Examiners' Report

June 2010

GCE Chemistry 6CH04

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Introduction

The paper was accessible to all candidates, but contained several challenging sections. The general standard was good, and the questions on kinetics and on entropy were both well answered. The calculations on partial pressure at equilibrium caused difficulty, and so did the sections relating to lattice energy in question 21. Many candidates wrote at length in the final sections of this question, while these sections were left completely blank in a significant number of scripts, suggesting that some candidates were short of time.

Only one calculation asked for the answer to be given to a particular number of significant figures, but a surprising number of errors appeared in the final figures of other values. Answers should be rounded correctly regardless of the number of significant figures given, so a calculator display of 2.8363 should be quoted as 2.84, not 2.83.

A data booklet is required for this paper. This is stated clearly in the specification and on the front of the paper. Despite this, some candidates wrote that they did not have one.

Question 17(a)-(c)

Many very good answers were seen. The majority of candidates could complete the table in (a) (i) with the correct value, possibly by working out how the rates in Experiments 1 and 2 related to the other data. The order of reaction with respect to C_4H_9Br in (a)(ii) was well explained, but the comment that "rate does not double when concentration of hydroxide doubles" is not enough to justify why the reaction is zero order with respect to OH^-, and the idea that rate did not change when concentration of hydroxide changes was needed. Candidates who looked at the time taken for hydroxide ion to be used up in Experiments 2 and 3 often thought that the reaction was first order with respect to OH^-, because the time increased by the same factor as the increase in concentration. This shows the need to distinguish time and rate when using this type of data. Credit was given in (a)(iii) if the rate equation was consistent with the orders in (a) (ii) and there were very few cases where the rate constant was missing. Calculation of the rate constant in (a)(iv) proved straightforward, and units were usually correct.

In (b), some candidates deduced that their rate equation showed that an SN1 reaction was occurring, but did not gain credit because they did not answer the question on the paper. Saying that the reaction is SN1 and therefore has two steps is not giving the evidence as required; the answer had to make clear that hydroxide ions are in the chemical equation but not in the rate determining step, and therefore must be in another step in the mechanism.

Regardless of what had been said about mechanism, the bromoalkane was often shown as primary in (c). Marks were lost if the starting and finishing positions of curly arrows were not shown clearly,or if the charge on the intermediate or transition state was incorrect. Some candidates knew that attack on a carbocation could be from either side, and drew two curly arrows from each hydroxide ion. Candidates who had produced a rate equation involving both the bromoalkane and hydroxide ion could still gain full credit in this section if their mechanism was consistent. The main difficulty here was showing the transition state correctly.

This shows the need to distinguish time and rate when using this type of data.

Experiment	[C_4H_9Br] /mol dm^{-3}	[OH^-] /mol dm^{-3}	Time for OH^- to be used up/s	Initial rate /mol dm^{-3} s^{-1}
1	0.017	0.0012	42	2.9×10^{-5}
2	0.034	0.0012	21	5.7×10^{-5}
3	0.034	0.0020	35	3.42×10^{-5}

(i) Complete the missing value of the initial rate in the table.

(1)

(ii) State the order of the reaction with respect to C_4H_9Br and to OH^-. Justify each answer by reference to the concentrations of both reactants.

(3)

Order with respect to C_4H_9Br .....First order...

Reason ...When the concentration C_4H_9Br was doubled, the time for OH^- to be used up, and rate, also doubled

Order with respect to OH^- ......First order...

Reason ...When the concentration OH^- was increased by 60%, the time taken for OH^- to be used up, and the rate also increased by 60%.

ResultsPlus
Examiner Comments

The answer for bromobutane says that rate is doubled when the time taken for the reaction is doubled, but a longer time would mean a slower rate.

ResultsPlus
Examiner Tip

Order of reaction is explained here in terms of time taken and also in terms of rate. The explanations contradict each other. Only one reason should be given.

(b) What evidence supports the theory that there is more than one step in the reaction mechanism?

(1)

overall order = 2   meaning its S_n1 mechanism , giving the two steps   needed in the   mechanism

ResultsPlus
Examiner Comments

The candidate wrote a second order rate equation and thought that this meant there were two steps.

ResultsPlus
Examiner Tip

The rate equation shows the species which take part in the slowest step. If a substance is in the chemical reaction but not in the rate equation, then there must be another step.

Question 17(d)

Some candidates misunderstood this question and simply described SN1 and SN2 mechanisms. Other answers were too vague, referring to easy attack on the primary halogenoalkane without explaining why it would be easier, or confusing stability of the bromoalkane with stability of the carbocation. A number of answers discussed the formation of racemates, again showing that the question had not been read carefully.

