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Examiners' Report

June 2011

GCE Chemistry 6CH05 01

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Introduction

The paper seemed to provide a fair examination of both the recall of factual knowledge and application of key concepts. There was very little evidence of candidates not having sufficient time, with attempted answers nearly always seen for all parts of the paper.

In general candidates showed evidence that they had taken time to learn key facts from the course. For instance, the majority recalled reagents needed for organic reactions accurately. As you would expect, the application of such facts was less consistent, but generally it was lack of detail and imprecise language which prevented award of marks, rather than deep-rooted misconceptions. The exception to this was the chemistry of fuel cells, where use of very simple ideas, such as the product of the combustion of hydrogen was used inaccurately.

Questions in a practical context provided more of a challenge, though standard techniques such as recrystallization seemed to have been learnt 'off by heart' by many candidates. When testing 'How Science Works', there was limited evidence that some candidates are getting more adept at distinguishing between accuracy and reliability, though many still use these two terms interchangeably.

The quality of diagrams was overall, slightly better, but the examining team still believe there is room for further improvement, especially when drawing apparatus. Worryingly though, there is evidence to suggest that there is a decline in the standard of presentation. Candidates should realise that it is not possible to award credit if an answer cannot be read.

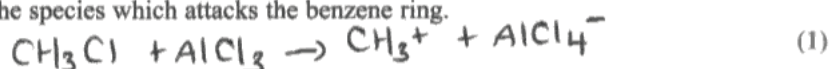
Question 13 (a) (i)

This proved to be a gentle start for the vast majority of candidates. The most common error seen was the use of CH_4 .

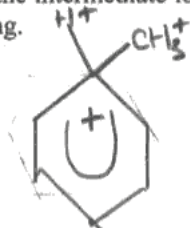
Question 13 (a) (ii-iii)

Most candidates were able to accurately write an equation to show the formation of the electrophile, CH_3^+ . Errors were more common in part (a) (iii). These included showing the ring with full delocalisation intact, extending the delocalisation over the carbon to which the CH_3^+ group was attached and presenting positive charges both in the ring and on either the methyl group or hydrogen shown in the intermediate.

- (ii) Write the equation to show how the catalyst, AlCl_3 , reacts with reagent A to form the species which attacks the benzene ring.



- (iii) Draw the structure of the intermediate ion formed when the species in (ii) attacks the benzene ring.



(1)



ResultsPlus Examiner Comments

Although in this example the candidate has been careful to show an appropriate degree of delocalisation in the ring and correctly shown a positive charge **within** the ring, they have shown additional incorrect positive charges on the attached groups. Hence, they did not score in part (a) (iii).

Question 13 (b)

It was pleasing to see many candidates score two marks in part (b). The concept of the methyl group donating or pushing electrons into the ring and the subsequent effect on electrophilic attack was well understood. A few candidates unsuccessfully tried to use an argument centred around lone pair donation, presumably based on concepts they had learnt in relation to phenol. Other weaker answers lost out due to a lack of detail or care. For instance a minority simply argued 'because the methyl group is an activating group', which does little more than repeat the question. Others confused the nature of nucleophiles and electrophiles.

(b) The methylbenzene formed in **reaction 1** generally reacts in a similar way to benzene but faster, as the ring is said to be activated.

(i) Explain how the presence of a methyl group activates the benzene ring.

(1)

The methyl group will distort the π orbital delocalized ring by donating electrons in and changing the shape and increasing electron density of the ring.

(ii) Use your answer to (i) to explain why methylbenzene reacts faster.

(1)

The ring is ~~less~~ slightly less stable when a CH_3 group is attached and will help the ring tend towards substitution making reactions faster



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Examiner Comments

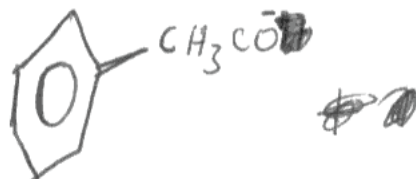
This example misses out on the second mark because, although they have tried to link a decrease in stability to greater likelihood of substitution reactions, they have not quite made the link between the increased electron density mentioned in (b) (i) to the increased chance of electrophilic attack.

Question 13 (c) (i)

Over 75% of candidates could suggest a correct structure in part (c) (i). However, careless drawing of the structure led to some loss of marks. This was generally when the structure was shown with the methyl group attached to the ring, rather than the carbonyl group. A small number showed formation of an aldehyde, suggesting $-\text{CH}_2\text{CHO}$ attached to the ring. Some weaker candidates showed 5-valent carbonyl carbons, the extra atom often being chlorine.

(c) (i) Draw the structural formula of **compound X**, formed in **reaction 2**.

(1)



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Examiner Comments

This example shows the most common incorrect response to this question. It is disappointing because the candidate has recalled the nature of the product, but has not considered the arrangement within the molecule correctly as the ring seems to be attached to the methyl group. In addition they have added a spurious charge to their structure.



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Examiner Tip

If you are unsure whether your proposed structural formula is correct, then sketch out a displayed version of the key groups to help you show clearly which atoms are attached to which.

Check the valencies of key carbons to ensure they add up to four.

Question 13 (c) (ii)

A disappointingly large number of responses simply stated that, use of microwaves for heating did not release greenhouse gases, with no consideration to the way the electricity was likely to have been generated initially. Weaker candidates who did discuss the catalyst often talked generically about why using a catalyst was better than no catalyst at all, missing the point of the question. A few candidates had a near miss by discussing the idea that using aluminium would produce no HCl, forgetting that the reaction itself gives HCl as a product, regardless of the catalyst. The best answers recognised the increased efficiency of microwave heating, often by discussing the selective nature of the way microwaves heat, as well as the easy way aluminium might be separated from the reaction mixture.

