GCE

Chemistry A

Advanced GCE **A2 H434**

Advanced Subsidiary GCE **AS H034**

OCR Report to Centres

January 2012

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Oxford Cambridge and RSA Examinations

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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OCR REPORT TO CENTRES

Overview

General comments

Entries this series continue to rise with over 1000 centres entering candidates for the assessment units.

The F321 entry comprises mainly of students in the first year of A-level study. The entry increased by 7% from January 2011. In this series, performance in the F321 examination is more diverse than any other unit, ranging from some superb high-flyers down to students struggling to get to grips with the higher standard of AS over GCSE.

The entry for F322 in January is almost entirely made up of re-sit candidates in the second year of their A-level course. The entry for F322 has shown a very small increase from January 2011.

The entry for F325 has doubled from about 2500 to about 5000. This reflects more centres teaching F325 prior to F324 in the A2 year. The increase in F325 entry is mirrored by a decrease, albeit smaller, in F324 entry.

Changes for 2012

This series has seen one significant change in the examinations, with an extra 15 minutes added to the examination times for the A2 units F324 and F325. This change was previously announced via a Notice to centres, see http://www.ocr.org.uk/qualifications/type/gce/science/chemistry_a/

There was no evidence that candidates had any difficulty in completing the papers in the time available this series.

Keep up-to-date with developments in GCE Chemistry

The new OCR community, www.social.ocr.org.uk , is becoming a useful reference point to help keep teachers up-to-date with GCE Chemistry (and science) developments. I would recommend visiting the site and registering if you find it useful. From 1 January we have seen the new Cambridge Chemistry Challenge launched, OCR is very pleased to be sponsoring this initiative from Cambridge University, see http://social.ocr.org.uk/groups/science/conversations/cambridge-chemistry-challenge

We are hoping to repeat the CPD Masterclass we ran last July (see http://social.ocr.org.uk/groups/science/conversations/new-asa-level-inset-gce-chemistry-0). Further details will be posted to www.social.ocr.org.uk when they are available.

F321 Atoms, Bonds and Groups

General comments

The number of candidates sitting the January F321 paper continued the trend of annual increase seen over the last three years; the number of centres entering candidates has passed the 1000 mark.

The paper discriminated well at all levels from the very weakest through to the top end. Centres had clearly prepared candidates well and questions on themes such as ionisation energy, in question 3(c), and associated periodic trends, in question 3(d), were strongly answered. Similarly strong responses were seen in areas such as defining relative isotopic mass in question 1a(i) and ionic '*dot-and-cross*' diagrams in question 2(d).

The paper illustrated the need for candidates to pause and think more carefully about what they were writing and not to assume that the answers must be the same as those of previous papers. Introducing the properties of ammonia in the unusual context of hydrazine in questions 5(b) and 5(c) presented many candidates with difficulty as they were required to apply their recall knowledge of the specification to a new context. A similar comment could be made about question 5a(i) where many used the stock definition of a salt as being an acid with its hydrogen ion being replaced by a metal ion without considering that the question specifically asked why ammonium sulfate can be described as a salt.

It is important for candidates to realise that although the material covered in this unit may appear relatively straightforward, its application can still be challenging and requires careful consideration.

The need for students to consider more carefully before supplying a response was illustrated by the often convoluted and poorly planned answers that were seen in the responses to question 4(b). For such responses, candidates are once again advised to consider the use of bullet points. (We do not require essay construction as a marking point for the extended writing responses.)

The Quality of Written Communication (QWC) marks on this paper are awarded for correct spelling of key technical words which must feature in the correct answer. Thus candidates should be advised that when the 'pencil' icon along with the accompanying statement 'In your answer, you should use appropriate technical terms spelled correctly' is seen then abbreviations such as e^-, ppt and vdW should be avoided and above all the terms used should not only be spelled correctly but also written in **legible** handwriting.

Comments on individual questions

Question 1

(a)(i) Most candidates made a sound start to the paper picking up both marks for this response. Some answers were a little muddled and it was not uncommon to see candidates refer to average or weighted mean mass which is redundant in this definition.

(a)(ii) All but a handful of candidates were able to complete the table correctly.

(b)(i) This was the first time in F321 where a response involving application of ratios of masses was required.

The expected response was to divide 70.0 by 126.9 and multiply this answer by 166.0. This route avoided the conversion of µg to g and back again.

Many candidates opted to convert 70.0 μg to moles of iodide ions which led to difficulty in appreciating where the decimal place should lie (although allowance was made for this in the marking). The second step of multiplying the number of moles of iodide ions by 166.0 created further confusion for many.

(b)(ii) The question was written with 'How Science Works' in mind but very few candidates opted to discuss any ethical problems associated with the proposal. Nearly all candidates focused on the hazards associated with either potassium, iodine or the salt. A mark was awarded for a reasoned, plausible response.

(c)(i) This was very well answered and candidates are becoming more confident in the use of ionic equations which can be used to demonstrate the reactivity of halogens.

(c)(ii) The candidates could have scored marks by answering by one of two routes. Most opted to explain that ICl had greater van der Waals' forces than Cl_2 but frequently omitted to state that this was caused by ICl having more electrons.

The other route was to use the fact that ICl has a permanent dipole and that permanent dipole–dipole attractions are stronger than the temporary dipole (or van der Waals' forces) attractions in Cl_2.

Candidates need to be aware that to assign dipole–dipole attractions to ICl would not score as Cl_2 also has dipole–dipole attractions. The key difference is that dipoles in ICl are permanent whereas those in ICl are temporary.

A very common misconception was that ICl contains covalent bonds (or even ionic bonds in a few places) in a way that Cl_2 does not so the energy needed to break the strong covalent bonds caused the difference in boiling points.

Question 2

(a) This was well answered. A number of candidates confused the precipitation test using silver nitrate with displacement reactions leading a significant minority of candidates to suggest addition of cyclohexane with a range of colour changes.

(b) Although answers to the opening part were often expressed rather badly, a pleasing number of students were able to identify that the lack of effervescence was the key point that needed to be made. Weaker candidates tended not to draw on the information from the stem of the question and suggested that **X** was the intended product, $CaCl_2$.