*(d) Explain why primary and tertiary bromoalkanes are hydrolysed by different mechanisms.

(2)

primary bromoalkanes can be approached by the nucleophile from many angles. ~~meaning that the~~ tertiary bromoalkanes can only be approached once the Br$^{\delta-}$ has broken off, because there is no other space ~~for~~ for the nucleophile to approach due to the crowding of the carbon groups.

ResultsPlus
Examiner Comments

This answer required good Quality of Written Communication. The idea of there being little space for a nucleophile to attack a tertiary carbon is correct, but the first sentence is meaningless, and the candidate may be thinking of attack on a planar carbocation being from either side.

ResultsPlus
Examiner Tip

Chemical terms should be used carefully, so the carbon groups should be described as alkyl groups. The atom which is being attacked by the nucleophile should be named.

Question 18(a)(i)

This question was usually answered correctly.

Question 18(a)(ii)-(v)

The reactions of butanoic acid in (a) were mostly well known. In questions where either a name or formula is required, candidates should not give both, as they will not be given the mark if one is incorrect. The name of the ester in (a)(iv) was the most common error, and water was often missing from the balanced equation. Some candidates gave molecular formulae for butanoic acid and the ester in this equation. As the formulae were in the question this did not matter, but use of molecular formulae in organic equations is rarely helpful as the structures of the chemicals usually have to be considered. In (a)(iv) it was disappointing that many candidates did not display the formula as required. The other common error was the inclusion of an extra O atom.

(ii) Identify, by name or formula, the reagent which is used with sulfuric acid to carry out **Reaction B**.

(1)

lithium aluminium hydride _pottasium dichromate_

(iii) What reagent is used in **Reaction C**?
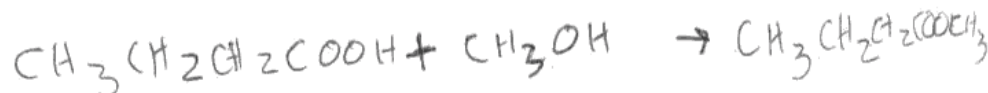
(1)

lithium aluminium hydride _lithium aluminium hydride_

(iv) Name the organic product of **Reaction D** and write a balanced equation for its formation.

(2)

Name _Methyl propanoate_
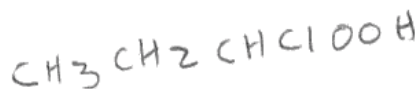
Equation

$$CH_3CH_2CH_2COOH + CH_3OH \rightarrow CH_3CH_2CH_2COOCH_3$$

(v) Write the **displayed** formula for **Z**, the organic product of the reaction of butanoic acid with phosphorus(V) chloride, PCl_5.

(1)

$$CH_3CH_2CHClOOH$$

ResultsPlus
Examiner Comments

The mistake in the ester name occurred frequently. Water is missing from the equation. The compound in (v) is incorrect.

ResultsPlus
Examiner Tip

Make sure that inorganic products are included in equations. If a question asks for a displayed formula, all bonds should be shown. This may let you see that some formulae, like this one, are unlikely or impossible.

Question 18(b)

In (b)(i) many candidates realised that nitrogen is inert, though some suggested it was used because it was denser than oxygen. Some thought oxygen burns rather than supports combustion. In both (b)(i) and (ii), candidates often gave more than one answer, and as referred to in (a) could lose marks as a consequence. The understanding of the principles of GLC was weak and a variety of random properties of the molecules was given, from mass/charge ratio to number of hydrogen environments.

(b) Butanoic acid and propane-1,2,3-triol are formed when fats in milk are hydrolysed. The presence of milk fat in low fat spreads is detected by hydrolysing the spread, and then analysing the products using gas chromatography (also called gas-liquid chromatography, GLC).

(i) Explain why nitrogen, rather than oxygen, is used as the carrier gas in GLC.

(1)

Oxygen is a heavier gas than nitrogen. Oxygen's relative atomic mass (ram) is 16 whereas nitrogen's RAM is 14, helping it to move faster.

(ii) What property determines whether butanoic acid or propane-1,2,3-triol would move faster through the chromatography column?

(1)

The eluent. The liquid phase eluent.

ResultsPlus
Examiner Comments

The first part of the answer is irrelevant to GLC. The second part is not a property of the compounds which are being separated.

ResultsPlus
Examiner Tip

Learn the nature of the phases which are present in different types of chromatography. Separation occurs because the forces between the stationary phase and the compounds in the moving phase differ in strength.