- (ii) The organic product of **reaction 2** is also formed when the same reactants, but with an aluminium catalyst, are heated using microwave radiation. Suggest two reasons why this technique may be considered 'greener'.

(2)

You aren't using as much energy up, and the catalyst is easier to remove, as it is heterogeneous.



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Examiner Comments

A brief, yet effective answer to the question. The candidate has considered both the heating and the catalyst giving simple yet creditworthy reasons to support the green credentials of the process. Sometimes less is more!

- (ii) The organic product of **reaction 2** is also formed when the same reactants, but with an aluminium catalyst, are heated using microwave radiation. Suggest two reasons why this technique may be considered 'greener'.

(2)

By heating in air you are giving off CO₂ which is a greenhouse gas, using microwave radiation you are not burning any gases which would form greenhouse gases.



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Examiner Comments

This illustrates the common misconception that use of electricity is automatically 'greener' because a fuel is not burnt at point of use.

Candidates pursuing this line of argument need to be careful to consider how the electricity is originally generated, to potentially gain credit.

Question 13 (d)

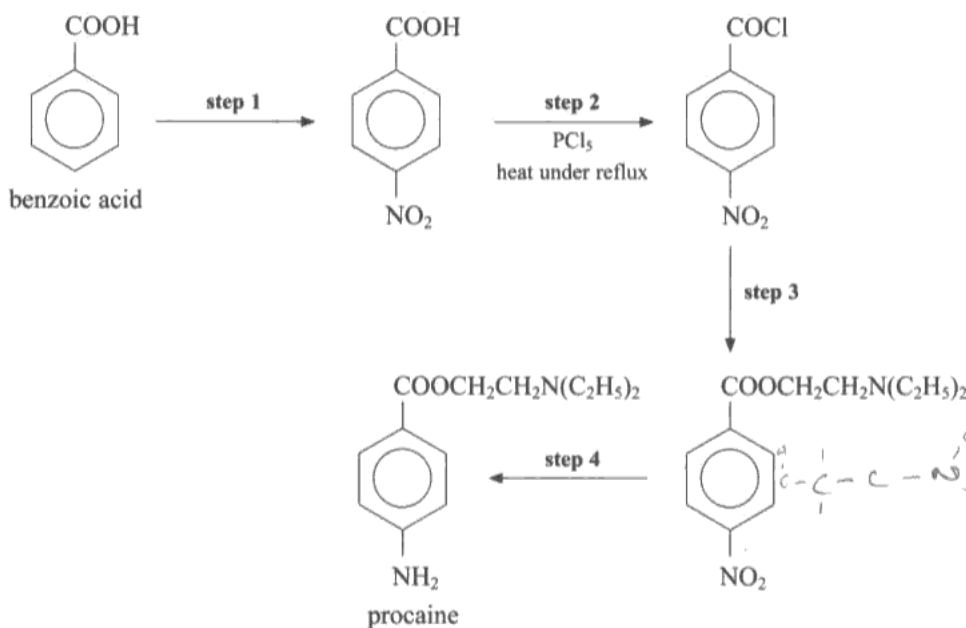
Over 60% of candidates suggested a correct reagent here. The most common correct response seen, not surprisingly, was fuming sulfuric acid. A number of candidates felt concentrated sulfuric acid was sufficient and so did not score.

Question 14 (a) (i)

Most candidates could recall the use of nitric and sulfuric acid, though a number failed to note the need to use concentrated acids. Common mistakes included use of NaNO_2 and HCl , perhaps thinking back to the formation of azo-dyes and use of concentrated hydrochloric instead of sulfuric acid.

14 This question is about synthetically produced painkillers and anaesthetics.

(a) The local anaesthetic procaine can be synthesised from benzoic acid. The simplified route is shown below.



(i) Suggest the two reagents needed for step 1.

(2)

Nitric Acid and H_2SO_4



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Examiner Comments

The candidate has chosen to use the names to identify the reagents here, which is fine. Candidates need to be aware that if they suggest both the name and formula, generally both need to be correct. No mention is made of the need for the acids to be concentrated in this reaction so only one mark was scored.



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Examiner Tip

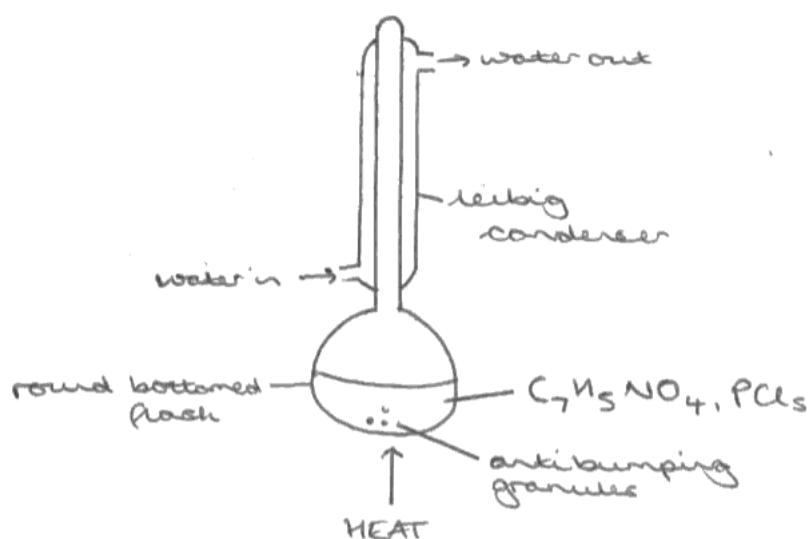
When learning about the use of acids as reagents in organic reactions, consider whether they need to be concentrated or not.

