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# Examiners' Report
# June 2018

## GCE Chemistry 9CH0 02

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# Introduction

The 9CH0/02 paper assesses advanced organic and physical chemistry topics such as synthetic pathways and reaction kinetics. This paper proved to both provide challenge to candidates and the opportunity to demonstrate their chemical knowledge and ability. This meant that it was an effective discriminator of candidate ability. There was little evidence of candidates running out of time to complete the paper as all questions were attempted to a satisfactory extent.

The mean on the multiple choice questions was quite high at 8.17 but slightly lower than the 8.26 value for last year. The most likely reason for the difference is that the comparable questions had higher demand, such as deducing the effect of three factors rather than two. The questions on the rest of the paper were from a wide range of topic areas, some in a familiar style while others were more novel. Those candidates who had revised using the previous past paper performed particularly well on the more familiar questions. The good candidates were able to also apply their knowledge and ability to the more novel questions and score highly.

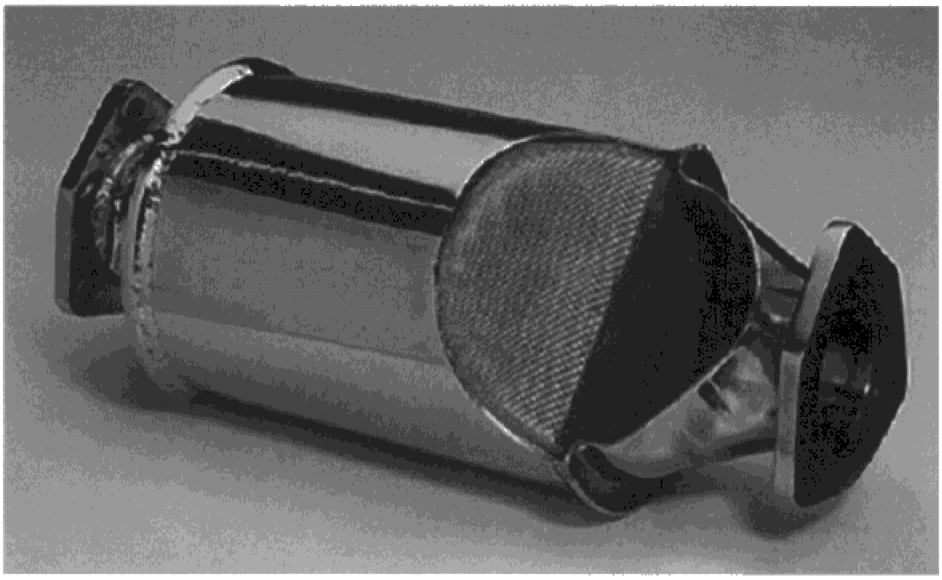
There were numerous instances, as will be evident from the examples that follow, of candidates not addressing the requirements of the question and so not scoring as well as hoped. This was true in all types of question, from data analysis to calculations to descriptive accounts. Candidates desirous of achieving their maximum must apply themselves carefully to the task set and not to what might be perceived to be the case. In addition, chemistry employs a wide range of specialist terms that have particular meaning depending on the context and so attention to detail is required if an otherwise correct answer is not to be ruined by the use of an incorrect term. For example, referring to hydroxide and iodide ions as molecules.

The extended open response question is part of the 'new' demands for this specification and those candidates who carefully plan their response before starting in earnest tend to avoid making lots of errors and going off on tangents for which there is no credit and uses up valuable time. This style of question typically has two pages of space to allow for this kind of planning and so it would be a worthwhile exercise for candidates to practise.

## Question 2 (b)

Over 80% of candidates scored one mark for the reference to the large surface area of a honeycomb structure but only a very small minority of candidates appreciated that the structure also allowed the gases to flow freely through.

(b) Catalytic converters of car exhaust systems have internal honeycomb structures as shown.



Explain why the honeycomb structure is used in a car exhaust system.