Question 18(c)

The polymer in (c)(i) was often shown correctly. Some answers showed too many oxygen atoms at the ends of the section; others thought that the instruction to show double bonds meant that the polymer contained carbon-carbon double bonds. Many candidates realised that hydrolysis with acid could occur, though every other reaction type featured and transesterification was a common answer.
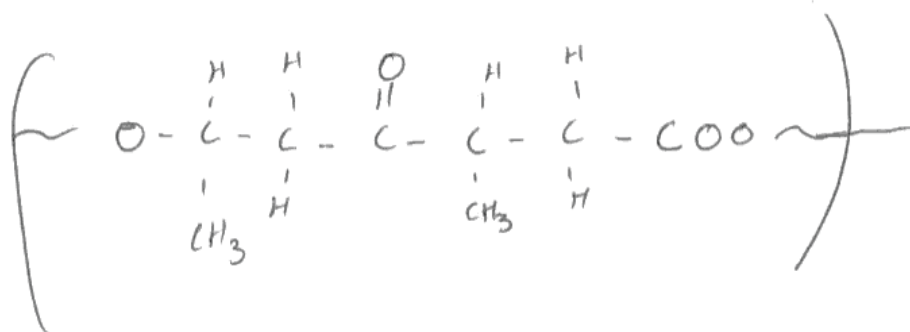
(c) The formula of 3-hydroxybutanoic acid is shown below.

$$HO-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}-CH_2-COOH$$
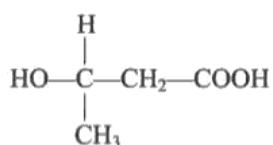
(i) 3-hydroxybutanoic acid can form a polymer which is used to make "green" packaging as it is biodegradable.

Draw a section of this polymer, showing TWO monomer units. Clearly show any double bonds.

(2)

(ii) The polymer cannot be used in acidic conditions. What reaction would occur when the polymer is in prolonged contact with an acid?

(1)

esterification

ResultsPlus
Examiner Comments

Neither the ester link nor the atoms at the end are correct.

ResultsPlus
Examiner Tip

Try drawing two monomers side by side and work out what would be formed when an H and an OH are lost, making water. This applies at the ends of the section too. A hydrogen will be lost at one end and an OH at the other.

Question 19(a)

There were very few expressions with square brackets in (a)(i). However, the method of calculating partial pressure in (a)(ii) was not well known. Few candidates seem to realise that the total pressure is the sum of the partial pressures, and most did complicated calculations involving numbers of molecules and mole fractions. These answers could, and often did, gain full credit in (a)(iii) as long as they were used correctly and were rounded to the required number of significant figures. A few candidates converted their answers in atm^{-1} to kPa^{-1}. This was perfectly acceptable if done correctly, but an unnecessary step.

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19 Ethanoic acid can be manufactured by the following reaction, which is carried out between 150 °C and 200 °C.

$$CH_3OH(g) + CO(g) \rightleftharpoons CH_3COOH(g)$$
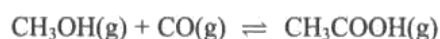
(a) A mixture of 50.0 mol of methanol and 50.0 mol of carbon monoxide reaches equilibrium at a pressure of 32.0 atm. At 175 °C, the equilibrium partial pressure of ethanoic acid is 22.2 atm.

(i) Write the expression for the equilibrium constant in terms of pressure, K_p, for this reaction.

(1)

$$K_p = \frac{P[CH_3COOH]}{P[CH_3OH] \times P[CO]}$$

(ii) Calculate the partial pressures of methanol and carbon monoxide at equilibrium.

(2)

$$\frac{50}{150} \times 32 = \frac{32}{3} = 10.6$$

Methanol .... 10.6 ....

Carbon monoxide .... 10.6 ....

(iii) Calculate the value of K_p for this reaction at 175 °C. Include a unit in your answer and give your answer to **three** significant figures.

(2)

0.148 atm⁻¹

ResultsPlus
Examiner Comments

This answer lost the first mark as square brackets indicate concentrations. The value for the partial pressure of ethanoic acid was not used in the calculation, and the candiate has assumed that equal numbers of moles of each compound were present.

ResultsPlus
Examiner Tip

When data, such as the equilibrium partial pressure of ethanoic acid, is given in a question it is needed somewhere. The difference betwen the total pressure and the partial pressure of ethanoic acid is the pressure due to the remaining gases.

