# Examiners' Report

## January 2014

# IAL Chemistry WCH04/01

## General Principles of Chemistry I – Rates, Equilibria and Further Organic Chemistry

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## General

Some candidates were very well-prepared for this examination and scored very high marks. Many candidates were able to demonstrate that they had a sound knowledge of the topics in the specification and could apply this to the questions with just a few errors or omissions. Some candidates would benefit from much more preparation to ensure that they know the basic facts, can express their ideas clearly and carry out calculations, showing their working.

## Section A

Candidates generally found these questions more difficult than in recent examinations. The highest scoring question was 2(a), with over 80% of candidates achieving this mark. The most challenging questions were2(c), 4 and 15 as less than 30% of candidates achieved a mark for each of these questions.

## Section B

### Question 16

Many candidates could write the structural formula for butanenitrile, although some ignored the instruction to show multiple bonds and just wrote CN. Some candidates wrote 3 or 5 carbon atoms in their structures, while others included a hydrogen atom attached to the carbon of the nitrile group. A few candidates wrote amine or nitro groups.

Many candidates could write the correct formulae for the reagents needed for Steps 1, 2, 4 and 5 of the reaction sequence, although it was disappointing to see some incorrect formulae such as $CH_2CH_3OH$ for ethanol. Some candidates had not revised all of these reactions so they did not know the correct reagents. Common incorrect answers were the use of acidified potassium dichromate(VI) in Step 1 and water in Step 4.

The equation for the reaction between sodium carbonate and butanoic acid was poorly answered by many candidates. A significant number did not attempt to balance the equation and it was surprising to see how many candidates did not know the formula for sodium carbonate. It was not unusual to see NaOH as a reactant or product.
Many candidates could give two differences between the low resolution proton nuclear magnetic resonance spectra of butan-1-ol and butanoic acid, although some stated incorrect numbers of peaks. A few candidates just wrote about the different numbers of proton environments and did not mention the differences in the spectra. Candidates who quoted actual chemical shift values from the Data Booklet tended to do well on this question. A small number of candidates confused these spectra with infrared and mass spectra.

Although candidates were asked to mention the bonds and wavenumber ranges for the peaks in the infrared spectra, many omitted the bond or wavenumber and some quoted incorrect ranges, particularly for the C=O bond.

Many candidates would benefit with more practice in drawing skeletal formulae. A significant number of candidates showed an oxygen atom below the main chain of carbon atoms with no bond or just one bond to a carbon atom. A number of structures did not have the correct numbers of carbon atoms in the butanoate and ethyl parts of the formula. A number of candidates did not read the question and gave a displayed formula.

Many candidates did not realise that butanoic acid should be converted into butanoyl chloride first and then react with ethanol to produce the ester. Some candidates stated 'acid chloride' as the reagent for the first step but did not state how to convert butanoic acid into an acid chloride. However, the majority of candidates did score a mark for a correct advantage of using this method, with ‘higher yield’ and ‘reaction goes to completion’ being the most common answers.

Question 17

The diagrams in part (a) varied considerably in quality. Some were very clear and showed apparatus that would work, whilst others were very poor. Common errors included: a delivery tube in a flask, starting below the solution in the flask so the gas would not be able to get out, no bung in the flask, very poor syringes that looked more like condensers or showing that the gas would collect in the plunger, collecting the gas over water and showing the delivery tube going through the side of the water container and collecting the gas in a test tube over water, rather than an inverted measuring cylinder or burette that would enable the volume to be measured. Many candidates would benefit from more practice in drawing common laboratory equipment. A surprising number of candidates omitted to mention time as one of the measurements needed to determine the rate of reaction.

The majority of candidates were able to give the correct unit of the rate constant, although a small number suggested 1/time. They should use an actual unit of time, such as s for seconds. Incorrect units included mol dm$^{-3}$ s$^{-1}$, kJ mol$^{-1}$ and K.
Many candidates could label the reactions correctly as fast or slow and some gave excellent explanations as to how these labels were consistent with the rate equation. However, some candidates struggled to relate the two. Some candidates stated that Steps 1 and 3 were slow as $N_2O_5$ is in both of them. Some candidates did not mention that the slow step is the rate determining step.
A large number of candidates suggested that a water bath would be used to keep the temperature constant. However, some thought that carrying out the reaction at room temperature, just measuring the temperature with a thermometer or carrying out the experiment in an air-conditioned room would be sufficient. A number of candidates suggested the use of a Bunsen flame.

A few candidates did not complete the table in (c)(ii). It is not clear whether they did not see this part of the question or they were unable to do the calculations involved. A small number of candidates rounded 3.125 x 10$^{-3}$ incorrectly as 3.12 x 10$^{-3}$ and -7.05 as -7.0. Some candidates plotted very clear graphs but many others made errors. The common errors included: starting the graph at 0,0 and plotting the points in a small part of the graph grid provided, choosing a difficult scaling and plotting the points inaccurately, not labelling one of the axes or labelling it incorrectly, omitting the 10$^{-3}$ for the 1/T numbers, omitting the units for 1/T or quoting them incorrectly as K, ignoring the minus sign in front of the ln *k* values and plotting them as positive numbers, plotting negative ln *k* values increasing up the y axis and using non-linear scales. Some candidates did not realise that the gradient of the graph would have a negative value, so ended with a negative value for the activation energy, which they should have realised cannot be correct. Some candidates substituted the gradient into the Arrhenius equation and could not calculate the activation energy as they did not have a constant to complete it. Some candidates wrote incorrect units for the activation energy, mostly copying the unit for the gas constant and many ignored the instruction to give their answer to three significant figures.