Question 14 (a) (ii)

Most responses showed an understanding of the reflux process and in general, the consensus from the examination team was that the standard showed a slight improvement from that seen in previous years. However, common errors still persist, including sealed systems and incorrect water flow. The problem of sealed systems for a minority of candidates was due to their desire to include a thermometer. The candidates who produced the best diagrams made life easier for themselves by using a ruler where appropriate.

(ii) Draw the apparatus needed to heat under reflux in step 2.

(3)



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Examiner Comments

This example is clearly drawn and labelled using a ruler. Unfortunately it did not score all three marks as the candidate has sealed the top of the condenser, so if used in this way pressure would build up in the system.



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Examiner Tip

Draw diagrams using a ruler for straight lines, but remember to always leave reflux systems open to prevent pressure build-up.

Question 14 (a) (iii)

Most answers sensibly suggested heating was required to make the reaction go faster or to ensure reactants reached the activation energy. However, a minority of weaker candidates thought incorrectly that, the heat increased the rate by lowering the activation energy.

The need for reflux was also understood, in the main, with most candidates justifying it in terms of the potentially volatile nature of the reactants products any solvents used. Some answers focused on the idea that reflux is important to ensure reactions go to completion, but this on its own did not score.

(iii) Suggest why the reagents for the reaction in step 2 are

(2)

heated they are heated so that the reaction occurs faster.

under reflux they are under reflux so that ~~the carboxylic acid gets~~
all of the reactants turn into products - theres complete oxidation.



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Examiner Comments

Had this example linked the idea of the reaction going to completion to the need to keep volatile reagents and/or solvent within the flask they would have scored the 'reflux' mark. As it is, they only scored one for the idea that the heat speeds up the reaction.

Question 14 (a) (iv)

Just over 60% of candidates could suggest a correct formula here. Common errors included suggestions of a tertiary amine, carboxylic acid or aldehyde, instead of an alcohol. However, candidates need to be careful with the way they show OH groups attached to a carbon chain. Structural formulae shown as $\text{OH}(\text{CH}_2)_2\text{N}(\text{C}_2\text{H}_5)_2$ were given the benefit of the doubt, but any hydroxyl groups shown displayed as $\text{O}-\text{H}-\text{C}$, were penalised.

Question 14 (a) (v)

Recall of these reagents was generally very good. However, some thought the reaction was classified as a substitution. A number suggested using the powerful reducing agent LiAlH_4 , which was not accepted. Use of imprecise language meant some scripts clearly implied NaOH was used **at the same time** as the concentrated HCl, which then lost the reagent mark.

(v) What type of reaction is taking place in step 4? Suggest the reagents used.

(2)

Reduction reaction. The reducing agents are tin and ~~HCl~~ hydrochloric acid. NaOH is later added to liberate procaine.



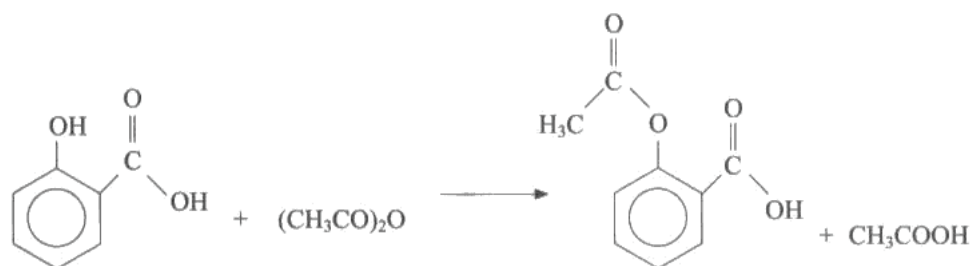
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Examiner Comments

In this example the candidate has clearly stated the use of the NaOH comes after the reaction with tin and hydrochloric acid. If they had said 'Reduction with Sn, HCl and NaOH' they would not have scored the second mark.

Question 14 (b) (i)

Many candidates showed evidence of the ability to calculate a percentage yield with only a very small minority simply comparing the masses. Even when responses revealed little understanding of the idea of yield, most realised that calculating the amount in moles of the two quantities was a good idea, so scored 2 marks. However, the most common way to lose a mark was to round up intermediate values too soon and end up with an imprecise final value. Whilst it is not sensible to expect candidates to write down each numerical value involved in the early stages of a calculation to four or five decimal places, it is quite easy to use these values stored in a calculator, rounding as appropriate once the final answer is obtained.

(b) A student produced a sample of aspirin by the esterification of 9.40 g of 2-hydroxybenzoic acid with excess ethanoic anhydride.



2-hydroxybenzoic acid ethanoic anhydride

aspirin

9.40g

7.77g

After purification by recrystallization, 7.77 g of aspirin was obtained.

