

Chemistry A

Advanced GCE A2 H434

Advanced Subsidiary GCE AS H034

OCR Report to Centres

January 2013

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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.

OCR will not enter into any discussion or correspondence in connection with this report.

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OCR REPORT TO CENTRES

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Overview

General Comments

Entries this session continue to rise across all assessment units.

The F321 entry comprises mainly of students in the first year of A-level study. The entry showed a small increase on the entry from January 2012.

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 was similar to that in January 2012.

The entry for F325 in January has increased over the last 3 years from ~2,500 in January 2011 to ~5,000 in January 2012 to ~7,000 in January 2013. This reflects more centres teaching F325 prior to F324 in the A2 year. The increase in F325 entry is echoed by a relatively small decrease in F324 entry.

Additional responses

F321, F322, F324 and F325 are now marked online with all scripts being scanned. When marking, examiners see only the part of the examination paper that has been allocated for the response.

Inevitably some candidates find the allocated space insufficient for their responses. Question papers often include pages for additional responses, and an extra answer booklet supplied by the centre can also be used. Examiners check the additional pages and answer booklets to ensure that any extra responses are seen. If a candidate uses additional pages, it helps the examiner to find a response if the candidate has indicated this on their script with comments such as 'Please see additional page'.

Some candidates squeeze extra responses down the side of a page or sometimes put extended responses at the bottom of a page. It help examiners to find these extra responses if the candidate indicates this in some way.

Last January series

Last year Ofqual announced that there will be no longer be January exams available for students from September 2013, whether in the first or second year of A level study. Therefore, we have now completed the last January series that will be available at A Level, with students only having the option to take exams in the summer.

Keep up-to-date with developments in GCE Chemistry

The 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.

On 1 January we saw another year of the 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>

OCR are organising a CPD Chemistry Conference on 1 July in London (see <http://social.ocr.org.uk/groups/science/conversations/new-ocr-chemistry-conference-theory-practice>). This event will include practical demonstrations by the Naked Scientists, as well as sessions on other key areas of Chemistry. Further details will be posted to www.social.ocr.org.uk when they are available.

F321 Atoms, Bonds and Groups

General Comments

Once again, the entry showed an increase on the previous January session and this year was marginally short of 30,000 candidates. The responses seen suggested that the majority of candidates had been well-prepared for the paper and candidates were able to attempt all the questions. Many of the recall style responses showed candidates were familiar with the expected assessable learning outcomes contained within the specification.

For many candidates, F321 is the first paper they meet following GCSE and the examiners noticed that there was a certain post-GCSE naivety with respect to using correct terminology, eg in Q1(a)(i), candidates referred to isotopes as 'elements' rather than 'atoms'; in Q3(c), candidates used the term 'nuclear charge' in place of 'nuclear attraction', and in 4(a), candidates used the term 'barium atoms' instead of 'barium ions'.

Questions which posed difficulty included those where non-recall formulae were asked for, eg Q3e(i) and 3e(ii). The calculation questions seen in the paper did not pose the difficulty seen with such questions in previous years.

Comments on Individual Questions

Question 1

1(a)(i) Although this was a very straightforward definition with which to open the paper, a significant number of candidates failed to pick up this first mark. Almost always this was because they omitted to mention 'atoms of an element' and instead referred to 'elements' with different numbers of neutrons. This is an example of where clear knowledge of the terminology would be helpful to candidates.

1(a)(ii) Nearly all candidates were able to secure this mark.

1(a)(iii) If this question had been based upon its usual format of asking for a definition of relative atomic mass there is no doubt that nearly all candidates would have written 'compared to $1/12^{\text{th}}$ the mass of C-12'. By asking the question in an unfamiliar way the degree of successful responses was considerably less than when a simple definition of relative atomic mass has been requested. This suggests that many candidates rely upon simple recall of a definition without understanding the meaning of that definition.

Frequently seen incorrect answers to this question centred upon units such as g mol^{-1} or amu; however, the most commonly seen response was in fact the correct answer of carbon 12.

1(b)(i) This part discriminated well, with many of the less able candidates of the cohort assuming the oxidation number of hydrogen in water to be +2.

1(b)(ii) On the whole candidates coped well with this unstructured calculation and the correct response of 3.6 dm^3 was frequently seen. Many candidates were able to secure marks for carrying forward an earlier error. This applied if an incorrect number of moles of WO_3 had been calculated or the 1 : 3 stoichiometric ratio of WO_3 to H_2 had not been used.

Question 2

- 2(a)** This familiar question was very well answered. The commonest error was the omission of the key word **pair** from the expected response of 'a shared pair of electrons'.
- 2(b)(i)** Almost every candidate gained a mark here for stating that electron pairs repel, albeit as part of the frequently seen phrase 'lone pairs repel more than bonding pairs'. Most went on to develop their answer in terms of the different degrees of repulsion between bonding and lone pairs, but only the better candidates realised that it is the number of bonding **and** lone pairs that determines the shape of the molecule.
- 2(b)(ii)** Good candidates had no problem with both angles. The diagram helped the weaker candidates identify the O–B–O bond angle of 120° but conversely the same diagram hindered the same group of candidates as often 180° was seen for the B–O–H bond angle.
- 2(b)(iii)** The majority of candidates knew the specification well enough to produce the correct answer of SF₆ as an example of a molecule with 90° bond angles. CH₄ was frequently seen as an incorrect response presumably based upon a flat representation of its displayed formula.

Question 3

- 3(a)** This familiar question elicited answers that, in the main, were worth all three marks. Where a mark was dropped it was invariably because of the failure to equate the number of electrons lost with the number of gaseous atoms. As a result, weaker candidates would suggest that one (single) electron was lost from a mole of gaseous atoms. It is important that candidates realise that each atom within a mole of gaseous atoms loses an electron.
- 3(b)(i)** Overall, this part was well answered. Errors included forgetting state symbols or using O₂ molecules instead of O atoms.
- 3(b)(ii)** The trend in successive ionisation energies is a concept usually well-known to candidates and most coped well with this graphical response. Nearly all candidates gained the first mark for showing an increase in the successive ionisation energies and the majority also gained the second mark for indicating the large increase between the 6th and 7th ionisation energies. Although not a specification requirement, some candidates who had been taught the '2p to 2s jump' showed this in their trend without affecting the mark awarded; occasionally some made the '2p to 2s jump' larger than the '2s to 1s jump'. Candidates are advised to stress the large jump between principal energy levels.
- 3(c)** This question was essentially about the trend in first ionisation energy across a period and was well answered by candidates. Candidates were expected to centre their answers on oxygen compared to fluorine but credit was given to responses written about the general trend across a period. Succinct responses which gained all three marks were seen in which only two lines of the answer space was used up. Other responses saw candidates compelled to fill up all available space – a policy which often introduced contradictory statements which nullified earlier credit awarded. Candidates are advised not to fill up every possible piece of answer space if it is not necessary to do so.