Question 19(b)

Calculating the number of moles at equilibrium in (b)(i) caused many problems, but calculating partial pressure in (b)(ii) from this sort of data was obviously a more familiar task than in the previous question. In (b)(iii) there were good answers applying Le Chatelier's principle, to work out that the reaction was exothermic.

(b) Another sample of 50.0 mol of methanol and 50.0 mol of carbon monoxide was allowed to reach equilibrium at the same pressure of 32.0 atm, but at a lower temperature. 93.6 % of the methanol was converted at equilibrium.

(i) Complete the table below to show the number of moles of each species in the equilibrium mixture.

(2)

93.6 $\frac{z}{5} = 0.4$

	CH_3OH	CO	CH_3COOH
Number of moles at start	50.0	50.0	0
Number of moles at equilibrium	3.2	3.2	46.8

(ii) Calculate the partial pressure of ethanoic acid in the equilibrium mixture.

(1)

$\frac{46.8}{2} \times 32 = 748.8$

ResultsPlus
Examiner Comments

This candidate did not work out the total number of moles present when calculating partial pressure.

ResultsPlus
Examiner Tip

If the partial pressure you calculate turns out to be much greater than the total pressure, you should look for the error which you must have made.

(b) Another sample of 50.0 mol of methanol and 50.0 mol of carbon monoxide was allowed to reach equilibrium at the same pressure of 32.0 atm, but at a lower temperature. 93.6 % of the methanol was converted at equilibrium.

(i) Complete the table below to show the number of moles of each species in the equilibrium mixture.

(2)

	CH_3OH	CO	CH_3COOH
Number of moles at start	50.0	50.0	0
Number of moles at equilibrium	3.2	3.2	46.8

(ii) Calculate the partial pressure of ethanoic acid in the equilibrium mixture.

(1)

$$\text{mol fraction} = \frac{\text{no mol}}{\text{total n° mol}} = \frac{46.8}{53.2} = 0.8796 \ldots$$

$$= 0.88$$

$$\text{partial pressure} = \text{mol fraction} \times \text{total pressure}$$

$$= 0.88 \times 32.0$$

$$= 28.16 \text{ atm.}$$

ResultsPlus

Examiner Comments

This is an example of a good answer.

Question 19(c)

A significant number of candidates lost credit by failing to justify their answers to either (c)(i) or (ii) as required in the question. Many appreciated that K_p is only changed by temperature. While many realised that addition of methanol would increase the equilibrium yield of ethanoic acid, the usual reason given was that the equilibrium moves to the right. This is just another way of saying that more ethanoic acid forms, but does not explain why. A comment was needed about the equilibrium moving to restore Kp or to use up the methanol, or one showing the application of Le Chatelier's principle.

(c) How, if at all, does the addition of methanol to the equilibrium mixture affect the following? Justify your answers.

$$CH_3OH(g) + CO(g) \rightleftharpoons CH_3COOH(g)$$

(i) The equilibrium constant for the formation of ethanoic acid.

(1)

~~intrinsic~~ un affected, as at eqb, proportions of reactants/products will be the same.

(ii) The equilibrium yield of ethanoic acid.

(1)

Yield increases as eqm is pushed to right.

ResultsPlus
Examiner Comments

This answer does not explain why the proportions of reactants and products remain the same.
Saying in (ii) that yield increases is equivalent to saying that equilibrium moves to the right, but the reason is not given.

ResultsPlus
Examiner Tip

The reasons in the answer have to be worded very carefully to make sure they are adding something new. The equlibrium constant does not change because concentrations change to keep it constant. In (ii), you need apply Le Chatelier's principle by explaining that the equilibrium moves to use up some of the added methanol.

Question 19(d)

There were many good answers to (d). They usually stated that reactions occurred at lower temperatures with a catalyst, and hence less fuel is used and less carbon dioxide is emitted. Very few answers were seen using the argument about atom economy. Some thought that re-use of the catalyst meant a saving of resources, but this does not make the comparison of a catalysed with an uncatalysed reaction. Other answers said that a catalysed reaction uses less energy as equilibrium is reached faster. However, few industrial reactions are actually left to reach equilibrium.

(d) In industry, catalysts are used even though they are often expensive.

State and explain ONE benefit to the **environment** resulting from the use of catalysts in industrial processes.

(2)

Catalysts provide an alternate route for the reaction, which requires a lower activation energy. ∴ less energy is needed to overcome the Ea meaning less energy is needed to be given to the particles. ∴ less energy needs to be generated. ∴ less fossil fuels burned (Total for Question 19 = 13 marks)

∴ less greenhouse gases in atmosphere

ResultsPlus
Examiner Comments

This is an example of an answer which scored both marks.