[M_r of 2-hydroxybenzoic acid = 138, M_r of aspirin = 180]

(i) Calculate the percentage yield obtained.

$$n = \frac{m}{M} = \frac{9.4}{138} = 0.068... \text{ mol} = \frac{\text{actual}}{\text{theoretical}} \times 100 \quad (3)$$

$$nM = m = 0.068... \times 180 = 12.26... = \frac{7.7}{12.26} = \underline{62.8\%}$$



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Examiner Comments

This example seems to be storing intermediate values in a calculator and so gets a precise value for the theoretical mass of aspirin. Unfortunately they misread the actual mass of aspirin from the stem of the question, so their final answer is incorrect.



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Examiner Tip

Use your calculator to store intermediate values in calculations, only rounding as appropriate at the final stage.

Double check that you have transposed values from the question stem correctly.

Question 14 (b) (ii-iii)

This question was a good discriminator with able candidates scoring three or four marks. Answers at this level seemed to fall into two categories; those who had been well prepared for this type of question and who gave an accurate but generic response and those who had clearly carried out this, or similar experiments. Either approach is acceptable although failing to recall the detail needed for full marks is more likely when candidates have learnt about, but not experienced, the technique. The most common 'missing' mark was the washing stage.

Weaker responses often confused the order of the processes and missed details. Hence, a number of candidates were obviously describing recrystallization but failed to emphasize the need for 'minimum' or 'hot' in relation to the solvent or 'washed' before the solid had formed. Additional, unnecessary drying agents were also quite common. A small number of candidates confused recrystallization with other techniques, most commonly salt preparation and solvent extraction.

Many candidates **described** the effect on the yield in (b) (iii), but few attempted to **explain** it, so creditable responses were rare. Some attempted explanations relied on using the catch all phrase 'transfer errors' without any additional detail, which did not score. A surprising number thought the yield would increase, perhaps getting confused with purity.

*(ii) Outline how to purify a solid, such as aspirin, by recrystallization, using water as the solvent.

(4)
Add minimum ^{hot} water to the solid and dissolve. The ^{hot} water should be added drop by drop slowly to ensure the solution is saturated. If undissolved impurities are seen, carry out hot filtration and keep the filtrate. Cool the filtrate slowly and allow crystals to form. After a certain length of time where no increase ^{amount} of crystals is observed, filter the solution ^{under} low pressure and keep the residue, which is the purified crystals.

(iii) Explain what effect recrystallization has on the final yield.

(1)

Decrease the yield.



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Examiner Comments

This response clearly described recrystallization in a succinct and logical way. The only piece of missing information is the need to wash the crystals in cold solvent, after the final filtration.

However, in (b) (iii) the candidate does not score, as although they have correctly realised the yield will decrease, they have made no attempt to explain this.



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Examiner Tip

When carrying out experiments, make sure you understand the procedure as well as being able to process the observations and/or measurements. Use the specification to identify which practical techniques you are expected to know in detail.

Question 14 (c) (i)

In the main only the weaker candidates failed to recall either the name or formula of a suitable reagent with most suggesting ethanoyl chloride. Most near misses suggested using ethanoic acid.

Question 14 (c) (ii)

Most of the creditworthy responses concentrated on the idea of reducing the risk of overdose or potential addictive nature of codeine to score here. Most candidates managed to score the mark.

Weaker answers, which often did not score, used vague terms like 'dangerous' or 'can cause you health problems'. Non-specific use of the term 'can cause side effects' also did not score without further amplification.

(ii) Suggest why sales of non-prescription painkillers, often containing paracetamol and codeine, are limited to 32 tablets.

(1)

They are harmful to the body in large doses.



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Examiner Comments

This answer was just allowed, as the term 'harmful' has a specific meaning in chemical risk management and they have linked it to the idea that the risk comes from a large dose.

(ii) Suggest why sales of non-prescription painkillers, often containing paracetamol and codeine, are limited to 32 tablets.

(1)

it is toxic and harmful.



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Examiner Comments

However, this response did not score as although they have used the terms 'toxic' and 'harmful' they have not linked these hazards to the amount taken.

Question 14 (c) (iii)

The question proved to be a good discriminator, with in general only the better candidates scoring. Only one mark was available and the best answers often seemed to have recognised the need for a brief but accurate statement explaining why certain parts of the structure of paracetamol would not interact with water, for instance because the benzene cannot form hydrogen bonds with water. Some candidates gave a much more detailed comparison of the intermolecular forces between solute-solute and solvent-solute, which if correct was given credit. However, this approach was much more than was required for a one-mark question.

Weaker answers often simply stated that 'paracetamol / benzene ring is big' so would not dissolve or failed to identify the specific parts of paracetamol that possessed a particular property that may inhibit solubility. Hence statements such as 'paracetamol is non-polar' were seen and not given credit.

(iii) Explain why paracetamol is only slightly soluble in water although it can form hydrogen bonds with water.

(1)

This is because the benzene ring is very stable so it doesn't react easily. The OH bond can in paracetamol allows it to hydrogen bond, making it slightly soluble

(Total for Question 14 = 21 marks)



ResultsPlus Examiner Comments

This was another fairly common incorrect response to the question. The sight of a benzene ring does trigger some candidates to start discussing stability of the ring regardless of the context of the question. Here such a discussion is not relevant so did not score.



ResultsPlus Examiner Tip

When considering the solubility of organic molecules use a comparison of solute-solute and solute-solvent intermolecular forces if a more detailed response is required. If a short answer is required, then make sure you are specific about which parts of the molecules concerned may / may not interact and why. For instance in this question 'the benzene **ring** is **hydrophobic**' would have scored.