Once again correct terminology should be considered. Nuclear charge is not the same as nuclear attraction but the two terms are obviously connected.

The expected response for a third mark required a statement of the particles being attracted together.

- 3(d)** The electron configurations was frequently correctly stated, but the explanation for why this reaction of oxygen is typical of a non-metal was seen very infrequently. The idea of electron gain was not awarded credit for the second mark as correct electron configurations would have already demonstrated this. Relatively few candidates were able to state that non-metals generally react with a decrease in oxidation number to form negative ions.
- 3(e)(i)** This question discriminated well amongst the top end of the cohort. SO_3^{2-} was seen more often than ClO_2^- .
- 3(e)(ii)** The correct response of $\text{Al}(\text{NO}_3)_3$ was frequently seen but perhaps not as often one might expect. Many candidates left the charge on the nitrate ion in their formula
- 3(e)(iii)** This part was generally well answered but it should be noted that a significant number of students did not gain the first mark because they attempted to give the formula of the base rather than its name, despite **name** being emboldened on the paper. This is a typical case of candidates rushing unnecessarily without reading the question carefully and may serve a purpose if undertaken as part of a past-paper exercise or a mock exam. The formula of nitric acid was well known.

Question 4

- 4(a)** This question was a degree more challenging in that it required a description of metallic bonding in a specified metal and candidates were instructed to include the correct charge on the metal particles, an instruction many failed to heed. It was not surprising therefore that the mark least often awarded was that for correctly labelling the Ba^{2+} ions as very often candidates labelled these with a single positive charge. The mark for delocalised electrons was given more often than the final mark for stating that a *strong* attraction exists between the barium ions and electrons.
- Weaker candidates often used incorrect terminology in describing metallic bonding. 'Atoms' instead of 'positive ions' was often seen as was 'strong intermolecular forces' as a reason for the high melting point.
- 4(b)(i)** Many candidates gained both marks here for an equation between a Group 2 metal and water. Some were only awarded a single mark for $\text{Ba}(\text{OH})_2$ as there would be some error in the equation. Weaker candidates incorrectly opted for BaO as the product.
- 4(b)(ii)** The pH of the solution resulting in 4(b)(i) was well known, but centres are reminded that pH ranges such as '7–14' include an incorrect pH.
- 4(b)(iii)** Nearly every candidate knew that OH^- ions are formed, often without the formation of $\text{Ba}(\text{OH})_2$ being seen in 4(b)(i) above.
- 4(c)** This was well answered and the majority of candidates were able to suggest magnesium hydroxide, oxide or carbonate. Incorrect guesses included the chloride, sulfate and nitrate. Many responded with 'milk of magnesia' which was not credited as it is medicine rather than the 'compound'.
- 4(d)(i)** The testing of the acid + carbonate reaction has been tested before and responses indicated that candidates were familiar with such reactions. In describing the observations almost all students noted correctly that effervescence or bubbling or fizzing would be seen but many then omitted to add that the strontium carbonate would disappear. Although SrCO_2 and SrCO were occasionally seen as errors, the equation was handled well and was correctly given in the majority of answers.
- 4(d)(ii)** The bonding in SrCl_2 was well known by all but the weakest of candidates. Occasionally covalent molecules were drawn. Some candidates opted to give both an ionic and a covalent version of a 'dot-and-cross' diagram. Centres should inform candidates that

this hedging of bets and providing both covalent and ionic forms results in a contradiction for which no marks can be awarded.

- 4(e)(i)** Most candidates knew that chlorine water would turn a bromide solution orange although a few 'cream precipitates' were seen from candidates less familiar with Group 7 chemistry.
- 4(e)(ii)** The ionic equation was well known although common errors included reacting bromine with chloride, a lack of balancing, or equations involving SrCl_2 .
- 4(e)(iii)** The key point to the trend in reactivity of Group 7 elements is the ease of forming negative ions by electron gain. The reasons why electron gain occurs more easily with chlorine compared to bromine were well known by candidates but candidates often gave rambling answers which frequently contradicted correct statements. Weaker candidates spend large parts of their answer focussing on the relative strengths of van der Waals' forces perhaps confusing the terms reactivity and volatility.

Question 5

- 5(a)** Such questions in the past have certainly been among the more difficult to answer in the paper, but this example was somewhat different as the stem of the question did much to point candidates in the correct direction. F_2 having van der Waals' forces was the most common mark awarded but when it came to identifying the intermolecular forces in HCl answers were much less secure. Most common among the incorrect comments here were to highlight misconceptions either that HCl had hydrogen-bonding, that HCl was ionic, or that covalent bonds were broken in HCl . Better candidates both identified that the intermolecular forces were stronger in HCl and also pointed out that this would mean that more energy would be needed to overcome them.

Some candidates stated that HCl would have greater van der Waals' forces because of more electrons, despite the question stating that F_2 and HCl have the same numbers of electrons.

- 5(b)** The question was designed to be one of the more difficult on the paper but candidates coped very well with the bonding of this ion. Occasionally the symbol for the lone pair of electrons did not match that used for the dative-covalent bonding pair.
- 5(c)** The majority of candidates were able to calculate correctly the amount of borax needed as 0.02 moles but many were unable to arrive at the correct molar mass of borax. Candidates struggled with how to calculate the contribution made by the water of crystallisation and frequently the molar mass of anhydrous borax (210.2 g mol^{-1}) was seen. However, many were able to carry this error forward and secure two marks with an answer of 4.024 g. Despite this, a relatively high proportion of candidates calculated the mass correctly as 7.624 g.

- 5d(i)** **(ii)** and **(iii)** were a continuation of a typical titration calculation which was broken into three structured parts.

Most candidates were awarded all three marks with only occasional slips being seen and even when slips did occur in parts 5(d)(i) or 5(d)(ii), error carried forward marks could be applied.