The majority of candidates correctly identified **X** as $CaCO_3$. $Ca(OH)_2$ was a common incorrect selection, often associated with candidates presumably having the misconception that hydroxides give off H_2 with an acid.

(c)(i) Surprisingly few candidates wrote the expected answer to this question. We were expecting to see '…*contains waters of crystallisation*…' but the majority used phraseology which suggested that there were water molecules associated with $CaCl_2$. Many candidates suggested that hydrated meant '…*being in solution*…' or even '…*with hydrogen*'.

(c)(ii) Candidates should be reminded that if the question demands that they show working, then answers **not** showing working will **not** be given full credit. Also candidates should be reminded to use the *Data Sheet*. The A_r of Cl is not 35 (nor is the A_r of Ca 40).

For many, however, the question was well answered with clear and concise working being seen. Some weaker candidates approached the calculation as if it were an empirical formula determination while others gave the formula of the anhydrous salt as $CaCl$, despite $CaCl_2$ appearing in the opening statement.

(d) Most candidates are now familiar with the typical *'dot-and-cross'* diagrams to be expected and consequently produced well executed diagrams.

Candidates need to realise that it is 'the finished product' which we are looking for and that the Ca^{2+} ion needs to have either 8 or 0 electrons in its outer shell. Candidates who show Ca^{2+} ions with 2 electrons present, usually with arrows going towards a correct Cl^- ion, are not showing the *'dot-and-cross'* diagram of $CaCl_2$.

(e) This item tested the knowledge of trends in reactivity of the two groups studied within the specification. A handful of candidates only scored one mark by simply stating the trend in reactivity within each group and not directly linking this to the two salts, but the majority of students picked up both marks.

Many responses contained detailed explanations of the reasons for the trends in reactivity. Candidates are advised to check on the number of marks available to ensure that they do not write more than is required.

Question 3

(a)(i) Weaker candidates tended to suggest that an orbital was the path or orbit taken by an electron with particle properties.

(a)(ii) Apart from the occasional electron configuration containing 32 electrons nearly all responses were correct.

(a)(iii) Most candidates assumed that the 16 electrons would occupy eight orbitals between them.

(b) The accurate concept of the mole is a difficult one for AS candidates. Better prepared candidates were able to produce a coherent definition although candidates do need to realise the difference between *particles* in 12 g of carbon 12 and *atoms* in 12 g of carbon 12. Credit was allowed for those who used the *Data Sheet* and quoted the value for N_A and related this to the number of atoms, but too many candidates seemed to have their own value for N_A.

(c) This question has now been asked before and as such elicited many responses that scored full marks. As in previous papers, the more common errors were either to fail to equate the number of electrons lost with the number of atoms (i.e. one electron being removed from one mole of atoms is incorrect) or to fail to indicate that the atoms were in the gaseous state. One mole of an element in the gaseous state does not necessarily equate to one mole of atoms in the gaseous state; take the halogens, for instance.

(d)(i) The trend in ionisation energies across a period was well known and most candidates were able to gain at least a minimum of two marks. This said, however, it is still surprising that so few candidates are able to structure their answers with many responses repeating points already made and often in this muddle omitting one of the key marking points. Addition of the data on the atomic radius helped candidates to focus on the attraction between the nucleus and the electron. A significant number of candidates presented answers which explained the data in terms of the stability of full shells.

This type of response is one where (weaker) candidates may be better advised to answer in bullet point form based upon nuclear charge, shielding and nuclear attraction. This may serve to avoid repetition or, worse still, contradiction.

(d)(ii) As with 3(d)(i), responses here too were often vague and lengthy when the marks could have been gained very succinctly. Once again weaker students based their answers on the fact that Ne had a full shell and how easy it is to lose only 1 electron from the outer shell of sodium atoms.

Question 4

(a) It was clear that many students were unaware of the types of lattice given in 1.2.2(q) of the specification. Despite a cue being given above that K had a giant metallic lattice, weaker candidates simply wrote '*ionic*' for KBr and often '…*hydrogen bonded (lattice)*…' for H_2O. Neither response received credit.

(b) This was a demanding question, not only in terms of the chemistry that was required, but also in terms of a candidate's ability to structure the answer and to make sure that they have addressed all the points in the question. Once again use of bullet points may have helped some candidates.

The forces mark for K and KBr was not always stated but candidates were awarded this mark if correct descriptions of metallic and ionic bonding were seen. Unfortunately the ubiquitous use of van der Waals' forces in K and/or KBr negated the correct response initially supplied.

The particles marks for K and KBr were initially gained but then lost by a significant number of candidates due to reference to inter*molecular* forces being present or indeed later use of incorrect terms such as atoms of K and Br being present in KBr or molecules of K being present in K.

The presence of hydrogen bonding in H_2O was the most often cited force of the three.

The particles mark for H_2O was frequently omitted but the mark was fortuitously gained by some through continued (over)use of intermolecular forces being applied to every situation.

The mark awarded the least often was for the relative strength of the forces. Most candidates did not use the melting points provided and so were content simply to say that both ionic and metallic bonds were strong in comparison to the hydrogen bonds between water molecules. Even those who had given the correct relative strengths for the bonds in KBr and K then became embroiled in an irrelevant discussion of the strength of the various intermolecular forces in water and never re-emerged to address this final part of the question.

Some very good responses were seen from candidates who produced an answer in tabular format.

(c) This question was relatively well answered. Common amongst the errors was either to forget to use the stoichiometric ratio from the equation or to use 24 in place of 24000 in the final step of the calculation.

Question 5

(a)(i) The explanation of what constitutes a salt is still not appreciated by many candidates. A significant number of candidates did not read the question in sufficient detail here and instead simply quoted a part of the definition of the salt that they had learned. Consequently they referred only to replacing the proton with a metal ion and made no mention of ammonium which was the ion specific to this question. Others failed to pick up the mark by referring to ammonia rather than ammonium.

(a)(ii) Candidates coped very well with this titration calculation. A common error was to either forget to double the calculated amount of H_2SO_4 or to apply the ratio incorrectly and so half instead of double the amount was used. A small number of candidates managed the first two steps of the calculation but were then unable to scale their answer to access the amount of NH_3 in the 400 cm^3 of solution.