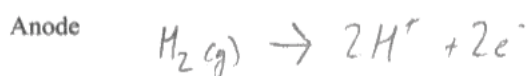
Question 15 (a)

Although seemingly a simple question these equations actually seemed to discriminate quite well, with generally only the more able candidates scoring two marks. The reaction of hydrogen at the anode was well known, but a common misconception was that the oxide ion would be formed at the cathode. One disappointing point to note is the number of candidates who seemed to be able to recognise appropriate reactants and products but who then made simple errors in balancing the equation.

15 Hydrogen gas can be used as a fuel in car engines by being burnt in a combustion reaction or reacted with oxygen in a fuel cell to produce electricity.

(a) Write half-equations for the reaction of hydrogen gas at the anode and oxygen gas at the cathode in the fuel cell.

(2)



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Examiner Comments

This example illustrates the most commonly seen response to this question. The formation of the oxide ion, rather than water or hydroxide ions, was a common misconception for the cathode reaction.

Question 15 (b)

Only about 20% of candidates were able to compare the two methods of using hydrogen as a fuel adequately. Some misinterpreted the question and compared hydrogen to fossil fuels. Others thought that the water produced in a fuel cell was simply recycled to give a never-ending supply of energy. The most worrying aspect was the large number of candidates, not always the weaker ones, who thought burning hydrogen produced carbon dioxide.

(b) Describe one advantage of using hydrogen in fuel cells rather than burning the hydrogen directly.

(1)

Water is the only waste produced where as burning the hydrogen directly produces CO₂ etc to produce the heat.



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Examiner Comments

Unfortunately this type of answer was surprisingly common.



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Examiner Tip

When considering power sources for vehicles or similar consider;

What fuel is used and how do we get it?
How efficient is the engine at transferring energy?
What effect, if any, do emissions have on the environment?

In this question the first and third points are the same for both methods as the fuel is the same in both cases, so the advantage is likely to be related to the efficiency.

Question 15 (c)

On a positive note, the majority of candidates picked up two relatively straightforward marks for recognising the idea that ethanol might be sourced sustainably from plants or using fermentation, whilst fossil fuels are a finite resource. However, a disappointing number of candidates thought that using water as a source of hydrogen was sufficient to make the process sustainable, without any consideration of the energy needed to obtain the gas. More worryingly a significant minority thought hydrogen gas was a component of air.

The best answers linked the energy needed for electrolysis to a renewable source, for instance solar power.

(c) Other fuels, such as ethanol, can also be used in fuel cells. By considering the possible sources of ethanol and hydrogen, explain why some scientists believe the use of such cells could provide a more sustainable source of energy for cars, compared with fossil fuels.

(3)

Fossil fuels are non-renewable and are running out quickly. Instead we could use ethanol or hydrogen to power our cars. ~~These sometimes~~ Hydrogen sometimes is produced from fossil fuels. However, for it to be a "green fuel" we could produce it from renewable sources by using renewable electricity from wind farms. Ethanol can be produced from crops which is very green. Both fuels wouldn't produce greenhouse gases. ~~don't~~

(Total for Question 15 = 6 marks)



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Examiner Comments

This answer shows the kind of response that would be awarded three marks. As the questions asks, they have considered both the source of the ethanol and hydrogen and tried to justify why they might be sustainable, though it could have been improved by linking the use of the 'wind power' to electrolysis of water. They also make the comparison to fossil fuels, as requested in the stem.



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Examiner Tip

Don't assume that a large amount of a raw material of a substance automatically makes the use of that substance sustainable. Consider the energy costs in obtaining the substance as well.

Question 16 (a)

The definition of a transition element was widely understood, with lots of examples of 'text book' definitions seen. This seems to emphasise the willingness of candidates to try to memorise information, but they need to be aware that such a strategy should be used to supplement and not replace real understanding and application of concepts. Errors were more prevalent in the electronic configuration, predictably $4s^23d^3$ being the most common mistake.

16 This question is about the transition metal iron and some of its compounds.

(a) Give the electronic configuration of the Fe^{3+} ion and use this to define what is meant by a transition element. (2)



A transition element can form atleast one stable ion with an ~~incomplete~~ incomplete d-subshell.



ResultsPlus Examiner Comments

Whilst the use of [Ar] to represent $1s^22s^22p^63s^23p^6$ was acceptable, a significant minority of candidates forgot to remove the 4s electrons before the 3d.



ResultsPlus Examiner Tip

Remember, whether you are filling up subshells to work out the electronic configuration of atoms or removing electrons to work out the electronic configuration of cations, it is always the 4s shell before the 3d.

Question 16(b)

The best candidates in 16 (b), as is often the case, seemed to have read the question carefully and hence produce a response focused specifically on what was asked. These answers described at a molecular level, precisely what the particles were doing during heterogeneous catalysis and **two** subsequent reasons to justify the increase in rate. The most commonly missed concept was the idea of reaction **and** subsequent desorption.

Weaker answers generally made the point about adsorption and then tended to adopt the approach of writing down as many points related to catalysis as possible as a justification. Fortunately, many of them went on to make salient points about the activation energy and sometimes bond weakening within the reactants. However, there was often a lot of irrelevant discussion of other factors, such as variable oxidation states of transition metals, that was treated as neutral, but perhaps cost such candidates valuable time.

*(b) Iron will act as a surface catalyst in some gaseous reactions. Outline the processes that take place during such catalysis and suggest two reasons to explain why the catalyst speeds up the reaction.