(d) In industry, catalysts are used even though they are often expensive.

State and explain ONE benefit to the **environment** resulting from the use of catalysts in industrial processes.

(2)

Less Pollution. The catalyst will speed up the reaction ~~on~~ and so the equipment won't need to be on for as long. ~~and this~~ This means less ~~waste~~ ~~material and~~ natural resources are needed to keep the equipment running, and pollution from the equipment decreases.

(Total for Question 19 = 13 marks)

ResultsPlus
Examiner Comments

The time for which the equipment is running is not the relevant point. Pollution from the equipment is too vague a term to score a mark for an environmental benefit. It could mean emissions from fuels or leaks from a container.

ResultsPlus
Examiner Tip

When writing about environmental benefits you should be specific. You could refer to the reduction in greenhouse gases produced or to conserving non-renewable resources such as fossil fuels

Question 20(a) (i)

Calculating the pH of a strong base is less straightforward than calculating the pH of a strong acid, and (a)(i) revealed various misunderstandings. Many candidates thought that the concentration of hydroxide ions was half the concentration of sodium hydroxide. Some used the expression for Ka of a weak acid producing a totally meaningless answer. Others made errors when manipulating the powers of 10 in their calculations.

Question 20(a) (ii)-(iii)

The expression for Ka required in (a)(ii) was well known, though marks were not given for the approximation unless the full version was also given. If an expression was given for a theoretical acid, HA, a key to the symbols HA and A- was required. The principle of calculating the pH in (a)(iii) from the Ka expression with approximations was well known, but actually doing the arithmetic caused difficulties.

(ii) Write the expression for the acid dissociation constant, K_a, for ethanoic acid.

(1)

$$K_a = \frac{[H^+][CH_3COO^-]_{\text{mm}}}{[CH_3COOH]_{\text{ym}}}$$

(iii) Calculate the pH of 0.125 mol dm^{-3} ethanoic acid at 298 K.

[K_a for ethanoic acid is 1.7×10^{-5} mol dm^{-3} at 298 K.]

(2)

$$1.7 \times 10^{-5} = \frac{[H^+]^2}{0.125}$$

$$[H^+] = \sqrt{1.7 \times 10^{-5} \times 0.125}$$

$$= 1.46 \times 10^{-3}$$

$$pH = -\log[H^+] = -\log[1.46 \times 10^{-3}] = 2.84 \quad (3sf)$$

ResultsPlus
Examiner Comments

This is a good clear answer with correct formulae, square brackets and the calculation in (iii) shown clearly which would therefore have got the first mark even if there had been an error in the final value.

Question 20(a) (iv)

In (a)(iv) the fact that pH = pKa at the point where half the acid has been neutralised in a titration had been learnt by some candidates. Some others worked it out using the Ka expression, but many assumed this occurred at pH 7, forgetting that the acid and base involved were not both strong.

(iv) When half the ethanoic acid is neutralized, the concentration of the remaining ethanoic acid equals the concentration of the sodium ethanoate which has formed. What is the pH of the mixture at this point? Justify your answer.

(2)

pH _____ 7 _____

Justification _____ Because there is an equilibrium and an equal amount of H^+ and OH^- so they cancel each other and make the solution neutral

ResultsPlus
Examiner Comments

This shows the common misunderstanding about the point where half the acid has been neutralised.

Question 20(a) (v)-(vi)

The titration curves drawn in (v) were very varied. Some were very poorly drawn with several crossings out, falling pH values, thick lines and other assorted errors. The mark gained least often was the one for appreciating that the vertical section of the curve would occur after addition of 12.5 cm3 of sodium hydroxide. The most popular assumption was that it would be half way across the graph at 15 cm3. Though many realised that a strong base was being added to a weak acid, the vertical section sometimes started round pH4 and went up to pH14. On some occasions the pH was shown as still rising very steeply after addition of 30 cm3 of sodium hydroxide.

In (vi), a significant number of candidates did not read the instructions and used their own indicator choice. The question rewarded those candidates who gathered the required information from the Data Booklet and used it appropriately. Though the majority grasped that thymolphthalein would be more suitable, it was apparent that a number did not understand the concept of range of an indicator. Credit was lost by not answering the part of the question which said ".. and why the other is unsuitable", with many explaining why the first indicator was suitable and assuming that it was then obvious why the second was not.

(v) On the axes below, sketch the titration curve for this reaction when 30 cm³ of the sodium hydroxide is added to 25.0 cm³ of the vinegar solution.