(b) This question proved challenging for many. Most candidates failed to appreciate that a hydrazine molecule could be considered as an ammonia molecule with an NH_2 group being present instead of one of the hydrogen atoms.

Many candidates assumed the hydrazine molecule to be NH_2 (despite being told it was N_2H_4 and had the structure $H_2N–NH_2$) and based responses on NH_2. Consequently most candidates assumed that the molecule was either going to be like water or they ignored the single electron and thought the molecule would be trigonal planar with a bond angle somewhat less than 120°. Many candidates were able to score the two marks for their general description of the relative strengths of repulsion between lone and bonding pairs irrespective of the bond angle assumed.

(c)(i) The unusual context for specification statement 1.1.3(d) '…*An alkali is a soluble base which releases* OH^- *ions in aqueous solution…*' meant that the majority of the candidates missed out this low demand response.

(c)(ii) This was designed as a high demand response based upon NH_3's ability to accept protons and was only accessed by the strongest candidates.

(d)(i) Responses here were mixed. Almost all candidates clearly knew that they were looking to assign a species that had increased in oxidation number and one that had decreased. The correct assignment for the C*l* was only slightly ahead of the correct assignment for N, which was perhaps the more challenging. Worryingly there were many responses that allowed species such as Na, H and O to change oxidation number.

(d)(ii) Although many gave the name of the salt as sodium chlorate very few added the required oxidation number that was needed for the mark.

(d)(iii) Candidates found this challenging. N_2 was fairly commonly identified as the colourless gas with an M_r of 28.0. However, on the negative side, so was CO (despite the lack of C in the reactants) as was occasionally, Si.

Many candidates, having identified NH_4Cl and N_2 failed to go on to balance the equation. It was particularly noteworthy how many clearly were unable to make any real progress with the equation, not even being able to propose nitrogen as one of the products.

F322 Chains, Energy and Resources

General comments

There was clear evidence that candidates had used the mark schemes from previous examinations to inform their revision. There was no evidence from the scripts that candidates did not have enough time to finish the examination.

Candidates were able to apply their knowledge to novel situations and were able to demonstrate positive achievement at all levels.

Candidates were able to use the different types of formulae with confidence and there seems to be an increased use of skeletal formulae.

In terms of calculations, candidates still need to be careful in the correct use of significant figures and decimal places. Candidates need to improve the presentation of their working out so that any error carried forward can be clearly seen and given credit.

Comments on individual questions

Question 1

This question focussed on hydrocarbons and some of the fundamental concepts of organic chemistry. Candidates of all abilities were able to do well in this question. In (a), most candidates could explain why cyclohexane was a saturated hydrocarbon. The most common error was to forget to include the word ‘only’ when writing contains single bonds and hydrogen and carbon. Although a significant proportion of candidates could write CH_2 as the empirical formula in (b) others gave the general formula C_nH_{2n}. Only a small proportion of the candidates gave answers such as CH or C_3H_6.

Most candidates in (c) could identify a pair of structural isomers and only a small proportion gave **G** and **H** which were stereoisomers.

The reason why the petroleum industry processes straight chain isomers into cyclic hydrocarbons was well explained in (d)(i). Candidates used a variety of different formulae to answer (ii), the most popular being skeletal formulae. A common misconception was to draw cycloheptane rather than methylcyclohexane. A small proportion of the candidates did not appreciate that hydrogen was also formed in this reaction.

The importance of chain length or molecular size in determining the strength or number of van der Waals’ forces was well known in (e) although some candidates did confuse intermolecular forces with covalent bonds.

The definition for stereoisomerism in (f) was well known but some candidates still omit the idea that the structural formula must be the same.

In (g) almost all candidates appreciated that the products of complete combustion were carbon dioxide and water. Candidates were usually able to balance the equation but common misconceptions included giving the wrong molecular formula for C and having oxygen as O rather than O_2. Candidates were often able to give the correct equation for the cracking of $C_{16}H_{34}$. In (g) and (h) a few candidates used skeletal formulae in their equations but most used molecular formulae.

A significant proportion of the candidates in (i) could recall the definition for a functional group and showed that they had used the mark scheme from the previous series to aid their revision. Some candidates referred to a functional group determining the properties of a molecule rather than the chemical properties. Candidates found (ii) very difficult and only a small proportion were able to state the correct number of structural isomers. Answers varied from 1 to 18. The definition for a radical in (iii) was well known but a few candidates referred to the presence of a lone or single electron which was not accepted in the mark scheme.

Question 2

This question was about carboxylic acids and esters.

In (a) a significant proportion of the candidates confused atom economy with percentage yield. Good answers referred to process 1 having an atom economy of 100% with a process that made no waste products and having a high percentage yield meaning that almost all the reactants were converted into products. However, other candidates referred to process 2 having a lower percentage yield because many waste products were made. Candidates often stated that process 1 used a lower pressure and this was given credit in the mark scheme. Candidates often recognised that process 1 used a toxic reactant and that this may be desirable, while others recognised that methanol could be made from a renewable plant source. It was not sufficient to just state that process 1 came from a renewable source since most methanol manufactured in the UK comes from crude oil.

The best answers in (b)(i) used the information provided to present a coherent argument why **J** had to be an aldehyde or a ketone. These candidates used the wavenumbers of the absorbances and the *Data Sheet* to identify the presence of a carbonyl group. Candidates often neglected to mention the absence of a characteristic carboxylic acid O–H absorbance and so rule out **J** as a carboxylic acid. Some candidates referred to C–O absorbances as evidence for carboxylic acids. Almost all the candidates were able to work out the molar mass of **J** as 86 g mol^{-1}. In (ii) almost all candidates gave the structure for butanoic acid rather than methylpropanoic acid. If candidates made a mistake with this part question it was more likely with the name of **K** rather than its structure.

Many candidates did not specify that propan-1-ol was the alcohol needed to make propyl ethanoate in (c) often just referring to propanol. A correct equation using structural formula could earn three marks and a significant proportion only got the mark for propan-1-ol from a structure such as $CH_3CH_2CH_2OH$ in the equation. The use of an acid catalyst such as sulfuric acid was well known. A significant proportion of the candidates could not draw the structure for the ester although the mark scheme allowed just the molecular formula. Other candidates did not include water as the other product formed in esterification.