(4)

The two gases ^{get} ~~get~~ adsorbed onto the surface of the iron catalyst. This ~~weaken~~ attraction to the catalyst weakens the bonds in the gas molecules, making them break and ~~re~~ reform as the product. The product then leaves the surface of the iron catalyst. The catalyst speeds up the reaction by weakening the covalent bonds in the reactants, causing them to break more easily. It also ~~also~~ lowers the activation energy by providing an alternate pathway for the reaction, lower activation energy will speed up the reaction.



ResultsPlus Examiner Comments

This answer concentrates on precisely what the question asked, describing what happens during surface catalysis and giving two reasons to justify the increase in rate without unnecessary superfluous information.



ResultsPlus Examiner Tip

Remember to focus on specifically answering the question, not simply giving a record of all you can remember about a topic. It will help to refer back to the question as you write. If you simply try to write down lots of ideas regarding a topic, including concepts not linked to the question, then at best you will waste time, at worst you risk contradicting yourself.

Question 16 (c)

This question did highlight a weakness for many candidates. There is of course, no expectation that the candidates should recall these equations. However, they should possess the skills to use data to predict the direction for each half-cell and then construct a full equation for the reaction. In addition, they should be able to justify how they arrived at their answer. There was only limited evidence of either of these skills.

When credit was given, it was generally for writing the equation for step one to show the oxidation of Fe(s). However, this was rarely justified, suggesting the equation was written by 'trial and error' rather than by combining half-cells. This view is supported to some extent by the large number of attempted equations that did not score, as the iron was not balanced. When the justification mark was given, it was nearly always for calculating E_{cell} rather than evidence of use of the electrode potential data to compare relative ability to oxidise or to predict the direction of each half-equation. Even then, it was surprisingly common to see $0.4 + 0.44 = 0.88 \text{ V}$ suggested.

Only the best candidates even attempted the 'correct' second step. Lots of attempts simply suggested $\text{Fe}(\text{OH})_2 + \text{OH}^- \rightarrow \text{Fe}(\text{OH})_3$.

Rather like question 15 (a) many responses seemed unworried about balancing charges.

(c) One of the components of rust, found on objects made from iron, is iron(III) hydroxide, $\text{Fe}(\text{OH})_3$. Use items 17, 19 and 44 from the Standard Electrode Potential table in your data booklet to show how it is able to form in two steps, writing an equation for each step. (4)

$$2\text{Fe} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{Fe}(\text{OH})_2$$
$$4\text{Fe}(\text{OH})_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{Fe}(\text{OH})_3$$


This candidate did manage to work out equations for both steps correctly. However, to improve this answer they would need to show how they used the data to arrive at their answers, for instance by comparing the ability of cell components to behave as oxidizing or reducing agents, using models such as the anti-clockwise rule or manipulating half-equations and standard electrode potentials to determine the feasible reaction.

Question 16 (d)

Candidates were not concerned at all about the slightly unusual context and most gave an accurate description of how the bonding took place in addition to naming the type of bond. A few responses lacked clarity though, leaving the examiners in doubt as to whether they thought a bond pair or a lone pair from nitrogen was used to bond to the ion.

(d) Haemoglobin is a complex containing iron(II) ions.

Describe how nitrogen atoms in the haemoglobin bond to the iron(II) ions.

(2)

The nitrogen atoms act as ligands. They bond by donating a pair of electrons to the iron (II) atoms. They form a dative covalent bond.

(Total for Question 16 = 12 marks)

TOTAL FOR SECTION B = 48 MARKS



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Examiner Comments

In this example it is not clear whether the candidate thinks the electrons are a lone pair or bond pair from nitrogen, so it scored one mark out of two.

Question 17 (a) (i-iv)

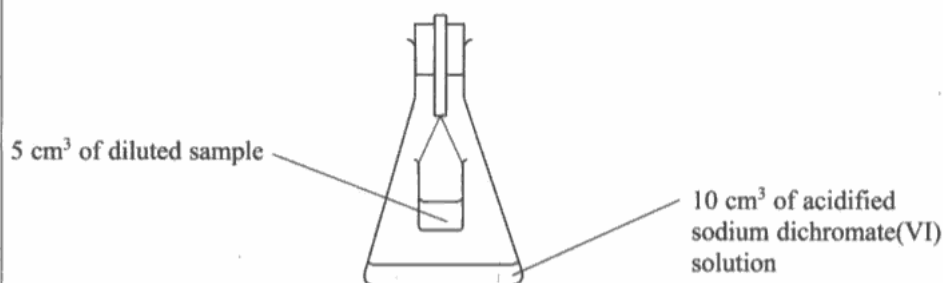
In (a) (i) it was rare to see both marks awarded. The dichromate half-equation caused fewer problems, though missing electrons was a frustrating near miss for some, again highlighting the reluctance of some candidates to check that charges balance. Many candidates did not know where to start with the ethanol half-equation, often resorting to adding oxygen gas or using [O] as in some organic reaction schemes. A large number of candidates failed to recognise the need to find the amount of dichromate that reacted with the ethanol, rather than that left over, so missed the subtraction in (a) (iii). However, most simply carried on regardless and were able to pick up transferred error marks for correct use of ratios and scaling up later in the section. Nevertheless, even some otherwise quite able candidates could not seem to scale up accurately in (a) (iv).

17

Alcoholic drinks contain ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, in aqueous solution. The percentage of alcohol in a drink can be determined by a redox titration, whilst the amount of alcohol present on the breath of someone who has consumed such a drink can be estimated using a breathalyser.