Minor slips included: in 5(d)(i) the decimal place was sometimes incorrect and in 5(d)(ii) some halved the value from 5(d)(i) instead of doubling.

- 5(c)(ii)** proved a little more difficult although the correct value of 0.144 was seen on the majority of scripts.

F322 Chains, Energy and Resources

General Comments

The paper contained a good range of questions from each area of the specification providing all candidates with the opportunity to display a sound knowledge of the material tested. The inclusion of two unstructured questions allowed the most able candidates to demonstrate a comprehensive knowledge of structure determination and reaction mechanisms.

It was clear from the candidates' responses that there was sufficient time to complete the examination paper. The less able candidates were able to attempt and succeed in carrying out many of the calculations, could recall definitions and complete diagrams to represent organic structures.

Overall the standard of responses was impressive and there were a number of questions where almost every student gained the vast majority of marks. This was particularly the case in Q1 which tested the candidates' knowledge and understanding of simple organic chemistry.

The questions that discriminated the most were those that assessed the candidates' ability to use a range of information to justify answers, apply knowledge to unfamiliar contexts, or where precise definitions or clear explanations were required.

These parts included

- Analysis of information: Question 8
- Application of knowledge: Questions 1(f)(i), 4(c) and 6(c)
- Equations: Questions 3(a)(ii) and 1(g)(ii)
- Precise use of technical language and formulae: Questions 3(a)(v) and 6(a)

Two parts deserve special comments.

- Question 1(d) required an explanation of the trend in the boiling points of three hydrocarbons.

Many candidates did not comment on the trend, rather just compared branched chained alkanes with straight chained alkanes. Where a question asks for an explanation of a trend, it is essential that the answer clearly demonstrates that all of the information provided has been used.

- Question 8 required the identification of molecules **X** and **Y**.

It was common for the candidates to identify by structure the two molecules, X and Y, and to produce an equation for the reaction of **X** with ethanoic acid. However many did not use all of the information provided to fully justify the structures given. The question allowed for extended writing and it was disappointing that candidates often failed to use the fragment peak at 31, corresponding to the ion CH_2OH^+ , to justify the structure of the primary alcohol, propan-1-ol.

Comments on Individual Questions

Question 1

- 1(a)** Most candidates were awarded this mark for stating that the empirical formula of hexane was C_3H_7 . A small number of candidates confused empirical formula with general formula and gave the answer C_nH_{2n+2} .
- 1(b)** This was a well answered question with the vast majority of candidates picking up both marks. Clearly candidates have been drilled that the word 'only' is important, as it often appeared more than once in the same sentence.
- 1(c)** Candidates appeared well practised in drawing skeletal formula and only a few candidates produced the incorrect skeletal formula of 2,3-dimethylbutane.
- 1(d)** The first marking point was occasionally not gained because candidates went laboriously through each hydrocarbon and its boiling point without demonstrating that they understood the trend and the cause of that trend – ie *more branching*. Answers which just compared straight against branched also fell into this category. A significant number of candidates thought that boiling involved the breaking of bonds rather than the van der Waals' forces.
- 1(e)** It was clear that candidates were well prepared for producing an equation to represent cracking. A number of candidates obviously wished to demonstrate their flair for chemistry by providing the equation $C_{10}H_{22} \rightarrow C_6H_{14} + 2C_2H_4$ which also gained credit.
- 1(f)(i)** This question proved quite difficult for the vast majority of candidates who failed to apply their knowledge of radical substitution to an unfamiliar example. The most common incorrect answer was $C_4H_{10} + Cl_2 \rightarrow C_4H_8Cl_2 + H_2$.
- 1(g)(i)** This was a very straightforward question where few candidates failed to score both marks.
- 1(g)(ii)** The definition of homolytic fission was not well expressed, although most seemed to understand the concept. Most did **not** refer to the breaking of a **covalent** bond and a good number could not adequately articulate the bonding pair of electrons dividing so that each atom in the bond received one of the electrons. This second marking point was often gained subsequently for mentioning the formation of radicals.
- 1(g)(ii)** Candidates were required to apply their knowledge of the propagation steps encountered in the reaction between methane and chlorine to an unfamiliar example. Unfortunately many could not make the connection between this question and what they had learned on the course. This was poorly answered by many, clearly revealing a lack of understanding about propagation reactions.
- 1(h)** This standard equation was completed correctly by the vast majority of candidates who clearly were familiar with the concept of balancing the equation using 4.5 or 9/2 rather than attempting to double each of the terms in the equation. This approach always will gain full credit.

Question 2

- 2(a)** Rather than asking for the standard enthalpy change of formation definition, this question was linked to an explanation of why equation 1 represented this enthalpy change. This posed a number of problems for candidates who failed to include both one mole of product and that the product is formed from its elements. The most common error was forgetting to include one mole. Under the pressure of examination conditions a number of candidates referred to formation of P_4H_{10} rather than P_4O_{10} .

- 2(b)** The correct numerical value of -368 was seen on the majority of scripts. The commonest errors arose from failing to multiply -286 by 6 or -1267 by 4 . Those completing the question by drawing an energy cycle sometimes failed to check their arrows resulting in an answer of $+368$. This answer was credited with two marks.
- 2(c)** Failure to include an equation prevented the award of either of the marks as the question specifically asked candidates to use their equation to comment on the 100% atom economy. Where an equation was provided, candidates clearly understood the concept of atom economy with most commenting that only one product was formed. A number of answers included the idea that it was a 100% atom economy because the reaction was addition. This is clearly not the case and no credit was given for this answer.

Question 3

- 3(a)(i)** Although this part was well-answered by many, a common error was use of a nickel catalyst.
- 3(a)(ii)** This question required an equation to show elimination using molecular formulae. Many failed to spot the word 'molecular' and gave the formula of the alcohol as $C_5H_{11}OH$.
- The more able candidates appeared to do better on this question and it discriminated well.
- 3(a)(iii)** One would expect the vast majority of candidates to score well on a question requiring the definitions of structural and stereoisomerism; however this was not always the case. Just over half the candidates scored full marks with the most common error being in the definition of stereoisomers. Typically this was because of a failure to state that stereoisomers have the same structural formula.
- 3(a)(iv)** This part was answered well by the vast majority of candidates using a mixture of full displayed, structural or skeletal formulae. Many were able to deduce the structures of **A** and **B**; however the structural isomer was usually left with an ambiguous C_3H_7 group rather than showing as $-CH_2CH_2CH_3$.
- 3(a)(v)** Precision in the use of language is important to ensure clarity and nowhere more important than here; many candidates could not express a clear understanding of the essential features of *E/Z* isomerism. It is important to emphasise that each carbon atom in the carbon to carbon double bond must be attached to two different groups.
- 3(b)** Many gave a correct equation for the formation of pentan-2-one. A number of candidates however struggled to balance the equation with the use of $2[O]$ as a reactant and H_2 as a product being the most common errors.
- 3(c)** This part was well-answered. Occasionally candidates put in or left out a CH_2 group. Candidates should be reminded to check that all atoms and bonds have been included if using full displayed formula. In addition the aldehyde group should be represented as $-CHO$ in structural formula not as $-COH$.

