A-LEVEL
CHEMISTRY

7405/3
Report on the Examination

7405
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General Comments

The second series of this exam again resulted in pleasing differentiation, with a normal distribution of marks around a mean mark of 47.98 (53.32% of maximum). The maximum mark scored was 89 (achieved by two students), and, at the other end of the scale, there was a single student who failed to gain a mark. There were no 'dead' marks on the paper, although only between 3 and 4% of students scored full marks for questions 01.8 and 04.6.

Students are advised to bear in mind the following advice.

- It is **not** good practice to start an answer by repeating the question (e.g. answers to 01.1 were seen that started "the use of a large excess of H_2O_2 and I^- means that the rate of reaction at a fixed temperature depends only on the concentration of H^+ because…" – by which time most of the answer space had been used and a significant amount of time wasted).
- They should **not** include apparatus lists with practical descriptions. Each piece of apparatus will be mentioned in turn when it is used in the method, so does not need a separate listing.
- They must **not** offer two alternative answers (even if one is on an additional page) as, if one answer is correct but the second is incorrect, the incorrect answer will negate the mark(s).
- When generating intermediate answers in a calculation, it should be clearly indicated what the number refers to (e.g. many of the calculations in question 04.5 were poorly laid out, making it difficult for examiners to identify which number on the page students were suggesting as the amount, in moles, of water formed).
- If additional pages are used, the questions should be clearly numbered and any rough work should be clearly crossed out.
- The instructions for completing the answers to Section B, and for changing answers from correct to incorrect and vice versa, are clearly explained at the start of the section. Despite this, a significant minority of students did not follow them, which resulted in many scripts having to be marked manually due to there being apparently multiple answers, or answers indicated by the wrong method. Attempts at answers should not be 'rubbed out' as the 'rubbed out' answer can still be picked up during scanning and make it appear as though two answers have been suggested

Section A

Question 1 Rate of Reaction

01.1 This proved to be a tougher starter question than anticipated (63.4% of students failed to score). In many cases, the question was repeated as an attempt at the answer with students suggesting that "the rate only depends on $[H^+]$". Since this information had been given in the question, answers such as this could not be credited. The expected answer, that 'a large excess makes the concentrations effectively constant so that they do not affect the rate', was seldom seen.

01.2 As with part 01.1, not many students were able to achieve both marks (only 9.7%), with few suggesting 'quenching'. Given how frequently quenching was, unnecessarily, suggested in answers to 01.8, this was surprising. In many cases, students described the process of titration itself rather than what should be done to the sample *before* titration. 74% of students failed to score here.

01.3 This question proved easier, with just over a third of students achieving both marks for appreciating that the line indicated a constant rate, showing that the falling concentration of hydrogen ions was having no effect.

01.4 A common error here was for students to start by (correctly) calculating the gradient of the line but then to divide it by a value for the $[H^+]$ (usually 0.5) or even by $[H^+]^2$ – despite having been told in 01.3 that the order with respect to $H^+(aq)$ is zero. 36% of students, however, did gain all three marks.

01.5 97.3% of students were able to plot the points correctly onto the given grid.

01.6 A significant number of students assumed that the instruction to ‘draw a line of best fit’ meant that the line must be straight. Students must learn that a best-fit line must be the best-fit to the points as plotted, so may be either straight or curved depending on the relationship between the plotted points; at A-level, students are expected to make this decision for themselves. Just under 40% of students did not gain this mark.

01.7 The idea of drawing a tangent (or, for award of ‘error carried forward’, simply constructing a ‘triangle’ on a straight line) proved tricky, with a significant minority of students simply dividing 0.35 by the corresponding time value from their line.

01.8 Fewer students than expected recognised the clue in the information given in the question that this was best done as a ‘clock’ reaction. Many students suggested answers that did not include ‘X’ in the initial mixture, as suggested, while many others used a variety of convoluted procedures involving what were essentially ‘continuous monitoring’ methods to generate concentration versus time graphs. In some cases, this was followed by a description of finding the gradient at t = 0, which addressed the requirement of the question to calculate an initial rate for each experiment. However, a direct measurement would have been much easier, both to do and to describe.
Credit was given for a wide variety of suggestions because, although a particular approach was hoped for, there are indeed several alternative approaches that would work. However, many students seemed to think that actual measurements of concentration (of what substance was often unclear from the descriptions) are needed, which led to suggestions that samples should be removed at timed intervals and titrated against X or placed into a colorimeter (the need to quench these samples was often over-looked). If a colorimeter was used, then the best approach for continuous monitoring is simply to allow the reaction to proceed in the colorimeter and take a series of readings at timed intervals – much easier than sampling. The mean mark on this question was only 1.8 out of 6.