(3)

3.125
12.5

Volume of NaOH added/cm³
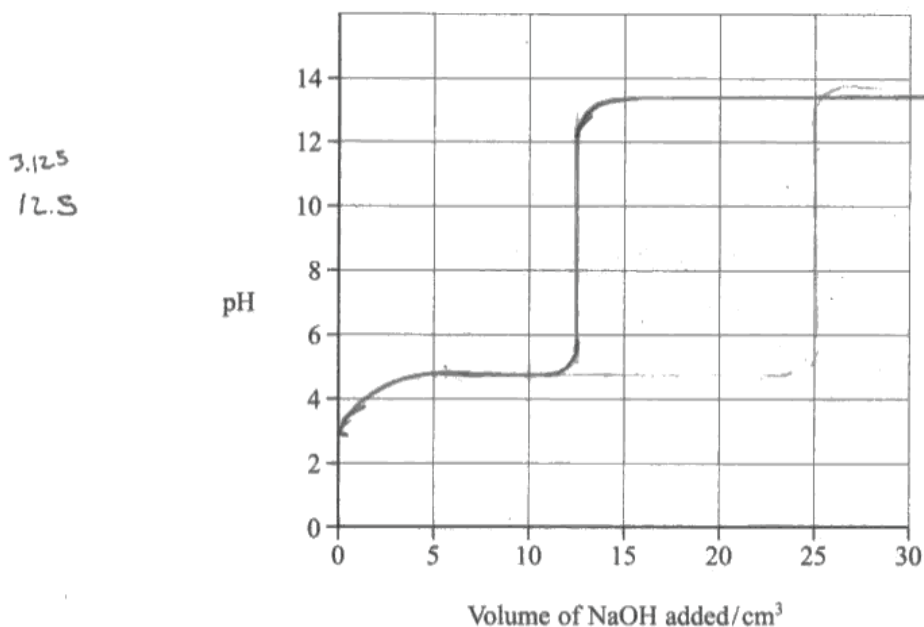
*(vi) The only indicators which were available for this titration were methyl yellow (in ethanol) and thymolphthalein. Explain which indicator is more suitable for this titration and why the other is unsuitable. You will need to refer to your data booklet.

(2)

Thymolphthalein as the pH range of 8.3-10.6 in which is changes colour is within the vertical part of the graph, so it will change colour sharply near the point of equilibrium. Methyl orange changes colour @ pH 3.2-4.4 so it would start to change colour before the point of equilibrium

ResultsPlus
Examiner Comments

This is an example of a good answer. The only error in the curve is the length of the vertical section. In (vi) the candidate refers to the point of equilibrium rather than equivalence, but the principle that the range of the indicator covers the region of rapid pH change is correct and was given the marks.

ResultsPlus
Examiner Tip

Titration curves for strong acid/ strong base have a long vertical section. The vertical section when a weak acid or weak base is involved is shorter.

Question 20(b)

In (b), the most common answer was sodium ethanoate. Candidates may have known that the shape of the titration curve of ethanoic acid with sodium hydroxide is due to the formation of sodium ethanoate, which makes the mixture a buffer. However sodium hydroxide would not be suitable as an additive to foodstuffs in order to produce a buffer, and was not allowed as an answer here.

Question 21(a)

This question showed good understanding of entropy. Many of the calculations in (a) were done well. In (a)(i), common errors were to use the entropy values for $H_2O(g)$ instead of $H_2O(l)$ and to forget to multiply the value for $H_2O(l)$ by 6. Occasionally, values of the enthalpy change of formation were used instead of entropy. These all suggest a lack of familiarity in using the Data Booklet. Answers to (a)(ii) usually referred to the formation of a liquid. Simply saying that disorder increased, without justification, was not enough, and answers saying that one reactant made two products should have referred to the number of moles of each in the equation. In (a) (iii) many candidates ignored the final decimal in the value of the enthalpy change and obtained an incorrect answer, even though they knew how to do the calculation. In (a)(v) the concept that there is thermodynamic stability when total entropy change is negative was well understood.

21 (a) Crystals of hydrated cobalt(II) chloride, $CoCl_2.6H_2O$, lose water when they are heated, forming anhydrous cobalt(II) chloride, $CoCl_2$.

$$CoCl_2.6H_2O(s) \rightarrow CoCl_2(s) + 6H_2O(l)$$

(i) Calculate the entropy change of the system, $\Delta S^\ominus_{system}$, at 298 K. Include a sign and units in your answer. You will need to refer to your data booklet.