Question 4

- 4(a)** Many of the most able candidates collected all three marks in this question. There were a number of different approaches followed by candidates, all of which were given credit. Some candidates rounded answers too early, for example $1000/24 = 41.67$ was sometimes given as 41.6 leading to a final answer of 680 rather than 681. A number of candidates completed all steps in the calculation correctly only then to fail to give their final answer to three significant figures.
- 4(b)** It is clear that candidates are being prepared more thoroughly for the drawing and labelling of a reaction profile diagram; however there are still some issues regarding the use of double headed arrows to indicate an enthalpy change. Whilst allowed by the examiners for showing E_a , a correct single headed arrow was required to illustrate ΔH . Candidates should also realise that the activation energy is the gap from the reactant line to the peak on the curve and as such should label this accurately.
- 4(c)** Many candidates struggled to calculate the enthalpy change of the reverse reaction failing to spot that the reaction as written releases 49.0 kJ of energy. The reverse reaction therefore must be endothermic with a value of +49.0 kJ.
- 4(d)** As a consequence of the answer given in (c) many candidates failed to add the value of the activation energy of the forward reaction to the value of the enthalpy change to give $+274 \text{ kJ mol}^{-1}$. This part was marked consequentially on the candidate's answer in (c) so, where a candidate added 225 to their answer in (c), a mark was awarded.
- 4(e)** Candidates performed well, demonstrating a good understanding of the influence of temperature change on the position of equilibrium. The best answers linked the direction that the position of equilibrium shifts to the exothermic nature of the forward reaction or the endothermic nature of the backwards reaction. Candidates should clearly state whether the forward or backward reaction is being referred to in their answers.
- 4(f)** On the whole candidates made a better attempt at this question than 4(e), the most being able to predict that the position of equilibrium would move to the left as more moles of gas are present on the left-hand side of the equation. It is important, however, that candidates identify which side of the equation has the most or least moles of gas.
- 4(g)** The examiners expected slightly more than the basic adsorption, reaction and desorption that some candidates included without thought in their answers. It is important that candidates clearly understand that it is the reactants that are adsorbed in order to react producing the products which are then desorbed. Vague references to gases being adsorbed at the end of the reaction were not credited as the reactants were also in the gaseous state.

Question 5

- 5(a)** Many clear calculations were seen, leading to the correct answer of 90%. Error carried forward credit allowed candidates to reach an incorrect final answer without penalising their understanding of intermediate steps. A major source of error was use of incorrectly calculated molar masses. Candidates should be encouraged to check molar masses before using them in subsequent calculations.
- 5(b)** Candidates did find it difficult to ensure that all the bonds broken and made featured in their calculations. The most able candidates tended to gain all three marks on this part. Some candidates sprayed their answers all over the answer page making the

calculations difficult to follow. A two columned approach listing bonds broken and bonds formed and the associated energy changes can lead to candidate scoring the two intermediate marks even if their final answer is incorrect.

- 5(c)** The most able candidates secured all three marks. Surprisingly, many candidates failed to score the third mark because they did not consider balancing the equation on the left-hand side by inserting an n before the chloroethene formula.
- 5(d)(i)** Most gained this mark. A common error was to react HCl with ethene.
- 5(d)(ii)** Similar questions have been set on previous examinations and candidates still appear to have not learned the standard answers. 'Sorting' was often missed when 'recycling' was the answer. 'Organic' was frequently missing when the answer mentioned 'feedstock'.
- 5(d)(iii)** A large number of candidates gained the available mark in this question by stating that the polymers could be biodegradable. Many candidates did not however specify a **type** of polymer, rather giving a polymer name such as poly(lactic acid) which did not gain credit.

Question 6

- 6(a)** Candidates generally struggled with this question. Many scripts correctly referred to bond-making as exothermic, then contradicted this by stating that bond-making 'needed energy'.
- 6(b)(i)** Candidates must prepare better for the environmental aspects of the course. In this question, a large number of candidates still referred to the molecule vibrating rather than the bonds in the molecule. It was however pleasing to see that very few referred to bond-breaking which has been a common answer to similar questions in past sessions.
- 6(b)(ii)** Answers showed a slight improvement on previous sessions and there were less candidates who referred to 'storing carbon' rather than carbon dioxide. Unfortunately many of the same basic misconceptions were seen in answers. When injecting into the sea, candidates need to understand that CO_2 should be injected deep into the ocean. Note that storing carbon dioxide by dissolving in water cannot gain credit.
- 6(c)** This was an unfamiliar question to many and candidate answers frequently failed to address the content of the question. Weaker answers mentioned enzymes as being 'natural' or 'biological', without specifically referring to toxicity of reactants/solvents. Many referred to the toxicity of the products. There were also vague answers about using less energy. Where candidates mentioned temperature as an advantage they failed to state that this would be lower.
- 6(d)** Candidates are very familiar with the Boltzmann distribution curve and there were many examples of excellent fully-labelled diagrams to illustrate the effect of an enzyme on the rate of a reaction. Some candidates labelled the x-axis with enthalpy which was not credited. Candidates should practice drawing the shape of the Boltzmann curve so that it clearly starts at the origin and does not cut the x-axis at high energies. As in previous sessions, the commonest mark that examiners did not award was for 'more successful collisions' in the presence of a catalyst.

Question 7

This question differentiated well with some very good answers but also some very weak responses. The most able candidates clearly had a good understanding of reaction mechanisms and produced diagrams which were clear, accurate and correct. Frequently, good candidates picked up eleven or twelve marks.

In the reaction of the alkene, some candidates noted that the alkene was unsymmetrical and as such there were two addition products. Candidates giving the structure of the two correct products or stating that two products were possible gained appropriate credit.