The extra answer space available this year meant that fewer students needed additional pages for this question, but many confused, badly ordered and muddled answers were seen that took up far more space than necessary through repetition and unnecessary elaboration.

Reading the question is always key, but here many students could have saved a lot of time and space by noticing that the question asked only about a method to determine the order of this reaction with respect to A. This would have avoided the need for them to repeat most of the procedure, looking at successively changing the concentrations of A, then B, then C, while keeping each of the other two constant.

Levels-of-response questions are marked using ‘levels’ and the key to success is for students to concentrate first on the inclusion of as much correct Chemistry as possible to ensure access to Level 3 (worth 5 or 6 marks). This is probably best achieved using a ‘bullet point’ approach to structuring the answer. Within a level, the mark awarded depends on the clarity and coherence of an answer, together with there being a clear, logical progression through the description.

Appropriate apparatus and quantities should be mentioned as necessary. For example, rather than stating “add A, B and C to a container”, a good start to the answer would be to write, “A measuring cylinder was used to measure known volumes, of known concentrations, of A, B and C into separate beakers”. Unless specifically asked to suggest suitable volumes/concentrations, then it is sufficient for students to indicate that they would make a measurement without needing to state a value.

Question 2 Period 3 Elements

02.1 This was expected to be a straightforward question on a familiar equation and set of observations. However, many students were unable to balance the equation, with $2Na + O_2 \rightarrow Na_2O$ seen frequently. Incorrect observations included numerous mentions of a ‘red’ flame and of the formation of a ‘precipitate’. Only 23.6% of students scored both marks.

02.2 The need for only a single observation probably resulted in the higher marks here than in 02.1 (39.4% fully correct). The formula of the oxide was usually correct, but incorrect reference to a ‘precipitate’ was again seen frequently.

02.3 This was another example where reading the question was key; many students incorrectly gave a comparison of sodium and magnesium (rather than their oxides), while others wasted time and space discussing the trend across the whole period. Any references to metallic bonding, or any suggestion of the presence of ‘molecules’, made it impossible to award credit in this question. 38.7% of students were able, however, to score both marks.

02.4 The confusion in students’ minds between ‘molecular’ and ‘giant’ structures was evident in many of the answers to this question. Contradictions were frequently seen, such as “silicon dioxide has a macromolecular structure with strong covalent bonds between the molecules”. An ideal answer would be structured with clear statements that silicon dioxide is giant covalent (or macromolecular) and phosphorous oxide is (simple) molecular, followed by the statement that the covalent bonds between the atoms in silicon dioxide are much stronger then the intermolecular forces in phosphorous oxide. Use of the word ‘bonds’ should be avoided when referring to intermolecular forces (apart from the specific case of hydrogen bonds, not relevant in the answer to this question).

02.5 This was answered quite well, although some answers were spoiled by reference to a water bath and many students failed to mention the need to heat slowly (near the melting point). More surprising at this level were those students who confused melting and boiling or who suggested dissolving the solid in water before starting to heat it.

Question 3 Preparation of Cyclohexene

03.1 Most students coped with the need to convert volume to mass and gave 9.6 g of cyclohexanol at the start, but too many then assumed that this meant the maximum possible yield of cyclohexene would be 9.6 g and so divided 5.97 by this. 47.5% of students completed the calculation successfully.

03.2 Most students (70.2%) were able to suggest the use of bromine water, with only very few getting the colour change the wrong way round. The most common wrong answer was the suggestion of a test for the absence of alcohol rather than a positive test for the presence of an alkene.

03.3 This was not answered as well as expected (42% correct), with many vague references to 'removing impurities' or 'separating the layers'.

03.4 The key to questions like this about understanding the method of a practical is to relate the answer to the position of the process in the overall method. The reference to periodic opening of the tap preceded the actual separation of the layers in the method, yet many answers referred to opening the tap to run off one of the layers. It was interesting that more students (57.4% correct) were able to suggest that this was to release pressure of CO_2 (due to reaction with acid) than were able to suggest, in 03.3, that the carbonate had been added in order to react with acid.

03.5 The low success rate in this question (28.2% correct) is explained by a lack of specificity in students' answers; the mark required a reference to a lack of reactivity with, or solubility in, **cyclohexene**.

03.6 Most students chose to draw a diagram rather than write a description; the former is the recommended approach. However, clear, simple cross-sectional line diagrams of a Buchner funnel and filter paper on top of a Buchner flask (with side-arm attached to a vacuum pump) were seldom seen. Tubes were often shown as sealed, bungs and side-arms were missing and the side-arm was often drawn on the funnel rather than the flask. Only 28.7% of students gained both marks; 37.1% failed to score.