(2)

$$\Delta S_{system} = \Delta S_{products} - \Delta S_{reactants}$$
$$= (109.2 + 6 \times 69.9) - 343$$
$$= +185.6 \ J k^{-1} mol^{-1}$$

(ii) Explain whether the sign of your answer to (a)(i) is as expected from the equation for the reaction.

(1)

The reaction produces a liquid, which is more disordered than a solid, so I would have expected ΔS_{system} to be a positive value.

(iii) The standard enthalpy change for the reaction, $\Delta H^{\ominus}$, is $+88.1\,\text{kJ mol}^{-1}$.
Calculate the entropy change in the surroundings, $\Delta S^{\ominus}_{\text{surroundings}}$, at 298 K for this reaction. Include a sign and units in your answer.

(2)

$$\Delta S_{surr} = \frac{-\Delta H}{T} = \frac{-(88 \times 10^3)}{298} = -295.3 \; Jk^{-1}mol^{-1}$$

(iv) Calculate the total entropy change, $\Delta S^{\ominus}_{\text{total}}$, at 298 K for the reaction.

(1)

$$\Delta S_{total} = \Delta S_{system} + \Delta S_{products}$$

$$= 185.6 - 295.3$$

$$= -109.7 \; Jk^{-1}mol^{-1}$$

(v) Does your answer to (a)(iv) indicate whether hydrated cobalt(II) chloride can be stored at 298 K without decomposition? Explain your answer.

(1)

This value means that there will be an eqm, well to the left, meaning there will be more reactants than products. However, there will be a little decomposition

ResultsPlus
Examiner Comments

The answers to (i) and (ii) are clear and correct. In (iii) the enthalpy change 88.1 should have been used, but the mark for (iv) was given in consequence of this. The mark to (v) was not given because of the reference to "a little decomposition"

ResultsPlus
Examiner Tip

The negative value for the total entropy change shows that the cobalt(II) chloride will not decompose.

Question 21(b)

Answers to (b) suggest that errors continue to be poorly understood.   A few candidates in (b) (i) referred to percentage errors or worked them out, though to get the mark they only needed to appreciate that the temperature change was very small. Suggestions for changing more than one measuring instrument appeared, but did not score. In (b)(ii), very few realised that a bigger temperature change would reduce the percentage error. Most candidates chose to repeat the experiment or use another more precise piece of equipment. Those who suggested using more cobalt chloride often thought that more water should be used as well.

(b) A student attempted to measure the enthalpy change of solution of anhydrous cobalt(II) chloride by adding 2.00 g of cobalt(II) chloride to 50.0 cm^3 of water in a well-insulated container. A temperature rise of 1.5 °C was recorded.

The student used a balance which reads to 0.01g, a 50.0 cm^3 pipette, and a thermometer which can be read to 0.25 °C.

(i)   Which measuring instrument should be changed to give a result which is closer to the accepted value? Justify your answer.

(2)

The thermometer needs to be changed as it's uncertainty value is very high when used in this ~~experiment~~ experiment, ~~the~~ being at 17% it is not within acceptable limits.

(ii) Suggest ONE **other** change the student could make to give a result which is closer to the accepted value. Justify your suggestion.

(2)

Use a larger amounts of reactants to give a more accurate results.

ResultsPlus
Examiner Comments

The candidate has calculated the error in the thermometer reading, though recognition of the very small temperature change would have been enough.
Using more water as well as more cobalt chloride will not give a bigger temperature rise.

ResultsPlus
Examiner Tip

The answer should say why the suggested change would make the results more accurate.

which is much higher than any of the other instruments.

(ii) Suggest ONE **other** change the student could make to give a result which is closer to the accepted value. Justify your suggestion.

(2)

use a greater mass of cobalt chloride so the overall temperature rise would be greater *as more energy is given out* and the percentage error due to the uncertainty of the thermometer would be less.

ResultsPlus
Examiner Comments

This is an example of a good answer to (ii)

Question 21(c) (i)

In (c)(i) the relationship and significance of the data was not understood by many candidates and much data was incorrect. A statement about the trend in the values of ionic radii was usually correct. However, in some cases, there were statements such as "as the ionic radii increase, the lattice energy increases". Since the lattice energies were quoted for formation of the lattice their values were negative and statements about increase and decrease are very hard to interpret. Candidates should describe them as becoming less negative or more negative, or refer to the magnitude of the lattice energy. After stating the trend in ionic radii, many candidates went on to answer their own questions rather than the one which was set. They explained the trend in ionic radii, the shielding of nuclear charge, the trend in polarising power of each ion, but frequently forgot to answer the part of the question about cobalt(II) chloride. Those who looked up the radius of the cobalt ion often selected the value for Co^{3+}, and atomic and metallic radii were sometimes given.