Question 3

This question was about enthalpy changes.

In (a) many candidates could recall the equation $q = mc\Delta T$ but a small proportion used the wrong mass or the wrong temperature change. Candidates could use either the 50.0 g of acid or 50.486 g of acid and magnesium instead. Candidates who used 0.486 were not awarded any marks for (i). Although most candidates gave the correct answer of 2.6752 kJ, other candidates were not able to convert from J to kJ. Almost all candidates could calculate the number of moles of magnesium used to be 0.0200 however there was evidence that a small number of candidates used the relative atomic mass of magnesium of 24 rather than the 24.3 in the *Data Sheet*. Candidates had most difficulty with (iii) and often did not get the correct answer of –134 kJ mol^{-1}. Many did not quote the number to three significant figures and others did not give the correct sign. In (iii), error carried forward was allowed and as a result many candidates could demonstrate their understanding of calculating an enthalpy change of reaction despite making errors in (i) and/or (ii).

Many candidates could define the standard enthalpy change of formation in (b)(i) but they sometimes forgot to quote the actual conditions as required in the question. Reference to 1 mol dm^{-3} in an answer was ignored in the mark scheme. Candidates often had difficulty putting the correct numerical values into the boxes in (ii). A significant proportion of candidates included a running total rather than the actual values provided and others put the same values in several times. The correct answer was –792 kJ mol^{-1} and some candidates got this even though they had put the numbers into the wrong boxes. Candidates found this style of question involving an enthalpy cycle more demanding than calculations involving enthalpy changes of formation.

Question 4

This question was about the reaction between hydrogen and chlorine.

Only a small proportion of the candidates were able to get the correct answer of +431.5 kJ mol^{-1} in (a), others got the negative value and some got double the answer. Candidates were not able to use their understanding of bond making and bond breaking to calculate the bond enthalpy and often were only able to calculate that +679 kJ were needed to break bonds.

In (b) candidates needed to state that the rate of reaction increased to be awarded full marks and candidates rarely forgot to state this. Some candidates just stated there were more particles and more collisions rather than qualifying both ideas in terms of more particles per unit volume and more collisions per second. Candidates needed to refer to particles or molecules in the answer but a small number referred to atoms which in this case is incorrect.

Some candidates were able to draw excellent Boltzmann distributions in (c) but other candidates needed to take much more care to ensure that the axes were correctly labelled, the curves were going through the origin and that the two different curves were clearly labelled. Only a small proportion of candidates thought that the activation energy changed but hardly any candidate actually stated this in their answer. The marking point was almost always given by the drawing of one activation energy on the graph. A small proportion of the candidates drew their two curves on different axes. In this case it was impossible to award some of the marking points. Many candidates correctly referred to fewer successful collisions.

In (d), candidates were able to apply their understanding of the mechanism of radical substitution of alkanes to the reaction between hydrogen and chlorine. Candidates were most likely to make an error in (iii) giving equations such as $HCl + HCl \rightarrow H_2Cl_2$.

Question 5

This question focussed on the manufacture of sulfuric acid using the Contact Process and the dehydration of alcohols using concentrated sulfuric acid.

Candidates were often able to explain why the reaction had a 100% atom economy in (a) although many referred to the reaction as an addition reaction. This error was ignored in the mark scheme.

Candidates found the percentage yield calculation in (b) quite demanding and rarely gave the correct answer of 94%. Candidates often got very confused with the powers of ten and the use of tonnes. Most candidates tried to work in grams and used the approach of calculating the actual and predicted amounts in moles. The most common misconception was to calculate the percentage yield straight from the masses given, i.e. getting 35% from an actual mass of 51.5 tonnes and a predicted mass of 147 tonnes. Full credit was given to candidates who worked with 51.4 g and 147 g and so avoided the issues of powers of ten.

Many candidates appreciated that the position of equilibrium did not change in (c)(i) but were less certain about the effect on the reverse reaction often quoting no change or that it went faster. Candidates could often apply le Chatelier's principle to the given reaction but found (iii) more difficult than (ii).

In (d), many could draw a primary alcohol and only a very small proportion gave the one given in the question. In (ii), candidates found it very difficult to get all three structures. The two stereoisomers were more likely to be correct but a branched structure was often given for **N**. Candidates often gave **N** as $C_3H_7CHCH_2$ and this was not given credit since the structure was ambiguous and could be a branched chain or a straight chain. A common misconception in (iii) was to draw the primary alcohol $(CH_3)_3CCH_2OH$.

Question 6

Most candidates in (a) could identify the *m*/*z* value as 46 although a small proportion gave 45 or 31 instead. The most popular correct answers were CH_2OH^+ or CH_3O^+ but a common misconception was not to include the charge or even put a negative sign. A small number of candidates included answers such as $C_2H_7^+$ or combinations that did not have a *m*/*z* of 3. A significant proportion of candidates realised that **O** was ethanol and gave a structural formula rather than the molecular formula that was asked for in the question.

Although a significant number of candidates could identify copper in (b) they often did not get full marks because they did not quote their answer to one decimal place or rounded up incorrectly and quoted 63.5 (the *Data Sheet* value) rather than 63.6, the calculated value.

Question 7

This question focussed on the chemistry of CFCs and was the most demanding question on the examination paper.

In (a), common misconceptions included the shape being pyramidal and the bond angle being 120 or 90°.

Candidates in (b) could often give a reason why CFCs were developed as aerosols but could not suggest why CF_2Cl_2 does not hydrolyse. Most candidates referred to the inability to form hydrogen bonds or it would not dissolve in water. Other candidates stated that the molecule was non-polar or had non-polar bonds. Candidates did not apply their knowledge of the hydrolysis of halogenoalkanes to appreciate that the C–Hal bonds were very strong and so difficult to break. In (c), the best answers gave three equations involving the initiation and propagation reactions. A common misconception was that the initiation reaction was the homolytic fission of a chlorine molecule or the wrong formula for a CFC was used. Another misconception was that chlorine radicals reacted with oxygen molecules rather than oxygen atoms or ozone molecules. The idea that chlorine radicals catalyse the decomposition of ozone was well known.