For the nucleophilic substitution mechanism, some of the weaker candidates attacked the halogenoalkene with KOH rather than with the OH^- ion. Statements that indicated that the bond fission was heterolytic due to the breaking of the KOH bond were not credited.

In mechanisms, it is important to show curly arrows starting either at a negative charge or from a lone pair of electrons. Some of the weaker candidates were careless with the start and end of arrows resulting in marks not being awarded.

Question 8

This free response question allowed candidates to demonstrate their understanding of the more complex aspects of the course and use their problem-solving skills to tie together all of the evidence.

Most interpreted the IR spectrum correctly, linking the correct absorbance with the presence of an $-\text{OH}$ group and to deduce that the compound was an alcohol. A few candidates still insisted that there must be a carboxylic acid present and found incorrect evidence for a $\text{C}=\text{O}$ in a COOH group.

The calculation of the empirical formula was completed well and most matched this to the mass spectrum. A few did not use the data to link the m/z value of 60 with the molecular formula $\text{C}_3\text{H}_8\text{O}$.

Many missed the significance of $m/z = 31$ and many who did realise its importance left out the positive charge on CH_2OH .

The equation for the esterification reaction usually included full structural or displayed formula enabling the marks for the structures of **X** and **Y** to be awarded; however, the equations frequently were not balanced due to the absence of the water molecule.

F324 Rings, Polymers and Analysis

General comments

The paper provided a good coverage of material for the unit although there was slightly less opportunity for longer free response type answers than in previous recent papers. Candidates seemed to be generally very well-prepared for the paper. There were few blank spaces with many candidates scoring in the 40s and 50s. In some places, candidates were expected to apply their knowledge to an unfamiliar situation, and these items gave the most able candidates an opportunity to earn the highest marks.

There was no evidence of any candidates running out of time on the paper, since the final part of question 4 was invariably attempted.

Two general points about the presentation of scripts:

1. Since papers are scanned in it is often very difficult to detect which answers are written in ink and are meant to be marked, and which responses are rough working in pencil or ink and are not meant to be marked. Therefore it is essential that candidates cross out all work other than the answer which they wish to have marked.
2. Pages 18, 19 and 20 were all available for use if the candidate wished to extend their answer. Despite this many chose to attach unnecessarily another answer booklet (sometimes 10 pages long) leaving pages 18-20 empty.

Comments on Individual Questions

Question 1

- 1(a)** Most students scored one mark for correctly stating, or showing in a labelled diagram, that pyruvic acid forms hydrogen bonds with water. However, some candidates only showed hydrogen bonds between pyruvic acid molecules. The second mark was more difficult to gain with the most common omissions from the diagram being lone pairs on the O and/or δ^+ on the H.
- 1(b)** Many candidates were not awarded marks due to omitting water as a product. Of those who gave the correct formulae, many failed to score the mark available for balancing, with $2[\text{O}]$ often being seen on the left of the equation. A minority attempted to produce a balanced equation by giving hydrogen or hydrogen ions as a product.
- 1(c)** Most candidates obviously knew the mechanism, but many did not gain full marks due to careless placement of the curly arrows. It was a requirement that arrows should start from a negative charge or a lone pair. Candidates should be encouraged to draw mechanisms as neatly as possible, and place curly arrows accurately. A minority showed the initial attack by the hydride ion on the $\text{C}=\text{O}$ of the $-\text{COOH}$ group, although the product was given as $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ in the question.
- 1(d)** This part proved to be a good discriminator. Many failed to recognise that pyruvic acid is a ketone as well as a carboxylic acid, and so suggested that Brady's reagent (2,4-DNPH) would be a suitable reagent to distinguish between the two compounds. Although allowance for this was made in the Mark Scheme, a large number of candidates did not score the mark available for observations as they stated incorrectly that pyruvic acid would not react.

The most successful candidates, as expected, chose Tollens' reagent. Almost all knew the "silver mirror", but the mark for the explanation of the type of reaction was not regularly awarded, often because candidates were not precise enough in their explanation of what was being oxidised or reduced. The organic product of the reaction was frequently omitted, or named as just a carboxylic acid. The mark was more commonly awarded to those who gave the correct structure of the product.

- 1(e)(i)** Unsurprisingly, the majority of candidates gave the correct molecular formula.
- 1(e)(ii)** A common mistake was to show the *Z* (cis) stereoisomer for compound **B**, or to propose a structure such as $\text{H}_2\text{C}=\text{CHCH}_2\text{COOH}$ which would not have stereoisomers. In these cases, ECF marks were available, where appropriate, for **C**, **D** and **E**. Weaker candidates attempted to match the molecular formula by various combinations of $-\text{CHO}$ and $-\text{OH}$ groups, and scored no marks.

Question 2

- 2(a)(i)** Candidates were well-prepared for this mechanism, and many scored full marks. However, some candidates did not offer equations for formation of the electrophile or for re-formation of the catalyst. A common error was an incorrect orientation of the "horseshoe", in many cases probably due to careless drawing rather than lack of knowledge. A few candidates formed compounds which were not 1,3 di-substituted.
- 2(a)(ii)** The majority of answers were correct, but electrophilic addition and nucleophilic substitution were suggested by some of the weaker candidates.
- 2(b)(i)** This part proved to be very straightforward.
- 2(b)(ii)** There were many good answers.

For Reaction 1, a common omission was not stating that HC/ must be concentrated.

For Reaction 2, a small minority confused their $>$ and $<$ signs and therefore did not score the conditions mark. A few others gave HNO_3 .

For Reaction 4, although many correctly gave NaOH as the reagent, fewer stated that it should be aqueous and hot or be refluxed. Errors included the use of Na_2CO_3 or even Na itself.

- 2(b)(iii)** This part proved to be a good differentiating question. Many candidates did not score the first mark by not using the term "delocalised", or any of the alternatives given on the Mark Scheme. Other errors included vague references to electrons rather than a lone pair, and not stating that the lone pair was from the nitrogen atom (of the amine). Some candidates seemed to misread the question and discussed the electrophilic substitution of phenol by bromine. The majority correctly stated that the amine would have a greater electron density than benzene. The third mark was often not awarded due to a suggestion that a dipole is induced in the diazonium ion.