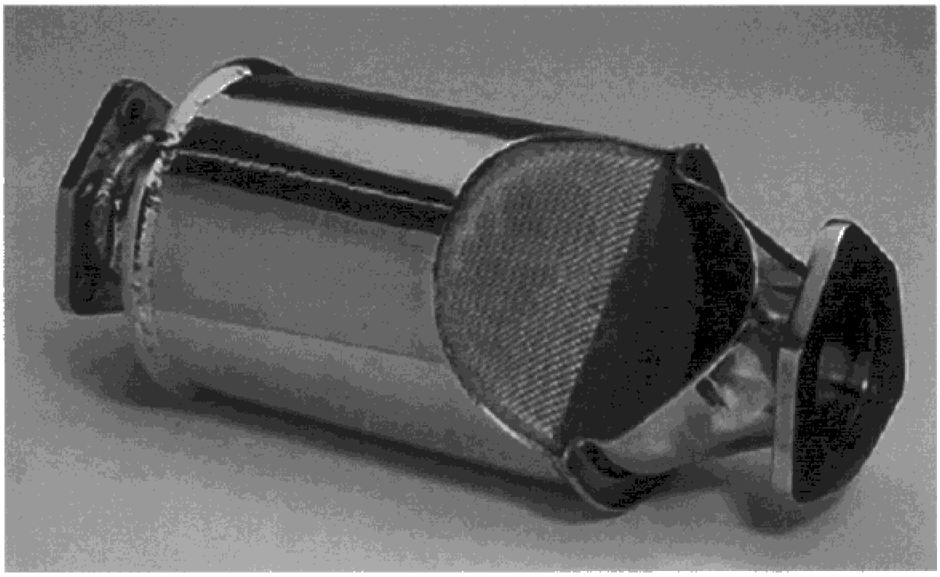
(2)

Prevents larger carbon particulates and methane and other large impurities ~~ta~~ that are toxic or cause global warming to not ~~escape~~ escape from the car exhaust and enter into the atmosphere.

ResultsPlus
**Examiner Comments**

This response is an example of one where the impression is given that the catalytic converter is acting as a 'filter' and so does not score.

(b) Catalytic converters of car exhaust systems have internal honeycomb structures as shown.



Explain why the honeycomb structure is used in a car exhaust system.

**(2)**

It maximises the surface area of the catalyst but also allows ~~gasses~~ gases to pass through the hexagons to leave the vehicle

**ResultsPlus**
**Examiner Comments**

This response scores both marks by referring to both the high surface area of the honeycomb structure but also that it allows the free flow of gases through it.

## *Question 3 (a) (i)*

In this specification the mathematical demand of 20% at level 2 or above is met, in part, by candidates deciding the appropriate number of significant figures and this question is an example of such. Chromatographic techniques are rarely very accurate but instead rather crude and so caution is needed when carrying out calculations such as on $R_f$ values. Hence while it can be common to have 'three significant figures' as appropriate in many chemical calculations (a so-called default option), this is not the case with $R_f$ values. One significant figure would not be accurate enough and fail to distinguish between samples so only two significant figures are appropriate in this example.

Although only given occasionally, an answer such as 0.16 was seen with brackets and 3SF after it. The answer 0.16 is not to 3SF and reflects a misunderstanding by the candidate. Therefore this suggests that further practise by candidates on the difference between significant figures and decimal places, with appreciating what is appropriate given the circumstances, would be very useful.

In contrast it was pleasing to see the $R_f$ value rarely being given with units because of course there aren't any.

(i) Calculate the $R_f$ value for the amino acid lysine.
Give your answer to an appropriate number of significant figures. **(1)**

SF = 10

A = 1.5

$\frac{1.5}{10} = 0.15 = 0.20$

**ResultsPlus**
**Examiner Comments**

Unfortunately this response did not score. An answer of 0.15 would have been awarded the mark but in this response it is clear that the answer has then been converted to 0.20 which is incorrect.

**ResultsPlus**
**Examiner Tip**

Only give one answer to a question because if two are given then both must be correct to score.

(i) Calculate the $R_f$ value for the amino acid lysine.
Give your answer to an appropriate number of significant figures.

(1)

$\frac{1cm}{6.3cm}$ = 0.159 (3s.f)

ResultsPlus
Examiner Comments

Three significant figures is not appropriate for an $R_f$ calculation and so this response is an example of one that did not score.

## *Question 3 (a) (ii)*

Just over 50% of candidates were able to correctly identify the two amino-acids in the sample. The better candidates were able to deduce that the absence of a third spot was due to one of the two amino-acids being present twice and so this question proved to be an effective discriminator.

On a few occasions the expression used by the candidates 'let them down'. For example, the statement that the lack of a third spot was due to 'two serines and two methionines' is incorrect because this would be true of a tetrapeptide and not a tripeptide as stated in the question.

(ii) Identify by **name** the two amino acids present in the tripeptide, giving a reason for the lack of a third spot.