In (d), candidates needed to refer to both UV light and increased effects on the Earth's surface such as increased risk of skin cancer. Some candidates gave vague answers that only referred to radiation rather than UV.

Candidates had to refer to two ideas in (e), one related to the continued use of CFCs and the other to the long residence time in the atmosphere. Candidates often referred to these ideas but were imprecise with their answers, for example referring to CFCs taking a long time to reach the atmosphere rather than a long time to reach the upper atmosphere.

Question 8

This question focussed on the reactions of some cyclo-compounds and reaction mechanisms.

Compounds **Q** and **R** were most likely to be correct. A common misconception for **P** was to have a pentavalent carbon, having a carbonyl and a hydroxyl group attached.
The colour change in (b) was well known but a small proportion of candidates gave the change for the reduction of acidified potassium dichromate(VI) instead.

A small proportion of candidates were able to draw the section of the polymer in (c) but other candidates linked the cyclopentane groups through carbon 1 and 3 instead. A significant number of candidates drew correct skeletal representations of the polymer.

The mechanism for the electrophilic addition reaction in (d) was well known but many errors were due to careless placement of the curly arrows. A small proportion of candidates changed halogens or used bromine as the molecule added. A common misconception was to put partial charges on the double bond or to start the curly arrow from a carbon atom.

Similar comments can be made for the nucleophilic substitution reaction in (e) but this time partial charges were often shown for the hydroxide ion and the chloride ion. Candidates must also take care to show that the curly arrow comes from the lone pair or the minus sign of the hydroxide ion. Candidates did not attempt an S_N1 reaction mechanism and found difficulty in spelling heterolytic.

F324 Rings, Polymers and Analysis

General comments

Candidates seemed to find most parts of the paper very accessible. This was the first examination that had the extra 15 minutes allocated to it and it appeared that candidates had made good use of this. The paper produced a full spread of marks from 1 to 60. There were still the usual errors made by candidates in structures of leaving out Hs (which is very important given the increasing use of skeletal formulae and mixed varieties involving skeletal formulae and symbols) and with errors in connectivity. Most papers were legible and relatively easy to mark but there were some highly disorganised and untidy scripts. Some work was hard to read possibly because of the use of unsuitable pens and also pencil, particularly for structures. This was exacerbated when a candidate then tried to erase part of an answer and replace it.

Comments on individual questions

Question 1

(a) The majority of candidates gave a correct definition of the isoelectric point and most were able to draw correct structures of alanine at the two pH values. The most common error was putting NH_2 in the ion formed at pH 1.5. Many showed the correct functional groups in (iii) but they were frequently reversed and some used ‘amide’ rather than ‘amine’.

(b) Most candidates gave a correct peptide link but marks were lost by showing more than two repeat units, by missing H from C or N, or omitting continuation bonds.

(c) Most candidates were able to explain why glycine does not show optical isomerism. However, in part (ii) many lost marks due to poorly drawn diagrams resulting in the central carbon being bonded to the H or S on the CH_2SH, or the H on the NH_2. Students should be encouraged to draw a second optical isomer as a mirror image of their first structure, and to avoid having the two bonds in the plane of the paper at 90 or 180º. A few candidates made no attempt at a 3-D structure by not using any ‘in’ or ‘out’ wedges.

Many candidates scored full marks in part (iii); some lost marks by repeating the same process for the synthesis of a single optical isomer, or giving transition metal complexes as a method of synthesising one isomer without stating that the complex should itself be chiral or stereoselective.

(d) Most answers were fully correct and very few candidates scored no marks here.

(e) This was a difficult question and it was encouraging to see so many good attempts at drawing a structure for the cyclic dimers. Minor errors in the first dimer included omitting the Hs on the N atoms. The proline anhydride structure proved the more difficult, with some good attempts having the nitrogen atoms bonded to hydrogen in an otherwise correct structure. Others who tried to use displayed structures often had trivalent C atoms due to missing hydrogen atoms in the structures.

Question 2

(a)(i) There were very many good answers to (i) with most students showing a good recall of the reagents and particularly the structures. However, a number of candidates included, for chlorination, a ‘halogen carrier’ alone without the chlorine itself! Some suggested HNO_2 or NO_2 for nitration, Sn and H_2SO_4 for reduction and a few added NaOH as well as Sn and HCl for reduction. Credit was given if it was clear that adding the NaOH was a second step (to liberate the amine). The very weakest candidates simply made up reagents.

(a)(ii) was also well-answered. Most common mistakes were a '+' charge in the wrong place, a triple bond between the nitrogens in the azo dye or missing chlorine atoms. The mark scheme was generous in allowing the phenol part to be substituted at any carbon (i.e. the 2-, 3- or 4-position for the –OH).

(b) Most candidates showed a good knowledge of the mechanism for electrophilic substitution and many scored highly. A common error was a missing curly arrow from the S=O bond to the oxygen. In the intermediate, many omitted the negative charge on O, kept three double S=O bonds or did not fully display the SO_3 part. Some had the curly arrow coming from the H atom rather than the bond.

(c)(i) This was very well answered though occasionally candidates tried to substitute bromine on the nitrogen or tried to react sodium with the amide part of the structure.

(c)(ii) This was meant to be more challenging and certainly proved to be so. Many correctly showed sodium ethanoate but the sodium salt of 4-aminophenol was not always shown — even when the phenol group had been shown as its sodium salt in part (i). Some candidates gained one mark for showing the carboxylic acid and phenol instead of the sodium salts. Some did not really appreciate how to attempt to hydrolyse paracetamol into two different structures and built their two answers around the original molecule.

Question 3

(a) The majority of candidates correctly mentioned the required tests for part (i). Sometimes an orange/red/yellow solution or just a colour was given as the result of using Brady's reagent. Although the question asked for a series of tests, a significant number only mentioned use of Tollens' reagent. Many must have read on to part (ii) and returned to (i) to add Brady's reagent with arrows or asterisks to indicate it should come first.

There were also many good answers to part (ii); however, some failed to score by mentioning boiling points rather than melting points. A large number of candidates unnecessarily described the purification procedures prior to taking the melting point. A minority had not read the question and suggested a spectroscopic method and a few others suggested chromatography.

