOH added.

In **(iii)**, candidates were required to link a feature of the indicator (its colour change, pH range or end-point) with the vertical section of the titration curve or the equivalence point. This part discriminated well with most of the upper half of candidates being successful.

(b) Parts **(i)** and **(ii)** were very well answered with well over half the candidates collecting all the marks. Candidates are now very competent in carrying out calculations using the K_a expression. Perhaps predictably, part **(iii)** proved to be much more difficult with many candidates using their calculated K_a value from **(ii)** rather than $[\text{H}^+]$. Consequently only the best quarter of candidates obtained the correct dissociation of 3.4%.

(c) There were some very impressive responses to this part and many candidates had clearly learnt how a buffer solution controls pH. The explanation of buffer action is a tried and tested question and many of the responses seen were obviously rote recall from previous mark schemes for similar questions, securing five marks. The main difficulty lay in the formation of the buffer solution and a significant number of candidates ignored this part of the question altogether. Attempts at an equation between ammonia and glycolic acid often produced amines or amides rather than an ammonium salt. The hardest mark was the realisation that an excess of glycolic acid is required. For these reasons, only the best candidates were able to get more than five of the seven marks.

(d) Candidates found this part very straightforward, the majority scoring both marks with ease.

(e) This part proved to be extremely challenging for all candidates. This was designed for stretch & challenge and required candidates to apply their knowledge and understanding of acid–base equilibria to the novel information provided in the question. Disappointingly, very few candidates were able to score here, despite many candidates making an attempt at equations. Some candidates managed to write a correct equation for the second reaction but the first equation was beyond almost all candidates.

Question 4

Overall, candidates found this question more difficult with some disappointing responses to the latter parts.

(a) Part **(i)** proved to be an excellent discriminator. Most candidates were able to draw a diagram of a complete circuit with a salt bridge labelled. The two half-cells introduced some problems. It was not uncommon to see a solution of one of the tin ions with an electrode made of the other tin ion. The concentrations of the solutions were also often omitted.

In **(ii)**, middle to good candidates were able to construct correct equations. Weaker candidates had little idea of how to combine the half-equations. Non-standard conditions and a high activation energy were common creditworthy responses for explaining why reactions may not take place.

(b) In **(i)**, less than half the candidates were able to construct an equation for the combustion of methanol. This was probably the most disappointing response seen on the paper as this reaction had been encountered for the first time during AS Chemistry.

Part **(ii)** could only be answered successfully using the correct equation from **b(i)**, and the supplied half-equation. Candidates do seem to have problems combining two half-equations and it was perhaps not surprising that very few candidates were able to perform the more difficult task of deriving the other half-equation taking place in the cell.

In **(iii)**, most candidates were able to respond with one of the two required reasons: reduced CO₂ emissions and greater efficiency.

In **(iv)**, candidates were required to comment that methanol is easier to store because it is a liquid.

Question 5

Overall, this question was tackled well with some very responses to the calculation in **(b)**.

(a) Nearly all candidates attempted to explain the signs of the entropy changes but marks were lost for omitted important detail. For example, in the first change, fewer moles of gas are produced, not solely fewer moles.

(b) Most candidates made a very competent attempt at the three calculations in this part. Almost all candidates were able to show that the entropy of reaction was 0.165 kJ K⁻¹ mol⁻¹ and most then attempted to use the Gibbs' equation to show that ΔG was positive. Use of this equation introduced mistakes, with some using °C rather than Kelvin. The commonest mistake though was the omission of units for the calculated value of ΔG .

Most candidates knew that the minimum temperature for reaction would coincide with the condition when $\Delta G = 0$. Disappointingly, the temperature was often shown with no unit or with incorrect rounding.

Question 6

(a) Most candidates showed the correct expression for K_w in **(i)** and then went on to use the expression correctly in **(ii)** to calculate the concentration of hydroxide ions. Surprisingly, the commonest answer here was 2.34×10^{-14} mol dm⁻³ with many ignoring the instruction to give the answer to two significant figures. Some candidates obtained the same answer using pOH and this approach is perfectly acceptable.