**(3)**

Serine and methionine are present. The third amino acid may not be soluble in the solvent used meaning it is unable to move ~~with~~ in the mobile phase. Therefore, it remains at the origin

**ResultsPlus**
**Examiner Comments**

An example of a response which scored two marks. The two amino-acids have been correctly identified as serine and methionine. However the lack of solubility is not a suitable reason for the lack of a third spot. If the amino-acid had been insoluble then there would have been a spot at the origin, i.e. a third spot.

## *Question 3 (a) (iii)*

In an acceptable answer there needed to be reference to the mobile and the stationary phase. Just over 40% of candidates failed to include a comment on either of these phases and so did not score. However about a quarter of candidates wrote an effective response which includes reference to both the mobile and stationary phases and so this question was another useful grade discriminator.

(iii) Give **two** reasons why different amino acids have different $R_f$ values.

(2)

They are more/less soluble in the mobile phase

**ResultsPlus**
**Examiner Comments**

This response scored one mark for the reference to solubility in the mobile phase and it is disappointing that there is no more to the response.

**ResultsPlus**
**Examiner Tip**

The question emboldens the word 'two' and so this number of reasons is required. The number of marking points is also two and so it is very clear that the number of reasons needed in the answer is two. Make sure that the answer addresses the demands of the question.

(iii) Give **two** reasons why different amino acids have different $R_f$ values.

(2)

Different amino acids have different weight therefore the lighter ones travel further up the paper & have a higher Rf value than the heavier ones that travel less

**ResultsPlus**
**Examiner Comments**

Molecular mass is not one of the reasons for the difference in the $R_f$ value of amino-acids and so this does not score.

## Question 3 (b) (i)

The vast majority of candidates correctly wrote about the inertness of the carrier gases. A small minority of candidates 'fudged' their answers by inserting descriptive terms such as 'not very/weakly/rarely' or similar in front of 'reactive' which makes the answer doubtful and so did not score.

(b) Gas chromatography can be used both to separate the components in a mixture and to determine the amount of each present.

(i) State why argon and nitrogen are suitable carrier gases for gas chromatography.

**(1)**

Argon and nitrogen are Fairly inert gases and will therefore not react with any of the components of the mixture.

**ResultsPlus**
**Examiner Comments**

This response is 'rescued' by the latter comment of the lack of reactivity with the components of the mixture. It is insufficient to comment on the gases being "fairly inert" because it is too vague.

## Question 3 (b) (ii)

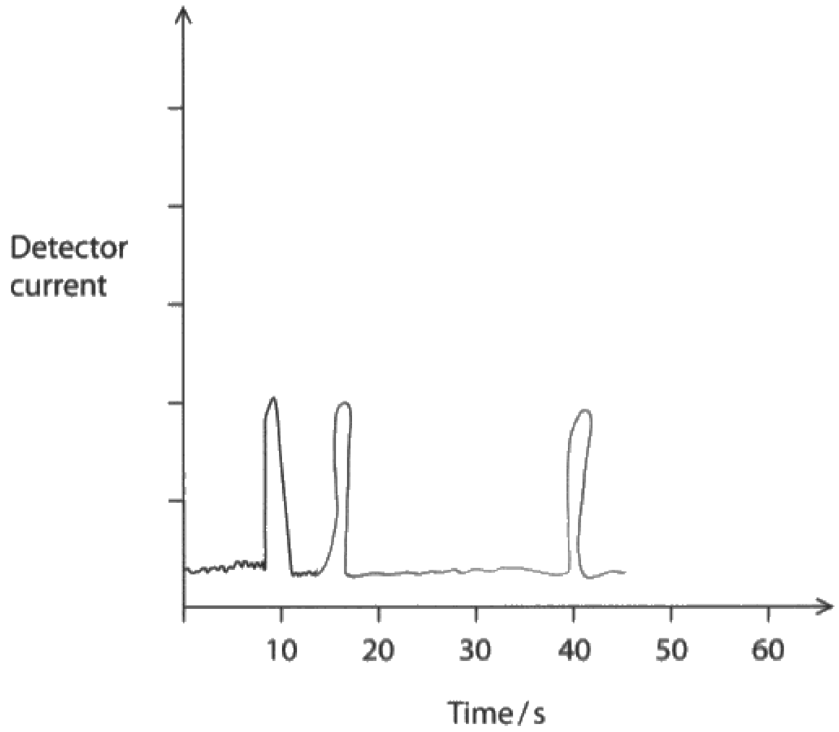
This was a well-answered question with just under three-quarters of candidates scoring all three marks for their sketch. The most common errors seen were: an incorrect height for the 'X' peak, an incorrect timing of the 'Y' peak and additional incorrect peaks.