Question 3

- 3(a)** The majority of candidates gave a correct answer but a common error was not to make clear that the amine and carboxylic acid group are attached to the *same* carbon atom. Other candidates just referred to a chiral carbon atom being present.
- 3(b)(i)** and **(ii)** Most candidates gave good answers to these parts. A few did not gain the parts by missing hydrogens or by careless copying of the R group.

- 3(c)** As expected there were many correct answers. The most common error was not showing a correct connection from the chiral carbon to one of the surrounding groups. This was the only question on the paper where connectivity was tested and so a carelessly drawn diagram often meant that the mark could not be awarded. Candidates also need to realise that HN_2 is not a correct mirror image of NH_2 and take the same approach with groups such as HS_3HC . Candidates should also be aware that in this sort of 3D representation, the two bonds in the plane of the paper cannot be at an 180° angle.
- 3(d)(i)** This was generally well answered. Common mistakes included giving a name only, rather than a formula as the question demanded, or giving the formula of a compound containing two carbon atoms.
- 3(d)(ii)** There were a surprising number of ester linkages, or peptide bonds with an oxygen in the middle. Some candidates included more than two repeat units or omitted a hydrogen atom in the structure.
- 3(e)(i)** This question on ^{13}C NMR spectroscopy proved relatively straight-forward for nearly all candidates.
- 3(e)(ii)** If the first mark was lost, it was usually for the absence of the S–H proton in the missing peaks. Many candidates did not gain the second mark, the most common reason being non-precision in explaining that D replaced H. Candidates often implied that D_2O replaced H.
- 3(e)(iii)** This part proved to be another good discriminator in the paper. While there were many good answers, many candidates failed to give correct chemical shift values (especially for COOH), splitting patterns or relative peak areas. Many candidates did not identify the “H” atoms clearly enough. Some gave a partial formula involving several protons without specifying which protons were responsible by not putting the relevant H atom symbol in bold or underlining it or highlighting it or circling it, etc.

Question 4

- 4(a)(i)** Many candidates omitted the “1” and simply suggested (2-)methylpropanol, which is ambiguous and did not score the mark. Quite a few referred to butanol in their answer.
- 4(a)(ii)** It was encouraging to see so many good answers to this question with the majority of candidates using skeletal formulae accurately.
- 4(b)(i)** There were many good answers referring to the time from injection of the sample to detection, but some candidates gave vague answers referring to the “GC machine” or just “time in the machine”.
- 4(b)(ii)** Most candidates referred to similar retention times and so scored this mark. A few wrongly discussed R_f values.
- 4(c)(i)** This was well answered by the majority. Careless drawing of the box was the most usual reason for the mark not being awarded as often the sides did not cut through the bonds if an end group had been included. Others omitted the end “–O” or had one at each end of the repeat unit.
- 4(c)(ii)** The correct answer of “hydrolysis” was generally seen although some candidates suggested “hydration”, “reduction”, or “condensation”.

- 4(c)(iii)** Some candidates failed to give a correct wavenumber range or to specify that the –OH absorption would be broad in the degraded product. Others failed to mention that the product was a carboxylic acid. However, there were many good answers.
- 4(c)(iv)** This final part was generally well answered. The most common errors included 1,4 rather than 1,3 linkages to the ring, terminal oxygens on both ends, or the ends closed off with –OH groups.

F325 Equilibria, Energy and Elements

General Comments

This F325 examination will be the last available in the January session. The examination paper had been structured with the higher demand Stretch and Challenge parts towards the end of the paper. Despite giving a feel of a very demanding paper, it was not exclusively for the most able and there were plenty of accessible questions in which weaker candidates were able to score.

Application of knowledge and understanding will always be assessed on F325 papers using questions set in an unfamiliar or novel context. Many candidates revise almost exclusively by practising old examination questions. Some candidates memorise old Mark Schemes in the hope that they will be able to write these out in the forthcoming examination. This strategy can help with some parts but, when tackling application questions, candidates do need to consider the information presented in the question rather than resorting to learnt marking points from previous Mark Schemes that often have little to do with the question.

Two general comments

- 5(a) (6 marks) and 7(c)(i) (6 marks) were both unstructured calculations with 5(a) being a type asked in previous papers. These parts were a lifeline for many weaker candidates, providing a significant number of marks. Well-prepared weaker candidates often respond better in calculation questions than in parts where explanations are required.
- 2(a)(i) required candidates to draw sketch graphs; 6(a) required candidates to draw a diagram of an electrochemical cell.

Overall, the standard of these sketches and diagrams were disappointing. Sketch graphs often showed curves that wandered up and down almost at random. In 6(a), some of the 'diagrams' were little more than rough drawings with little evidence of pencil and ruler being used.

There was no evidence that any time constraints had led to candidates underperforming.

A final general comment should be reserved for the quality of responses seen by the very best candidates. Several candidates obtained close to full marks on this paper showing exceptional knowledge and understanding at this level.

Comments on Individual Questions

Question 1

This was an unthreatening first question for candidates that assessed different aspects of transition metal chemistry. In (a), although symbols were asked for, names were accepted.

1(a)(i) This easy starter provided most candidates with their first mark.

1(a)(ii) Some candidates found this part very difficult with few obtaining both marks for Ti and Ni. This suggests a lack of understanding about how the d orbitals are filled. Even the easier Ti was seen comparatively rarely. Cr and Co were the commonest incorrect responses.

- 1(a)(iii)** Although the majority of candidates responded correctly with Co, a sizeable number went for the obvious distracter of Cu. This shows the importance of learning the specification content for the examination.
- 1(a)(iv)** Almost all candidates correctly responded here with Mn.
- 1(a)(v)** This part caused unexpected problems – candidates either saw what to do, giving the correct response of Cr, guessed, or missed out the part out entirely. The chemistry required has its roots in F321.
- 1(b)** This part was recall of specification-listed copper species. Success was almost entirely dependent on whether the work had been learnt but less than half the candidates scored all three marks. The examiners allowed the chemically correct $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$. Unrequired brackets were allowed as long as their meaning was unambiguous.

Common errors included incorrect charges on the complex ions and inclusion of Na in what should have been $\text{Cu}(\text{OH})_2$. It was also common to see $[\text{Cu}(\text{NH}_3)_6]^{2+}$ and $[\text{Cu}(\text{NH}_3)_2(\text{H}_2\text{O})_4]^{2+}$. A common error was inclusion of charges within the complex, such as $\text{Cu}(\text{Cl})_4^{2-}$, resulting in an overall charge that was incorrect. Candidates are advised to give the overall charge on a complex ion at the end of the species only.