The earliest breathalysers used the colour change that occurs when dichromate(VI) ions react with ethanol to measure the amount of alcohol. Later models measure the current from a fuel cell. Cheaper versions of these meters are available for drivers to buy for self-testing. Some police forces also use fuel cell breathalysers in conjunction with infrared breath analysers, which can determine the amounts of alcohol from an infrared spectrum.

In an experiment to find out the concentration of ethanol in a drink, a small beaker containing 5.00 cm^3 of a diluted sample of the drink is suspended above 10.0 cm^3 of excess acidified sodium dichromate(VI) solution, of concentration $0.0800 \text{ mol dm}^{-3}$, and left for 24 hours in a warm place.

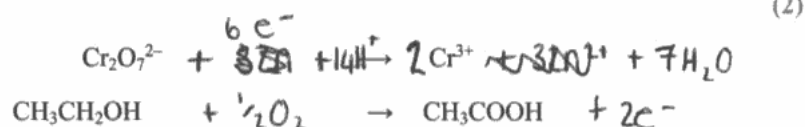


The ethanol vaporizes and reacts with some of the acidified sodium dichromate(VI) ions. Excess potassium iodide is then added to the unreacted acidified sodium dichromate(VI), forming iodine, $\text{I}_2(\text{aq})$.

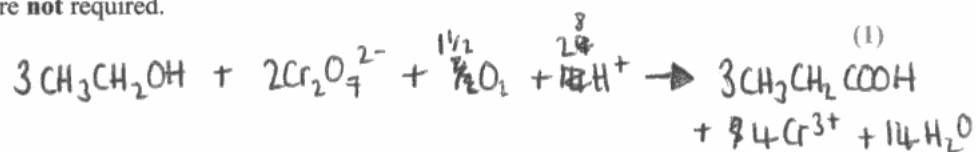
The $\text{I}_2(\text{aq})$ is then titrated with a solution of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, of concentration $0.0250 \text{ mol dm}^{-3}$.

(a) Ethanol and dichromate(VI) ions in acidic solution react in the mole ratio 3:2.

(i) Complete the two half-equations below. State symbols are **not** required.



- (ii) Use either the half-equations in (i) or that the mole ratio of $\text{CH}_3\text{CH}_2\text{OH}:\text{Cr}_2\text{O}_7^{2-}$ is 3:2 to construct the ionic equation for the reaction between ethanol and acidified dichromate(VI) ions. State symbols are **not** required.



- *(iii) The iodine formed in the experiment reacted completely with 34.40 cm^3 of the $0.0250 \text{ mol dm}^{-3}$ sodium thiosulfate solution. Use this information, the fact that the mole ratio of $\text{CH}_3\text{CH}_2\text{OH}:\text{Cr}_2\text{O}_7^{2-}$ is 3:2 and the equations below, to calculate the concentration of the ethanol in the 5.00 cm^3 of the diluted sample of the drink.

(6)



$$\text{moles thiosulfate} = \frac{34.4 \times 0.025}{1000} = 8.6 \times 10^{-4}$$

$$\text{moles iodine} = \frac{8.6 \times 10^{-4}}{2} = 4.3 \times 10^{-4}$$

$$\text{moles } \text{Cr}_2\text{O}_7^{2-} = \frac{4.3 \times 10^{-4}}{3} = 1.433 \times 10^{-4} \text{ reacted}$$

$$\text{moles ethanol} = \frac{(1.433 \times 10^{-4})}{2} \times 3 = 2.15 \times 10^{-4}$$

$$\text{concentration} = \frac{(2.15 \times 10^{-4}) \times 1000}{5} = 0.043 \text{ mol dm}^{-3}$$

m u c
100

- (iv) The solution used in the experiment was made by adding 10.0 cm³ of the drink to a 100 cm³ volumetric flask, making up the remainder of the volume using distilled water. Use the information and your final answer to (a)(iii) to calculate the concentration, in mol dm⁻³, of ethanol in the undiluted drink.

$$\frac{0.043}{2} = 0.0215 \text{ mol dm}^{-3}$$

(1)



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Examiner Comments

This example shows the candidate correctly determining the half-equation for the dichromate reduction, but fails to apply the same technique to the ethanol oxidation. It perhaps suggests this candidate has recalled the former, but has not learnt how to balance a half-equation from first principles, which in the long term is a better approach.

In the calculation the work is clearly laid out and each step is labelled. This is good practice. Unfortunately they neglected to determine the amount of dichromate that **actually** reacted with ethanol as this method used the unreacted dichromate to produce iodine for the titration. Hence, it scored a maximum of four marks.

Unfortunately the candidate appeared to have not read the question carefully in (a) (iv) and scaled incorrectly. Another common similar error was to multiply by 2, scaling from 5 cm³ to 10 cm³.



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Examiner Tip

Follow a logical procedure when balancing half-equations. A sensible approach is to

- Balance atoms other than hydrogen or oxygen.
- Balance oxygen by adding water.
- Balance hydrogen by adding hydrogen ions.
- Balance electronically by adding electrons.

You should then be able to combine your half-equations to cancel out the electrons and get an overall equation for the reaction.