(ii) A mixture containing one part substance **X**, two parts substance **Y** and one part substance **Z** was separated by gas chromatography.

Substance **X** has a retention time of 10 seconds, substance **Y** of 15 seconds and substance **Z** of 40 seconds.

Complete the sketch of this chromatogram.

**(3)**




**ResultsPlus**
**Examiner Comments**

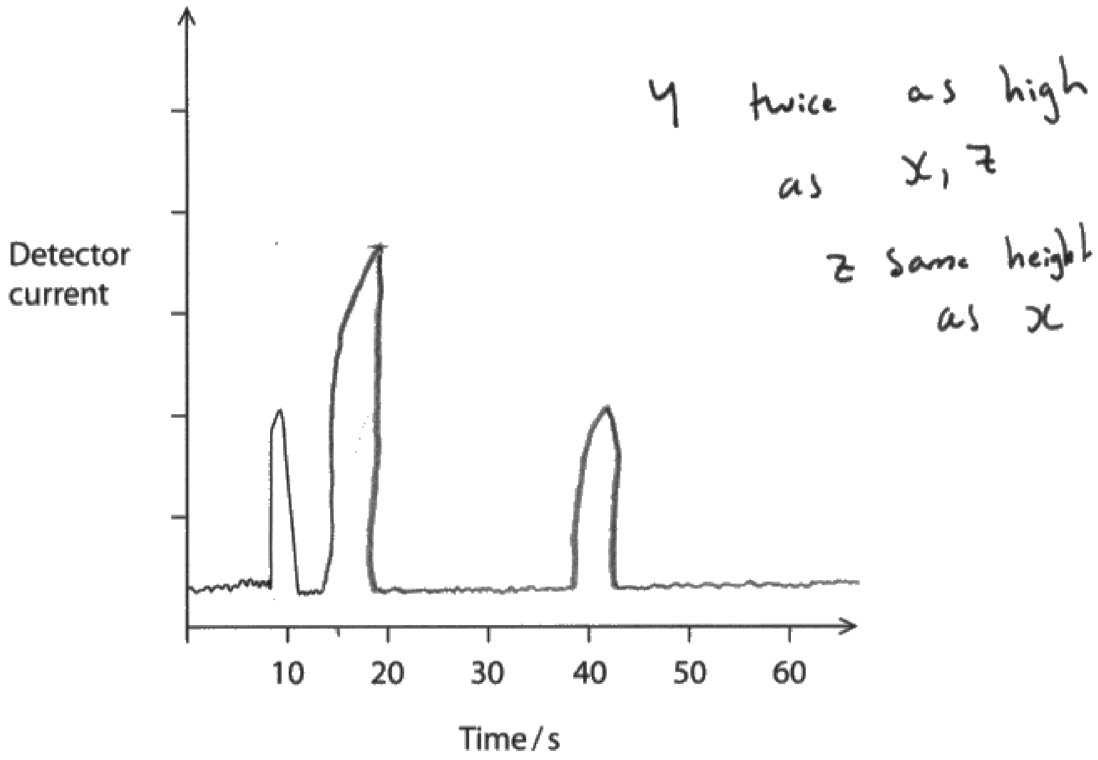
This response scored two marks as there are two peaks at the right time position and the 'Y' peak is at the right height. The third mark is not awarded because the 'X' peak should have been twice the height of the other peaks.

(ii) A mixture containing one part substance **X**, two parts substance **Y** and one part substance **Z** was separated by gas chromatography.

Substance **X** has a retention time of 10 seconds, substance **Y** of 15 seconds and substance **Z** of 40 seconds.

Complete the sketch of this chromatogram.

**(3)**




**ResultsPlus**
**Examiner Comments**

This response scored all three marks. The height of the 'X' peak is not quite twice the height of the other peaks but the comment alongside the sketch helps to allow the mark.

**ResultsPlus**
**Examiner Tip**

If you are concerned about the accuracy of the sketch drawn then a comment alongside can be helpful supportive evidence for the examiner.

## *Question 4 (a) (i)*

A high-scoring question with just under 90% scoring the mark. The most common error was to think that sodium was diatomic.

**4** Many vehicles are fitted with airbags which provide a gas-filled safety cushion to protect the occupant of the vehicle if there is a crash.

(a) The first reaction in airbags is the thermal decomposition of sodium azide, $NaN_3$, to form sodium and nitrogen gas.

(i) Write the equation for this decomposition of sodium azide. State symbols are not required.