Some candidates who successfully gave the yellow solution as CuCl_4^{2-} , also responded with Cu in the earlier 1(a)(iii) for a blue solution.

- 1(c)(i)** Almost all candidates successfully responded with octahedral.
- 1(c)(ii)** This part required candidates to write the formula of an unfamiliar complex ion of nickel. As in (b), residual charges such as $\text{Ni}(\text{F})_6^{4-}$ were often seen. The main problem was with the overall charge with 2– and 2+ commonly seen. Some candidates did not read the question and gave a complex ion containing F_4 instead of F_6 . Complex ions using *F* as the symbol were not credited, a disappointing but only too common error.
- 1(c)(iii)** Most candidates were able to draw 3D representations of the required optical isomers. The examiners wanted to see that the bidentate ligand had been attached correctly rather than a detailed structure of 'en'.

Question 2

- 2(a)(i)** This unfamiliar question was tackled well with very few candidates failing to score. Care was required however in drawing the curves to show that both rose rapidly on addition of 25 cm^3 , both pH curves finished well into an alkaline pH value and that the curve for CH_3COOH started at a higher pH than that of HCl . Some excellent sketch graphs were seen but it was surprising that more had not used a ruler to align 25 cm^3 with the steep rise. Some freehand sketches were very disappointing. Many drew both curves starting at a pH of 0. The examiners expected more precision and care with the sketch curves.
- 2(a)(ii)** This part was answered well with most linking the colour change or pH range of the indicator to the vertical section of the curve. Many used the term equivalence point for their comparison rather than the 'vertical section of the pH curve' and this was accepted by the examiners.

2(b)(i) This was the first of three definitions asked for on the paper; for some, it was one of three that had not been learnt. The weakest responses gave no numerical value at all but many stated the definition in terms of neutralisation of 1 mole of an acid by 1 mole of a base rather than in terms of formation of 1 mole of water.

2(b)(ii) This calculation caused many candidates problems with only about half scoring more than 1 mark. Even good candidates obtaining the correct numerical value of 57.5 sometimes omitted the negative sign. Many candidates did correctly calculate the energy change as 4827.9 J or the moles of HCl and NaOH 0.084; however, they then did not know what to do with their two numbers. Some doubled 0.084, presumably as there was both NaOH and HCl.

Overall responses to this part were disappointing.

2(b)(iii) Most candidates responded with an incorrect temperature change of 8.25°C, presumably as twice the volume of HCl had been used. The best candidates spotted that the same energy change was heating a volume that had increased by one-third, resulting in a temperature rise that would be 11°C, two-thirds of 16.5°C. This part discriminated extremely well with some excellent justifications that calculated the temperature change using 4827.9 J from (ii).

Question 3

3(a)(i) This part required two further definitions but there was again evidence that these had not been learnt. Weak responses were muddled with references to dissolving to form 1 mole of solution or involvement of 1 mole of gaseous atoms. Potentially, these were three easy marks but fewer than half the candidates secured them.

3(a)(ii) Responses here were generally very good with most candidates comparing the sizes and charges of Na⁺ and Mg²⁺. Many candidates fell down with their responses for the third mark with attraction between ions being quoted often rather than attraction between ions and water molecules.

3(a)(iii) This part was answered well with most candidates showing correct species on both lines. Candidates are advised to write state symbols clearly – it was difficult on some scripts to decide whether the candidate had written (s) or (g).

3(a)(iv) The majority of candidates obtained both the calculation marks to produce the correct answer of $-2694 \text{ kJ mol}^{-1}$. The commonest errors were the omission of '2' for the involvement of 2OH⁻, incorrect signs, or use of only two of the three values from the start of the question.

3(b)(i) Most candidates were able to link the positive enthalpy change with the need for bonds to be broken. 'Increased disorder' usually explained the increase in entropy but comparatively few stated that the increase in disorder is much larger from a liquid to a gas than from a solid to a liquid.

3(b)(ii) This part required candidates to interpret enthalpy and entropy changes in a novel context. Candidates were in new territory here and most saw the need to calculate ΔS with 22 being seen on the majority of scripts.

Most then tried to link their value of ΔS with ΔH , T and ΔG . The key here was recognising that $\Delta G = 0$ when ice melts. This could be shown either using the Gibbs' equation or by showing by calculation that the temperature at which $\Delta G = 0$ is 273 K. A common error that crept in was caused by not converting 22 J to 0.022 kJ first, a mistake that led to a ΔG value of -5999 , consistent with a melting point for ice of $-273,000 \text{ K}$.

Question 4

- 4(a)** Candidates are well versed with initial rates problems where they are provided with data and asked to find the orders. This question assessed whether the candidate could describe how the data had been obtained; candidates found this far more testing. Despite the question describing the key experimental steps to obtain a single value of time, many candidates described a different experiment, often using colorimeters to continuously monitor the iodine colour. Such responses then went on to consider half-lives from a concentration–time graph. Success here depended on the candidate varying the concentration of each reactant in turn while keeping the other concentration constant, relating time to rate, and finally linking the experimental results to order.
- 4(b)** In contrast to (a), this calculation was almost always correct with 3.75 being seen on almost all scripts, units providing the only real stumbling block.
- 4(c)(i)** This part required candidates to interpret information to derive the two equations starting from the reaction involving Fe^{2+} . Most candidates obtained at least one of the two available marks. Marks were most commonly lost by showing the correct equations in the wrong order or by omitting one or more of the balancing '2's.
- 4(c)(ii)** As with many descriptive parts, (c)(ii) proved to be harder to answer than calculations. The examiners simply required a statement that Fe^{3+} and I^- would react first.

Question 5

- 5(a)** This type of unstructured equilibrium calculation has now been asked on many papers. Candidates have clearly practised these calculations and most candidates were able to obtain a value for K_c . The correct numerical value of 14.6, with correct units, was seen on many scripts. The majority of marks were still available by ECF for use of a correct method. Some weaker students were able to gain a number of marks on this part-question. The commonest errors arose from incorrect equilibrium moles especially for H_2 , omitting the scaling stage, poor calculator skills when calculating K_c or for expressing the K_c value to more than three significant figures.
- 5(b)** Most candidates described, in terms of ΔH and numbers of moles, how increased temperature and pressure shifts the equilibrium position in opposite directions (an AS skill from F322) and that K_c decreases because of increased temperature and ΔH . Far fewer candidates then went on to explain that the overall shift was difficult to predict as it would be uncertain which effect were the more dominant.