(b)(i) Although most students were able to show some correct structures in part (i), few scored all six marks. Common errors included additional terminal oxygen atoms and no double bonds in one or both of the monomers for synthesis 2. Many candidates seemed to have worked back from the polymer product to get the correct reduction product in synthesis 2, but then still gave an alkene–aldehyde rather than the correct alkene–carboxylic acid as the product of elimination.

In synthesis 3, the main errors seemed to be careless, such as an extra carbon in the diacid, a missing carbon in the diol and incorrectly connected OH groups. Other candidates had too many oxygen atoms in the repeat unit or tried to put more than the required one repeat unit.

(b)(ii) was generally well-answered, with some losing the mark by referring to esterification rather than condensation.

Question 4

(a) This was generally well-answered but some lost marks due to carelessness in the structural formulae, particularly that of the ester. The mark scheme allowed the second mark for a correct structure of the reactants and the other organic product, ethanoic acid.

(b)(i) Many correctly realised this was concerned with (relative) solubility. Absorption, adsorption and partition were the most common responses which did not receive credit.

(b)(ii) This was not very well answered at all with many candidates either failing to understand the question or failing to address the issue of the comparative length of the retention times. Many others did not explain their answers as was required in the question. For example, candidates would state that the esters would have similar retention times but with no reasons. Of the others that did attempt to address the question of retention times, many had the alkane and alcohol retention times the wrong way round. Some candidates thought that the alcohol would form hydrogen bonds with the stationary phase and so have a long retention time. Many gave good generalised answers but were not specific enough in their references to the four given compounds in the mixture. Others discussed compounds other than those in the mixture.

(c) There were some excellent answers to this question as many students used the information sensibly and logically and were able to arrive at either the correct structure or one which was nearly correct for the ester.

Most candidates started by correctly working out the empirical formula and using the mass spectrum to find the M_r of 144 for the ester and hence the correct molecular formula. A few selected an incorrect M_r from the mass spectrum — 149 and 157 were the most common incorrect ones seen. Others unfortunately obtained the correct molecular formula but then came up with structures for the ester which did not match this molecular formula.

The NMR analysis was pleasingly attempted by many but, weaker candidates, whilst being able to identify some peaks, could not link the peaks and splitting patterns to produce a correct or nearly correct ester structure. Even some good candidates lost marks by not explicitly stating the groups associated with each peak, or by not clearly stating the information given by the splitting patterns. The most common omission was the interpretation of the peak at chemical shift 0.9 ppm, with $C(CH_3)_3$ often missed out. In the final ester structure the most common structural error was to have a straight chain ester with a propyl group. There were a number of instances of the ester link being reversed. There were too many examples of poor descriptions of adjacent hydrogens/protons. Students should certainly be discouraged from using abbreviations and text-talk such as '…*OH on a C*…' for '…*no hydrogens on adjacent carbon*…'!

F325 Equilibria, Energetics and Elements

General comments

This was the first F325 examination for which an extra 15 minutes had been allocated for candidates to complete the paper. There was no evidence of candidates not completing the paper, nor of rushed responses to the latter questions.

The Examiners were impressed with the high standard of many of the scripts. Very able candidates excelled and were able to score very high marks. Very poor scripts were seen comparatively rarely.

Many candidates were extremely well prepared for this examination and questions assessing knowledge and understanding were often extremely well answered. Candidates started to encounter difficulties when confronted with questions set in an unfamiliar context and when attempting questions that assessed application of knowledge and understanding. It was in these areas that strong candidates were able to really shine.

Overall most candidates had the mathematical and calculator skills required to tackle the calculations on this paper. Rounding errors do continue to lose candidates marks. These often resulted from truncating, rather than rounding, a number e.g. 907.9 K to 907 K. Some candidates over-rounded numbers at an early stage of a calculation, using these values to obtain a final answer with more significance. In an unstructured calculation, ideally any rounding should take place at the end using either the significance of numbers provided in the question or requirements in the question itself.

It was impressive to see the level of chemistry knowledge and understanding displayed by many of the candidates, many taking this assessment unit in the first half of the A2 year. The demands of A2 are a step up from AS and it was refreshing to see that many had taken this challenge in their stride.

Comments on individual questions

Question 1

(a) Analysis of initial rates is one of the easier parts of the specification and the majority of candidates completed this part with comparative ease. Most were able to link the horizontal line in the graph to zero-order where the rate is unaffected by concentration. The data in the table was analysed well with few being distracted by the factor of 2.5 for HCl. Those that were distracted often incorrectly chose a scaling factor of 2 or concluded that the reaction was second-order with respect to HCl.

A correct rate equation and rate constant of 7.00×10^{-5} dm^3 mol^{-1} s^{-1} were seen on most scripts, the only common error being incorrect units, e.g. mol dm^{-3} s^{-1} or omission of s^{-1} altogether.

(b) Candidates found this part more testing. The first mark was available for a first step equation in which the reactants matched the species in the rate equation. Candidates were then often able to complete the equation for the first step and to provide an equation for the second step such that the two steps added up to the overall equation. This was frequently not the case and candidates are advised to check that each step is balanced and that the combined steps are a reflection of the overall equation.

Question 2

(a) The commonest error was to use 1 mol of gaseous ions. It was disappointing to see some able candidates throwing away such easy marks.

(b)(i) Almost all candidates correctly labelled each box and collected the three available marks with ease.

(b)(ii) A calculation of an unknown value from Born–Haber related data causes two notable problems: the inability to manipulate different signs and the need to consider '2' for the atomisation and first ionisation energy of sodium. Although a good proportion of candidates did obtain the correct value of –2520 kJ mol^{-1}, many omitted the factor of '2' entirely and obtained –1916 kJ mol^{-1}, a response that was credited with 1 mark. The Examiners did see many other numerical values resulting from a combination of the factor '2', incorrect signs or wrongly transcribed values from the table. This is clearly an area requiring more practice and care.