*(c) The lattice energies of magnesium chloride, $MgCl_2$, calcium chloride, $CaCl_2$, and strontium chloride, $SrCl_2$ are shown in the table below.

Chloride	Lattice energy/kJ mol^{-1}
$MgCl_2$	−2526
$CaCl_2$	−2258
$SrCl_2$	−2156

(i) Use data on ionic radii, from your data booklet, to explain the trend in these values. Estimate a value for the lattice energy of cobalt(II) chloride, giving ONE piece of data to justify your estimate.

(4)

Around ~~-2300~~ −2250 as the ionic radii ~~ee~~ ~~do~~ increase in size as you go down group 2 from $Mg^{2+} => 0.072nm$ to $0.113nm$ for Sr^{2+} and so as the ionic radii increases the less energy will be needed ~~to break the~~ for the lattice energy as the shielding means less attraction so ~~the~~ since ~~& energy~~ cobalt ion will have similar size as ~~a~~ calcium since in same period they'll have similar lattice energy

ResultsPlus
Examiner Comments

The link between shielding (of the nucleus - not stated) and lattice energy is not clear. The answer does not compare the size of the cobalt $^{2+}$ ion with the magnesium ion. It is smaller, so the lattice energy for cobalt(II) chloride will be more negative than for magnesium chloride.

Question 21(c) (ii)

In (c)(ii) many realised that data on enthalpy of hydration was needed, but very few were succinct about the fact that whether something dissolves depends on the relative amount of energy required to break the lattice and the energy recouped by hydration. Many thought that a high positive value for heat of solution indicated that solubility was more likely.

(ii) Explain how lattice energy values, together with other data, can be used to predict the solubility of ionic compounds.

(3)

The ~~la~~ greater the lattice energy the more soluble the compound as the ΔH would be more negative. This in turn would give a positive value of $\Delta S_{surrounding}$ and hence a positive value for ΔS_{total}. ~~The lattice energy shows that~~

ResultsPlus
Examiner Comments

This doesn't specify what enthalpy change is being discussed. If the enthalpy change of solution is negative, the comments on the entropy change of surroundings and total entropy change would be correct. However, enthalpy change of solution cannot be calculated unless the enthalpy changes of hydration of the ions are known.

ResultsPlus
Examiner Tip

The answer should say what data, other than lattice energy, are needed to find the enthapy and entropy changes.

Question 21(d)

In (d), answers lacked precision. It was stated that Mg^{3+} could not exist, without any reference to ionisation energy. Some answers tried to give an explanation in terms of the electron affinity of the chloride ion. Some candidates thought that there would not be space for three chloride ions round one magnesium ion. Answers which stated that the third ionisation energy of magnesium was very high often did not develop this, or say that the compound would not have a big enough lattice enthalpy to compensate.

*(d) Cobalt forms another chloride, CoCl₃, but scientists predict that MgCl₃ cannot be made. Suggest a reason for this.

entropy can be calculated so solubility can be predicted.

You should consider the enthalpy changes in the Born-Haber cycle, which provide evidence about why cobalt(III) chloride is known but magnesium(III) chloride is not.

(2)

mgCl₃ cannot be made as the mg ion would have to form a 3+ ion that is not as stable compared to mg²⁺ ion. MgCl₃ would have a negative positive lattice energy and the ionisation energies of magnesium would be very positive negative so would not form a stable compound of mgCl₃. Reaction would be endothermic.

(Total for Question 21 = 20 marks)

ResultsPlus
Examiner Comments

The answer says the Mg3+ ion is not stable, but does not refer to the ionisation energy needed to produce it. The lattice energy of formation of magnesium(III) chloride would be negative, but not large enough to compensate for the size of the ionisation energy.

ResultsPlus
Examiner Tip

When an ionic compound is made from its elements, the lattice energy of formation is negative, and compensates for the energy needed to form ions from atoms.

Nearly every examiner's report contains the advice to read the question. This one is no exception, as marks were frquently lost when the question which was answered was not the one which was asked. Reading the question carefully is probably the best way for a candidate to improve marks.

Grade Boundaries

Grade	Max. Mark	a*	A	B	C	D	E	N	U
Raw boundary mark	90	77	69	61	53	45	38	31	0
Uniform boundary mark	120	108	96	84	72	60	48	36	0

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