Question 17 (a) (v-vii)

Lots of examples in (v) to (vi) suggested either candidates had not read the stem carefully or had only very limited practical experience. Although some candidates appreciated that other substances in drink may react with the dichromate, many more were concerned that adding the drink directly to the flask would result in some kind of explosion. This seems a little odd as you may have thought that they would recall the need to heat this reaction to get it to proceed from their previous experience. Candidates were more successful in (a) (vi), the majority linking either the warmth or time to the idea of evaporation. A number of candidates seemed to ignore the last instruction in the stem, so made no comment about the effect on the final result. Other kept their response so vague that credit could not be given, for instance 'it would make it less accurate'.

However, the meaning of reliability in the context of a titration was often understood, with lots of responses recognising that only one titration was not reliable.

(v) Suggest why the sample was suspended above the acidified sodium dichromate(VI) solution, rather than simply being mixed with it.

(1)

It would react too quickly if it was mixed

(vi) Suggest two reasons why the apparatus was left in a warm place for 24 hours. What would be the effect on the final result if this procedure were not followed?

(3)

- heat is needed to vaporise the ethanol so it can reach the potassium dichromate
- if it ~~was~~ was not in a warm place the potassium dichromate would remain orange.

- It was left for 24 hours for the whole reaction to complete

(vii) Do you think that this experiment gives a reliable result? Explain your answer.

(1)

no as the experiment was not repeated



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Examiner Comments

It doesn't seem as though this candidate recalls practical experience of this reaction as their response implies simple mixing will allow it to proceed at a very rapid rate. They do however manage to justify the need for the warmth and time left, but only discuss their belief that the mixture will stay orange, rather than considering the effect on the final result of the whole experiment.



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Examiner Tip

In unfamiliar practical contexts draw on your own practical experience to find ideas that are applicable, so will help you answer the question. For instance in this question, knowledge of the reaction between ethanol and acidified dichromate from your organic chemistry would have helped in several parts.

Question 17 (b)

The best answers in (b) used the stem to help draw out creditworthy responses. In (i) most recognised the colour change of the dichromate crystals, often with some attempt to quantify the procedure by discussing the intensity of the colour change. Discussions of the fuel cell often went into considerable detail about the reaction linking this to the current produced. In the use of IR, many answers simply referred to production of peaks without any discussion of the absorption of IR.

Successful responses in part (b) (ii) clearly stated a molecule that could be present on the breath that would absorb IR because of an O-H bond, most commonly water. Near misses recognised other molecules may have an O-H group, without giving an example.

Earlier evidence showed that reliability was understood in the context of titrations. However, in (b) (iii) candidates did not apply the idea successfully, often claiming that use of both breathalysers gave a more accurate result.

In (b) (iv) some answers were very simplistic and so failed to score. For instance a minority simply stated that an advantage was to 'test how much alcohol you had drunk' without considering why this might be beneficial. However most questioned the accuracy of the personal models to score the second mark. A number failed to read the question carefully, so assumed the personal models involved dichromate. They then concentrated on considering the risks of such use as a disadvantage.

* (b) (i) Explain how each type of breathalyser, mentioned in the passage, shows the amount of ethanol present. (3)

Earliest type. ~~The intensity of the green solution that is formed when the alcohol being oxidised by the orange dichromate ion indicate~~
amount of ethanol present.

Fuel cell. Amount of ~~er~~ current that ^{is} produced from the fuel cell.
More current means more alcohol present.

Infrared. The intensity of peak of absorption shown on the spectrum.
~~The absorption is~~ The infrared used the C-H absorption. More intense the absorption, more alcohol is present.

(ii) Suggest why infrared breathalysers do not use the OH absorption to detect the amount of alcohol on the breath. (1)

There is water present that interfere with the reading.

(iii) Suggest why some police forces use infrared breathalysers together with fuel cell breathalysers.

(1)

To compare the amount of ethanol detected using by both methods and be certain of the real ~~level~~ content of alcohol ~~is~~ ~~there~~ present in blood of the driver. This is because fuel cell breathalysers is less reliable method than infrared breathalyser.

(iv) Suggest one advantage and one disadvantage of buying a personal breathalyser.

(2)

A driver can limit ~~to~~ his consumption of alcohol when he knows the alcohol content shown by the personal breathalyser. So that he does not exceed the ~~permissible~~ allowed amount of consumption.

However, buying a personal breathalyser might not be that accurate in determining his alcohol amount because the personal breathalyser is cheap so ~~there is~~ it is probably has low quality.

(Total for Question 17 = 22 marks)

TOTAL FOR SECTION C = 22 MARKS

TOTAL FOR PAPER = 90 MARKS



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Examiner Comments

This example does precisely what the question asks by describing simply how each type of breathalyser works, attempting to link the result of each type to the amount of alcohol consumed.

The candidate got the benefit of the doubt in (b) (iii) as although their use of the word reliable itself would not have scored here, earlier they had explained the importance of using both methods as a double-check of the alcohol level result.

Summary

Tips for revision:

- Practise drawing simple equipment used in organic reactions, such as reflux apparatus.
- Use a ruler where appropriate.
- Learn the technique to balance half-equations, rather than trying to recall each example.
- Practise using justifying the feasibility of redox reactions using standard electrode potentials.
- Label each step of a long calculation to show clearly what you are attempting to work out.
- In multi-stage calculations don't round up or down until the final step.
- Use your calculator to store intermediate values.
- Read questions carefully, especially in section C or question with an unfamiliar context.
- Often you will find information to help you construct your answer.

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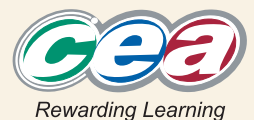
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