(b) In **(i)**, candidates were asked to use **Fig. 6.1** but many ignored the graph and did not respond in terms of K_w changing with temperature. Weaker students wrongly assumed that the dissociation would be exothermic. The best answers went beyond the mark scheme

requirements, explaining that the increase in K_w with temperature shifts the equilibrium to the right, increasing dissociation; as K_w increased with temperature, the change must be endothermic. Some candidates also referred to the bond breaking process in dissociation being endothermic.

Able candidates tackled the calculation extremely well in **(ii)**, estimating the value of K_w at 37 °C from **Fig. 6.1** and then using this value in the K_w expression to obtain a pH close to 6.8 (the exact answer was dependent on the K_w estimate). Acceptable estimates lie in the range 2.2– $2.6 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$. Weaker students did not really know where to start and used related numbers sometimes almost at random. It was also surprising to see how poor were some of estimates of K_w with 10^{-14} being omitted on many occasions. The commonest mistake here was for candidates to calculate the $-\log$ value of the estimated K_w , to obtain a very alkaline pH of water at body temperature.

Part **(iii)** linked the possibility of anomalous scientific data to the variation of K_w with temperature and a statement that this variation might make the data invalid or inaccurate was the key requirement for an acceptable response.

(c) Enthalpy change of neutralisation is a new requirement of this specification but there was clear evidence from blank responses on a significant number of scripts that this topic had not been revised. The question was not difficult but did require candidates to generate some lucid extended writing. The key requirements were for measured amounts of an acid and alkali to be mixed together and the temperature change to be recorded. The energy change is then determined using $mc\Delta T$ which is then scaled up for the production of 1 mol of water. Finally a negative sign is needed to reflect the exothermic nature of this enthalpy change. Marks were often lost by omission of any quantities, use of $mc\Delta T$ without referencing what the symbols meant and omission of the negative sign. As with more open responses of this type, this part discriminated very well.

(d) This part created considerable problems for most candidates, the commonest errors being use of wrong particles. The different particles encountered in chemistry have always proven to be a difficult area for many candidates. It was common to see responses such as 'potassium has a smaller atomic radius' (with no reference to ions) and 'potassium fluoride has greater attraction between the molecules' (when the attraction is between K^+ and F^- ions). A successful response required candidates to identify that K^+ ions are smaller leading to greater attraction with F^- ions in the ionic lattice. K^+ ions would also attract water molecules stronger during hydration. The difference between the enthalpy changes of solution depend upon the relative sizes of lattice enthalpy and hydration enthalpies, the experimental evidence reflecting that lattice enthalpy is the dominant factor in this example. The final comparison was beyond almost all candidates and many were unable to get beyond the comparison of size and ionic attraction.

(e) Better candidates realised that the dissolving process increases entropy and that $T\Delta S$ must be greater than ΔH for the process to be feasible. Provided that $T\Delta S > \Delta H$ endothermic values of ΔH are possible. The pattern of responses here was very polarised: successful responses included entropy discussions in the answer; unsuccessful attempts usually excluded entropy entirely.

Question 7

Although this was the last question in a long examination, the vast majority of candidates attempted both parts to some credit.

(a) In **(i)**, almost all candidates identified that an easy mark was available for simply calculating the amount of thiosulfate ions.

Subsequent stages proved to be more difficult, requiring calculation of the amount of O_2 sampled, scaling up by a factor of 40 to give the O_2 concentration and final conversion to a concentration in mg dm^{-3} . The Examiners were able to credit these distinct steps, even if there

was an earlier error in a sequential calculation. The discrimination was very good and the expected answer of 7.87 mg dm^{-3} was often seen on the scripts of the best candidates. In **(ii)**, most candidates were able to decide whether the fish would survive, but not all justified their answer by comparing their answer in **(i)** and 5 mg dm^{-3} .

(b) In **(i)**, the majority of candidates were able to deduce that the correct gas is NO, although N_2H_2 was also credited. Some very unlikely responses were seen here with molar masses far in excess of 30 g mol^{-1} .

Part **(ii)** proved to be much more difficult and candidates struggled to assemble a starting equation using correct species. The examiners accepted responses using either H^+ ions or H_2O on the left-hand side. Only the very best candidates were able to balance this equation, the commonest mistakes being equations with residual charges on one side or the other.

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