03.7 This part gave numerous examples of repeating the question, with many answers seen along the lines of "the retention time is shorter because the retention time is shorter". Some students also inverted the question and tried to describe why cyclohexene had a longer retention time, while others thought incorrectly that cyclohexene is polar due to the C=C bond. An inversion of reasoning that was often seen was the incorrect idea that cyclohexanol has hydrogen bonding, which is why it is polar. 34.9% of students scored zero here.

03.8 Too many students failed to remember the need always to mention both the wavenumber range **and** the bond responsible in questions of this type. Most correctly stated that a peak in the range 3230–3550 would not be visible, but many then failed to state that this peak relates to the O–H bond in an alcohol. As a result, only 43.7% of students gained the mark.

Question 4 Enthalpy of Neutralisation

04.1 The usual advice is that a scale on a graph is 'suitable' if the plotted points take up more than half of the available space. In this case, the decision about the suitability of the scale was more 'relaxed' due to the need for students to allow space for the extrapolation to go higher than the highest plotted point. However, a significant number of students still managed to miss the mark by choosing scales that led to the plotted points being squeezed in to only a couple of squares on the vertical axis. There still seems to be a misconception amongst some students that all scales need to start at zero. Having plotted the points, most students recognised that their lines of best fit should ignore the point at 5 minutes. Although a lot of 'S-shaped' curves were seen (the reminder clue in the question was that candidates should draw suitable *lines* of best fit), some students failed to draw any line between 0 and 3 minutes, and the lines were sometimes not extrapolated to the 4th minute. A surprising number of students quoted the 'final' temperature at the 4th minute rather than giving ΔT. Pleasingly, 34.3% of students scored all five marks.

04.2 Far more students than expected failed to double the uncertainty given in the question to reflect the fact that two temperature readings are taken with the thermometer. As a result, only 19.3% of students were awarded this mark.

04.3 As expected, this was the easiest question on the paper with the vast majority of candidates (90.7%) able to suggest a way to reduce heat loss.

04.4 This was another example of a question where some students were let down by not reading the question, which clearly asked for a change that would reduce the percentage uncertainty *in the use of the same thermometer*. Given that percentage uncertainty is calculated as apparatus uncertainty divided by measurement made, it was hoped that more students would recognise the need to increase the size of the measurement made, i.e. the temperature change. Many students who did recognise the need to generate a bigger temperature change suggested doing so by using smaller volumes; they thus failed to appreciate that this would reduce the amounts of reactants as well as the volume, so that less heat would be given out and the change in temperature would be the same as in the larger scale experiment. 58% of students scored zero.

04.5 Despite the formula and name being given in the question, many students failed to recognise that ethanedioic acid is diprotic, which affected their equation and subsequent calculation. In the calculation, most were able to calculate the initial amounts of each reactant, but many then failed to recognise the idea that one is present in excess so that the other would be the limiting reagent and so determine the amount of water formed. Calculations involving adding 0.02 to 0.045, or subtracting 0.02 from 0.045, were frequently seen, although it was not always clear what students thought they were calculating when they did so, due to poor layout of calculations. There were also a lot of variations seen in the mass used for the $mc\Delta T$ calculation. In any enthalpy change or calorimetry experiment of this type, it is the solution that is increasing in temperature, so it is the mass of solution that needs to be used (100 g here as 25 cm^3 of one solution was added to 75 cm^3 of another and all have a density of 1.00 g cm^{-3}). This calculation discriminated extremely well between students of different abilities; 21.2% scored maximum marks and only 6.4% failed to score anything.

04.6 This was expected to be a high-level discriminator and that certainly proved to be the case for the second mark (achieved by only 3.3% of students). Although many gained a mark for referring to the fact that sulfuric acid is a stronger acid than ethanedioic acid, the second half of their answer often then incorrectly referred to ideas such as “it therefore reacts with more KOH”, “more water is produced”, and “bonds between K^+ and sulfate are stronger than between K^+ and ethanedioate”. Only the best students recognised that the overall enthalpy change is the net result of the difference between ‘energy supplied’ and ‘energy released’. In this case, the ‘energy released’ will be the same for both acids. Therefore, the difference in the enthalpies of neutralisation must be due to ethanedioic acid needing more energy to be supplied, in order to break O–H bonds during the neutralisation reaction (whereas the sulfuric acid is already fully dissociated).

Section B

05 55.5% of students chose the correct response. The commonest incorrect responses were B and D; presumably students failed to recognise that P_4O_{10} could be simplified, while CH_3 is not the formula of a stable compound.

06 72.6% of students were correct. D was the commonest incorrect response, which had the correct bonding but polarity reversed.

07 For this question with a 72.6% success rate, A was the commonest incorrect response.

08 While 66.9% of students correctly identified A, there was a fairly even distribution of wrong answers between B, C and D.