(c) This part essentially assessed the different factors affecting lattice enthalpies. The Examiners required a comparison of the ionic sizes and charges of Na^+ and Mg^{2+} and the ionic sizes of O^{2-} and S^{2-}. An additional requirement was the consequential effect on attraction between ions, making it difficult to predict the relative sizes of the lattice enthalpies of Na_2O and MgS. Weaker candidates often compared the attraction on outer electrons from numbers of shells and shielding (from F321). Responses often interchanged the words ions and atoms and it was not uncommon to see O^- discussed. The Examiners ignored such particle errors or very few would have scored at all, although use of 'molecules' was a misconception too far.

(d) This was set in a completely new context and, although almost all attempted the two parts, the attempts were often completely unsuccessful.

(i) Examiners were looking for a statement that the enthalpy changes included formation of the carbonate ion from its component elements. This was clearly beyond all but the very ablest of candidates with many discussing the breaking up the carbonate ion.

(ii) Most candidates attempted to construct the required Born–Haber cycle, the part associated with lattice enthalpy being the most successfully answered. It should be stressed that state symbols are essential when showing changes within these energy cycles. The factor of '2' was often omitted for the hydration of sodium ions. Cycles associated with solution need to be carefully planned. The majority of cycles seen showed an endothermic enthalpy change of solution, rather than the exothermic change required by the question. The most able candidates were able to construct this cycle and were rewarded with 3 marks. The attempts of weaker candidates often included ions of carbon and oxygen or CO_3^- and $NaCO_3$.

Question 3

(a) Candidates generally answered this part well and it was comparatively rare to see an incorrect configuration for a cobalt atom. Candidates found the configuration for a cobalt ion more difficult, common errors being removal of all 3 electrons from the 3d sub-shell and also formation of $4s^1 3d^5$, presumably by analogy with a chromium atom. The analogy should have been with $3d^6$ in Fe^{2+}.

(b) Most candidates successfully responded in terms of colour or catalyst. As cobalt(II) and cobalt(III) were exemplified in the question, the Examiners did not allow a response in terms of different oxidation numbers.

(c) Examiners awarded this mark to most candidates, with many near perfect definitions being seen. Electron pair donation to a metal ion was required and the omission of 'metal' was the main reason for not awarding the mark.

(d) In contrast to (a), (b) and (c), the responses to this part were disappointing, especially as these reactions of Co^{2+} are taken straight from the specification. Many candidates were confused between precipitation in (i) and ligand substitution in (ii).

(i) The Examiners required $Co(OH)_2$ or $Co(OH)_2(H_2O)_4$. Although $Co(OH)_2$ was often seen, it was disappointing to see this formula associated with a charge or even the '$_2$' being shown inside the parentheses. Many candidates thought that this reaction was ligand substitution.

(ii) Success here was rarer than in (i) with $CoCl_2$ being seen often. Where a charge for the $CoCl_4^{2-}$ ion had been included, this was sometimes shown as 4– rather than 2–. The type of reaction given was often imprecise, ligand substitution being required rather than just 'substitution' or 'displacement'. Nucleophilic substitution was also a notable incorrect response.

(e) This part was set in an unfamiliar context that mirrored some early experimental investigations into complex ions.

(i) Candidates coped very well with this part, often presenting four complete structures that could be awarded all 4 marks. The Examiners were impressed that almost all candidates had been careful to show all coordinate bonds from the metal ion to the nitrogen atom of each NH_3 ligand. Some showed incorrect connectivity to NH_3 ligands on the left-hand side of the complex ion and this was not credited the first time it was seen. Some also showed Cl^- rather than Cl.

(ii) This part discriminated extremely well with able candidates identifying the link between the amount of AgCl precipitate obtained and the amount of complex used, and then realising that only complex **B** contained $2Cl^-$. The majority of candidates did not realise that the precipitate was AgCl, instead dividing 2.868 by 0.01 mol of complex. Those that did use silver chloride often thought its formula was $AgCl_2$. Some obtained 2Cl by completely incorrect logic. Many then thought that the complex was **C** or **D**, presumably from the two Cl ligands in the complex ion rather than the $2Cl^-$ ions in the formula of the overall complex.

Question 4

Most of this question was tackled well although (d)(ii) did cause problems for all but the most able candidates.

(a)(i) This straightforward part was answered correctly by almost all candidates although it should be noted that the Examiners did require a comparison between the full and partial dissociations of the two types of acid.

(a)(ii) This was generally answered well but candidates should be reminded that the K_a expression contains both $[H^+]$ and the concentration of the conjugate base as numerator, rather than just $[H^+]^2$. Some omitted a sign from NO_2^-.

(a)(iii) Almost all were able to obtain either the correct pH of 1.89 for 2 marks or a rounded pH value of 1.9 for 1 mark. Modern calculators render weak acid pH calculations a relatively easy task and most candidates encountered few problems, even when handling a square root of two terms.

(a)(iv) In this part marks were lost mainly from omitting a charge on $H_2NO_2^+$. The Examiners were also often presented with an equilibrium that did not balance or even an equilibrium with no H on the right-hand side. A second mark could not be awarded unless the equilibrium contained two acid–base pairs. Some candidates transferred a proton from HNO_2 to HNO_3 for which a second mark could still be credited by error carried forward.

(b)(i) Almost all candidates responded with '…*a proton acceptor*…', although there was a smattering of '…*proton donor*…'.

(b)(ii) Most candidates obtained at least 2 of the 3 available marks but only the best candidates obtained the correct pH value of 2.90 for all 3 marks. The commonest error was not considering that the hydroxide concentration would be twice that of $Ca(OH)_2$. This omission resulted in an answer of 12.60 which was awarded 2 marks. Some realised that $2OH^-$ were involved but divided, instead of multiplied, the concentration of $Ca(OH)_2$ by 2, arriving at a pH value of 12.30 which also gained 2 marks. A significant number of candidates approached this problem using pOH and this approach was perfectly acceptable, receiving full credit if correct. It was disappointing to see the common incorrect pH response of 1.40 from –log 0.04, an acid pH which received no credit at all.

(c) Candidates found the acid equations here easier than in recent papers. The commonest error was a failure to balance the equation between calcium hydroxide and nitrous acid.

(d)(i) The majority of candidates responded with well-practised answers for the mode of action of a buffer solution, obtaining the full 5 marks for this part with ease. Most candidates explained the role of equilibrium shift in their response.