Question 18

The majority of candidates were able to use the formula given and calculate the concentration of hydroxide ions. They could then use this to calculate the pH of the ammonia solution. Some candidates omitted the minus sign in front of the pH of the hydrochloric acid. The titration curve was drawn well by many candidates, however, some did not read the question and they drew a curve for adding ammonia solution to hydrochloric acid instead of the other way around. Other common errors included: not starting at the pH they had calculated in (a)(ii), not having the vertical section when 25 $cm^3$ of hydrochloric acid added was added, starting the vertical section at too high a pH or extending it too low and not finishing just above the pH they calculated in (b)(i). The majority of candidates were able to select a suitable indicator for the titration, although not all of them were able to give the correct colour change – they should use the Data Booklet to help them to do this. There were also some vague descriptions to justify their selection of indicator. Candidates should note that litmus (azolitmin) is not a suitable indicator to use for an acid-base titration.

Some candidates were confused by the combination of a volumetric calculation and a distribution equilibrium between two solvents in part (c). Some candidates did not use the titration result to calculate the concentration of ammonia in the aqueous layer in part (c)(i) and they just used the volume and concentration of the original ammonia solution. They should have realised their error when the concentration they calculated was considerably higher than the original solution (usually 12.5 mol $dm^{-3}$). Many candidates did not realise that a simple subtraction was required in (c)(ii), although if their answer to (i) was greater than 4 mol $dm^{-3}$, this was difficult. Many candidates did score a consequential mark for (c)(iii).

Hydrogen bonding between ammonia and water was suggested as the reason for ammonia being more soluble in water than trichloromethane by many candidates but there were also many vague answers such as they are both polar or ‘like dissolves like’. A few candidates just stated that ammonia has hydrogen bonding but this is not enough to score a mark.

## Section C

### Question 19

The standard entropy change of the system was calculated correctly by many candidates, however, some lost a mark as they did not show the plus sign or gave incorrect units. Some candidates did not find the correct values for the standard entropies of carbon dioxide and water and another common error was to multiply the standard entropy of oxygen by 12 instead of 24. There were many correct answers for (a)(ii), with the most common errors being the omission of a sign and use of an incorrect sign or units. A few candidates ignored the final significant figures and rounded their answer incorrectly. Although (a)(iii) involved the addition of the answers to (a)(i) and (a)(ii), candidates did need to ensure they were in the same unit and some ignored this and added an answer in J $mol^{-1}$ $K^{-1}$ to an answer in kJ $mol^{-1}$ $K^{-1}$. Some candidates did not realise that the significance of their answer is that it has a large positive value so the reaction is thermodynamically feasible and they stated the number of significant figures in their answer. Many candidates were able to state the effect of increasing the temperature on the standard entropy of the surroundings and the total standard entropy change for the reaction. As these both decrease, many assumed the reaction would be less likely to take place or the position of equilibrium would shift to the left. However, only a small number of candidates realised how large their answer to (a)(iii) was and that the small decrease will still mean that the reaction will take place. Candidates should be encouraged to think about the particular reaction in the question. Is sugar really less likely to combust at higher temperatures? Many candidates realised that the reaction may have a high activation energy so sucrose is stable. Only a few realised that icing sugar has a large surface area and there is a danger of an explosion. The majority of candidates could suggest two risks associated with high levels of sucrose in the diet. Many candidates could identify the four chiral centres on the structure of glucose, although some only circled two of them. Although many candidates did state that molecules with chiral centres rotate the plane of plane-polarised light, there were many other answers given that were not physical properties, for example, they have four different atoms or groups, are non-superimposable on their mirror image or are optically active. Many candidates were familiar with the use of Benedict's or Fehling's solutions, but they did not express their answers clearly. Many omitted the starting colour of the solution as blue or just mentioned it turned red and omitted the precipitate. A few thought that one of these solutions would form a silver mirror. Some did not state there is an aldehyde group in glucose and others did not state that it is oxidised during the reaction or that the $Cu^{2+}$ ions are reduced. A few candidates thought that the alcohol groups would be oxidised during the reaction.

## Hints for revision

Read the questions carefully and make sure that you answer all parts of them.
Practise using the Data Booklet so that you can select information from it and quote correct numbers or ranges, with units.

Practise drawing diagrams of common laboratory equipment set up for experiments carried out during the course.

Practise drawing graphs for determining the activation energy of a reaction, making sure that the scale is suitable and the axes are labelled correctly, with units if necessary. Then calculate the gradient of the line and the activation energy, making sure the sign, units and significant figures are correct.

Practise drawing titration curves for weak and strong acids added to weak and strong alkalis and vice versa, thinking about the start and end pH values, where the vertical section is and the pH range of the vertical section.

Practise entropy change calculations, selecting the correct values from the Data Booklet, giving the correct sign and unit for your answer.

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