09 This was an extremely accessible question (96.7% correct).

10 B was the commonest incorrect response suggesting confusion about the name of the mechanism of aldehyde reduction. 54.4% of students chose the correct response.

11 This was one of the few questions answered incorrectly more often than correctly (41.7% success rate) – C was the commonest incorrect response. If students draw the structures as their rough working, it should be clear that –OH will not add in position 1 of 2-methylbut-2-ene.

12 43% of students chose correctly. A was the commonest incorrect response, perhaps suggesting that those students were expecting the orders in the rate equation to match the balancing in the reaction equation instead of working out the orders from the rate data given.

13 A was the commonest incorrect response here, suggesting that those students thought it was a concentration v time graph rather than a rate v concentration graph. 76.5% of students were successful.

14 On this question with a 47% success rate, C, followed by B, were the commonest incorrect responses. Students choosing C either failed to remember that the standard enthalpy change refers to starting from the element in its standard state, or thought that iodine is a gas. Those choosing B presumably thought that the molar reference in the definition is to the starting element rather than to a mole of atoms being formed.

15 Although 73.8% of students chose the correct response, B and A both attracted significant numbers of students.

16 59.5% of students were successful here. B was the commonest incorrect response – possibly due to students failing to appreciate that carbons 2,3,5 and 6 are all equivalent.

17 D (followed by B) was the commonest incorrect response. It is not clear why so many students would choose a simple molecular element in preference to a metal as having the highest melting point. 68.9% were, however, correct.

18 C was the commonest incorrect response, which is to be expected as these are the products with **hot** aqueous alkali. The success rate was 68.9%.

19 Although 73.5% of students chose the correct response, A was a significant distractor, suggesting confusion with the reaction between magnesium and cold water.

20 C was the commonest incorrect response, which gave the correct position for the litmus paper but with the colour change reversed. 72.2% of students correctly chose D.

21 This was another extremely accessible question (94.2% correct).

22 A was the commonest incorrect response suggesting that students failed to realise that hydrogen must be directly attached to an electronegative atom in order to take part in hydrogen bonding. 51.2% of students gained this mark.

23 46% of students scored here. Three-quarters of the incorrect responses were D, but there are no changes of oxidation state in this reaction, so it is not a redox reaction. The H_2SO_4 transfers a proton to the HNO_3 so the HNO_3 acts as a base.

24 A was the commonest incorrect response. 58.3% of students realised that electron-releasing alkyl groups increase the availability of the lone pair on N, making amines more basic than ammonia (D).

25 In a question where just under half of students arrived at the correct answer, D was the commonest incorrect response. This was presumably because sulfur forms an acidic oxide that reacts with alkali – but sulfur oxides are molecular, not ionic.

26 D was the commonest incorrect response; presumably the presence of only 3 ligand molecules in the product meant that some students did not realise that the cobalt still has a co-ordination number of 6. 73.9% of students did, however, give the correct response.

27 D was suggested as the answer more often than the correct response (B, identified by 36% of students). This suggests confusion between geometric and optical isomerism in transition metal complexes.

28 A was the commonest incorrect response to this question which had a 47% success rate. This suggests there were many students who recognised that the answer is an aldehyde, but who then missed a possible isomer. Drawing out possible structures in a logical sequence is the key here. Students are advised to start with a 5C chain, then 4C and find

possible positions for the fifth C (carbon 2 or carbon 3), and finally a 3C chain and find positions for the remaining two carbons (both on carbon 2).

29 Just over two-thirds of students arrived at the correct answer. D (followed by A) was the commonest incorrect response.

30 While 72% of students gave the correct answer, D and A were chosen with almost equal frequency as incorrect responses.

31 D was the commonest incorrect response, presumably from a failure to recognise that $Mg(OH)_2$ is sparingly soluble as well as $BaSO_4$. 46.8% of students were successful.

32 C (followed by A) was the commonest incorrect response, suggesting that students failed to realise how low the pH is when the plot ceases to be vertical in a strong acid-weak base titration. The success rate was 41.9%.

33 The correct response was only the third most 'popular' choice for this question, suggesting that this concept is not well known. Poor agreement between theoretical and experimental lattice energy values suggests that the ionic compound has covalent character. This is due to anion polarisation and is most likely when the cation is small with a high charge density and the anion is large (D, chosen by only 23.1% of students). A and C were chosen more often than the correct answer, but the fluoride ion is very resistant to polarisation due to its small size, so fluorides usually match the ionic model and have good agreement between theoretical and experimental values.

34 D was the commonest incorrect response, suggesting that the effect of pressure on equilibrium position was understood better than the effect of temperature. The success rate on the final question was 76.3%.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.