Question 6

Overall, candidates tackled this question well.

- 6(a)** Compared with previous sessions, the quality of the diagrams seen for cells was poor. Although most candidates were awarded a mark for a correct circuit, there were often gaps between components and examiners were very strict not to credit such incomplete circuits. This is the first time that a hydrogen electrode has been assessed and many diagrams reflected a lack of learning. Diagrams were seen containing no platinum electrode, a solid H_2 electrode and even a solution of H_2 . The Fe/Fe^{2+} half cell should have been much more straightforward but many candidates instead drew a cell for $\text{Fe}^{2+}/\text{Fe}^{3+}$ with a platinum electrode.

- 6(b)(i)** This question was very clear that an **alkaline** hydrogen–oxygen fuel cell was being discussed – the supplied redox systems for OH^- and H^+ ions had been provided so candidates had to choose the relevant information. The prompts ‘oxygen’ and ‘hydrogen’ electrode should have informed candidates that O_2 and H_2 are on the left-hand side of the required equations, after which all that is required is to copy the relevant equations the correct way round from the table. The responses seen were very disappointing, often showing equations for an acid cell or even a mixture of equations for acid and alkali cells. Consequently only about 25% of candidates wrote two correct equations, with nearly a half scoring neither mark. This was despite examiners awarding one mark for two equations under acid conditions. Students clearly need to work on selection of relevant information.
- 6(b)(ii)** The required response here was the overall equation for any hydrogen–oxygen fuel cell but fewer than half the candidates were able to write this, perhaps as many tried to combine their incorrect equations from (b)(i), forgetting that they were answering a question about a hydrogen–oxygen fuel cell.
- 6(b)(iii)** Responses for the standard cell potential were either the correct 1.23 V, or 0.40 V. Presumably 0.40 V had been written as either the standard **electrode** potential of the O_2/OH^- redox system or as a cell potential from alkaline O_2 and acidic H_2 . Another distractor was 0.83 V which could have only come from an alkaline H_2 coupled to an acidic H_2 .
- 6(c)** This part required recall of specification statement 5.2.3(j) – examiners also allowed responses in terms of a continuous supply of the fuel. Many responses were in terms of recharging. Again responses were disappointing, especially bearing in mind the simple recall nature of the question, with less than half the candidates obtaining the mark.
- 6(d)** This question was linked to aspects of ‘How Science Works’ and required a response that carbon-containing compounds or fossil fuels have been used in the production of hydrogen or the fuel cell. Many responses were superficial, not picking up this link and omitting the essential reference to carbon-containing compounds.
- 6(e)** This synoptic part was set in an unfamiliar context and required the linking together of different aspects of chemistry. This question contained Stretch and Challenge and most candidates made little headway beyond obtaining 0.028 for the moles of Cr and a guess for the metal. In comparison, it was refreshing to see the accomplished way in which top A and A* candidates solved this novel problem. This was one of the best discriminating questions on the paper.

Question 7

- 7(a)** This part assessed the construction of an unfamiliar equation. Weaker candidates often suggested unrealistic formulae for compounds (even for calcium carbonate) or did not balance their equations. This was another part where use of the information in the question might have provided more success.
- 7(b)(i)** Most candidates stated that a weak acid partially dissociated but far fewer were able to write the required equation including use of an equilibrium sign.
- 7(b)(ii)** The overall equation was unfamiliar and, as with 7(a), caused problems. The ionic equation should have been more straightforward. Unfortunately, many candidates were distracted by the presence of Ca in the formula, often leading to the production of calcium metal as a product.

7(b)(iii) Four marks were available here for showing acid–base behaviour using prescribed equations. Unfortunately, it was common to see different reactants being used, sometimes simply dissociation of HSO_3^- rather than the reaction with H^+ or OH^- asked for in the question. This part was answered better than 7(b)(ii).

7(c)(i) In contrast to responses in 7(a) and 7(b), the answers to this unstructured calculation were impressive with many correct numerical answers of 122 g mol^{-1} . As with 5(a), weaker students were able to gain marks on this question.

In contrast, identification of HA proved to be much more taxing. Subtraction of 45 (for COOH) leaves 77 which must have 6 C atoms, hence the formula $\text{C}_6\text{H}_5\text{COOH}$. Successful candidates often then drew out the structure of benzoic acid. Identification of HA required some ‘chemical flair’ and this part was beyond most candidates who either guessed or suggested the nearest straight chain carboxylic acid, hexanoic acid ($M_r = 116$). A few candidates calculated the actual equilibrium HA concentration rather than using the usual approximation for the undissociated concentration, obtaining 116 and hexanoic acid. This excellent response received full credit.

7(c)(ii) In contrast to (c)(i), few candidates could decide whether the student in the question was correct or incorrect, most guessing one way or the other. The very best candidates identified that the weak acid would dissociate more during the titration, releasing all H^+ ions in doing so. This was another part that discriminated well.

Question 8

8(a) Candidates generally answered this part well and it was comparatively rare to see an incorrect configuration for vanadium in its +3 oxidation state. The commonest mistake was loss of 3d electrons from V atom, rather than 4s electrons, giving $\dots 3d^6 4s^2 3d^1$.

8(b) About half the candidates responded successfully in terms of an empty d sub-shell or removal of electrons from the 3p sub-shell.

8(c)(i) The key point here was that MnO_4^- and V^{n+} ions have similar colours. Many candidates just referred to either MnO_4^- or V^{n+} but not both. Others discussed colours of Mn^{2+} and VO_3^- . As with earlier parts, success here was dependent on interpreting the unfamiliar information, a skill that needs to be practised.

8(c)(ii) This part required candidates to interpret information set in a practical titration context. The question included some Stretch and Challenge marks and many candidates found this part very demanding. The difficulty here was that candidates were required to find an equation from titration results whereas in previous papers the equation has been provided.

Notwithstanding this difficulty, there were still three marks that could be achieved using standard methods, the moles of V and MnO_4^- and for correct scaling by 5.

The best candidates were able to obtain a reacting ratio for $\text{V}^{n+} : \text{MnO}_4^-$ as 5 : 3 and the value of n as 2. For the equation, some candidates then went on to give correct vanadium and manganese species and the very best were able to balance their equation. It was truly impressive to see some perfect responses to this question that could be awarded all 7 marks.

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