Significantly there were some candidates who had obviously not learnt this part of the specification and it was rare to be able to credit their responses with any marks at all.

(d)(ii) This part proved to be very testing for weaker candidates who seemed to have little idea of where to start. In contrast, able candidates were able to work through a logical calculation in which they first calculated K_a using the data at pH 7.4 before obtaining the correct 6.6 : 1 ratio for all 5 marks. Consequently, this part discriminated extremely well.

Sometimes, weaker candidates did secure some marks by calculating $[H^+]$ at pH 7.2 and 7.4 but the attempts usually then fizzled out. Some attempted to work out K_a using the weak acid approximation of $[H^+]^2/[HA]$, a method that is obviously flawed as a buffer solution relies partly on $[A^-]$ being much greater than $[H^+]$. Some others got in a muddle between HA and A^- and obtained the ratio the wrong way round. Others inverted the 10.5 : 1 ratio at pH 7.4 to obtain an answer of 16.6 : 1, which could obtain some credit via error carried forward. The Examiners did experience some problems trying to make sense of many confused pages of numbers with little indication of what each value was intended to be. Candidates should be encouraged to organise their responses to such questions to make it clearer for the Examiner.

Question 5

Overall, candidates tackled this question well.

(a)(i) This part was answered particularly well with most candidates constructing a correct circuit with a correct nickel half-cell. The Fe^{3+}/Fe^{2+} ion half-cell proved to be more difficult and only the better candidates used a platinum electrode and stated the need for the ions to have the same concentration. Weaker candidates often used an electrode made of one of the ions or iron itself or introduced hydrogen as well as platinum.

(a)(ii) The correct cell potentials of 1.02 and 0.49 V were often seen although often matched to the wrong sign for the nickel electrode.

(b) Many candidates obtained the first two marks available for showing correct equations for each half-cell. Fewer explained that the change in cell potentials reflected a change in the concentrations of ions in each half-cell. Although the question asked for equations, many did not include any. The first two marks were not awarded unless correct equations had been included.

(c)(i) Candidates answered this part well. The Examiners credited a correct equation in which MH had lost an electron, either by reaction with OH^- or by formation of H^+.

(c)(ii) This easy mark was collected by almost all, for either '…*adsorption*…' or '…*as a liquid under pressure*…'.

Question 6

(a) Almost all knew the Gibbs' equation and were awarded the mark.

(b) Two marks were awarded in most cases, showing that most candidates are able to recognise the sign of an entropy change from the different physical states and stoichiometry of equations.

(c) Most candidates were awarded the 2 marks for obtaining the correct entropy change of 185 J K^{-1} mol^{-1}. The commonest error seen was the predictable wrong sign: –185.

(d) This part caused problems for many. In this reaction, $T\Delta S$ becomes more negative as temperature increases. At high temperatures, $T\Delta S$ would become more negative than ΔH and $\Delta H - T\Delta S$ would then become positive. It should be stressed to candidates that '…*more negative than*…' should be used rather than '…*greater than*…', which means the opposite when comparing negative values.

(e) In comparison to the explanation required in (d), this calculation was answered well with most candidates obtaining the correct minimum temperature of 908 K. Some did not convert the given entropy change J K^{-1} mol^{-1} to kJ K^{-1} mol^{-1} and obtained a minimum temperature of 0.9 K, a value so low that it should have indicated that an error had been made. The question did ask for working and the first mark was awarded for evidence that the minimum temperature is reached when ΔG or $\Delta H - T\Delta S = 0$. This then justifies subsequent use of the expression $T = \Delta H/\Delta S$.

Question 7

(a) Candidates found this calculation challenging but the best candidates were able to obtain the correct answer of 0.0781 dm^3 mol^{-1} and to be awarded all five marks. The Examiners looked for a correct method and credit could be given for each step in this unstructured problem by error carried forward. Working out the equilibrium amount of N_2O_4 proved to be the most difficult step, with many ignoring the stoichiometry in the equation and obtaining 0.8 mol rather than 0.4 mol N_2O_4. Others did not work out concentrations, omitting the division by 2 of the equilibrium amounts.

(b) This part proved to be much tougher than the calculation in (a) but the Examiners were hugely impressed by some excellent explanations of a very difficult concept.

Many candidates correctly stated that K_c would not change. Only the best candidates then went on to consider that increased pressure would increase the denominator in this K_c expression more than the numerator. The equilibrium would then shift to the right, increasing the numerator concentration term and decreasing the denominator term to restore the K_c value. This challenging idea is beyond some candidates but stresses the importance of K_c in shifting the position of equilibrium rather than '…*le Chatelier's principle*…' quoted in many weaker responses.

Question 8

(a) Surprisingly, the straightforward equation here caused candidates more problems than the redox equations in (b), perhaps as this equation had to be constructed from scratch. Many candidates did not even start with iron(III) oxide, with $Fe(OH)_3$ or Fe^{3+} being seen often.

(b) As the relevant half-equations were given in the question, candidates had a head start and those able to combine equations were able to collect the 2 marks. Weaker candidates were unable to tackle this task successfully.

(c) This unstructured titration calculation required distinct stages. Many were able to calculate the amount of $Cr_2O_7^{2-}$ used in the titration and to multiply this by 6 and then by 10 to determine the amount of Fe^{2+} in the 250 cm^3 solution. The next step caused the most problems, despite just requiring multiplication by 55.8 to obtain the mass of Fe^{2+} in the ore. Many candidates were diverted by iron(III) oxide, Fe_2O_3, and these first divided or multiplied by 2 and then used 159.6 instead of 55.8. The final percentage stage was far easier. The correct answer of 54.6% was seen on many scripts with error carried forward being applied for candidates who had omitted, or who had errors in, one of the intermediate stages.

(d) Although most candidates attempted this part, only the very best linked the problem to Cl^- /Cl_2. Consequently this part discriminated extremely well. Successful responses identified that the electrode potential of MnO_4^- is more positive than for Cl_2, resulting in a reaction with Cl^- ions and the release of chlorine gas. It was far more common to see responses comparing the ease of seeing the end-points of the two titrations being compared.

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