**(1)**

$$NaN_3 \longrightarrow Na + \frac{3}{2}N_2$$

ResultsPlus
**Examiner Comments**

A balanced equation with fractions rather than whole numbers is perfectly acceptable.

## *Question 4 (a) (ii)*

This question discriminated well and the full range of marks was awarded from 0 to 4. The weaker candidates struggled with the conversion of the units. The stronger candidates were evident from their use of the 2:5 molar ratio and the quotation of the final mass to only 2 or 3 SF.

(ii) In the reaction in (a)(i), a typical airbag is inflated by about 67 $dm^3$ of gas. Calculate the **minimum mass** of sodium azide, in grams, needed to produce this volume of gas. Use the Ideal Gas Equation and give your answer to an appropriate number of significant figures.

For the purpose of this calculation, assume that the temperature is 300 °C and the pressure is 140 000 Pa.

**(4)**

$pV = nRT$

$n = \frac{pV}{RT}$

$\frac{\text{mass}}{\text{mols} \times \text{mr}}$

$\frac{140\,000 \times 67}{8.31 \times (300 + 273)}$

$= 1969.91 = n = \text{mols}$

$1969.91 \times (23 \times 2) + (14 \times 3 \times 2)$

$= 46 \quad = 84 \quad 46 + 84 =$

$= 1969.91 \times 130$

$= 256088.3$

**ResultsPlus**
**Examiner Comments**

A response which does not convert the measurements correctly and so loses M1. The rearrangement of the equation and calculation using the number stated is correct for M2. There is no use of the stoichiometry so no M3. The molar mass value used is incorrect and the final mass is quoted to an inappropriate number of significant figures so no M4.

Hence one mark awarded.

## *Question 4 (b)*

It was surprising that even with incorrect oxidation numbers stated, the equation was often still balanced correctly. Perhaps these candidates balanced by inspection of atoms and then considered the oxidation numbers. If so, then this is inadvisable because balancing by oxidation numbers will always derive the correct answer.

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$10\ Na + 2\ KNO_3 \rightarrow 1\ K_2O + 5\ Na_2O + 1\ N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

**(3)**

Ox (N): 5 → 0 , Ox (Na): 0 → 1

2N gives total −10 charge and 10Na gives 10 charge ∴ no net charge ∴ balanced.

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**Examiner Comments**

The omission of a '+' sign from the relevant oxidation numbers was penalised once only and so this response scores two marks.

**ResultsPlus**
**Examiner Tip**

It is important to remember the signs when stating oxidation numbers and this includes the '+' sign.

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$10\,Na + 2\,KNO_3 \rightarrow \ldots\,K_2O + 5\,Na_2O + \ldots\,N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

**(3)**

Nitrogen goes from an ox. state of +5 to 0 (is reduced).

Sodium is oxidised, goes from ox. state of +1 to +2.5

**ResultsPlus**
**Examiner Comments**

An example of a response where the equation is balanced correctly for one mark but the oxidation numbers stated are not all correct. The reduction of nitrogen from +5 to 0 is correctly given but the oxidation number change of sodium is incorrect so two marks only awarded.

## *Question 4 (c)*

This proved to be possibly the hardest question on the paper and accessible to only the very best of candidates. One mark for identifying the type of reaction was the most likely scored and only achieved by a small minority of candidates.

It was disappointing to see the rather bizarre comments made by candidates in their justification for why the reaction was necessary. These ranged from stating that silicon dioxide was deadly to that it was worse to breathe than oxygen. Candidates should have known that metal oxides are corrosive and that the salts produced from their reaction with the silicon dioxide are inert or unreactive.

(c) **The third reaction in the airbag is between the metal oxides and silicon dioxide.**

**State the type of reaction taking place and justify why this reaction is necessary.**

**(3)**

This is a neutralisation reaction which is necessary as silicon dioxide is toxic + harmful to the environment.

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**Examiner Comments**

This response scored one mark for correctly stating that the type of reaction is neutralisation.

The silicon dioxide is part of the air-bag system and is present to react with the corrosive metal oxides produced by the second air-bag reaction. Many candidates will know that silicon dioxide is commonly known as sand and so the reference to it being harmful to the environment is clearly not true.

## *Question 5 (a)*

Just under 60% candidates correctly balanced the half equation and also gave the right colours for all of the species. Occasionally no response was given for the hydrogen ions and the water despite the dotted answer lines, and so this meant that the 'colours' mark was not awarded. It was very pleasing to see very few 'clear' answers which did not score so this point seems to be well-understood by candidates.

## *Question 5 (b) (i)*

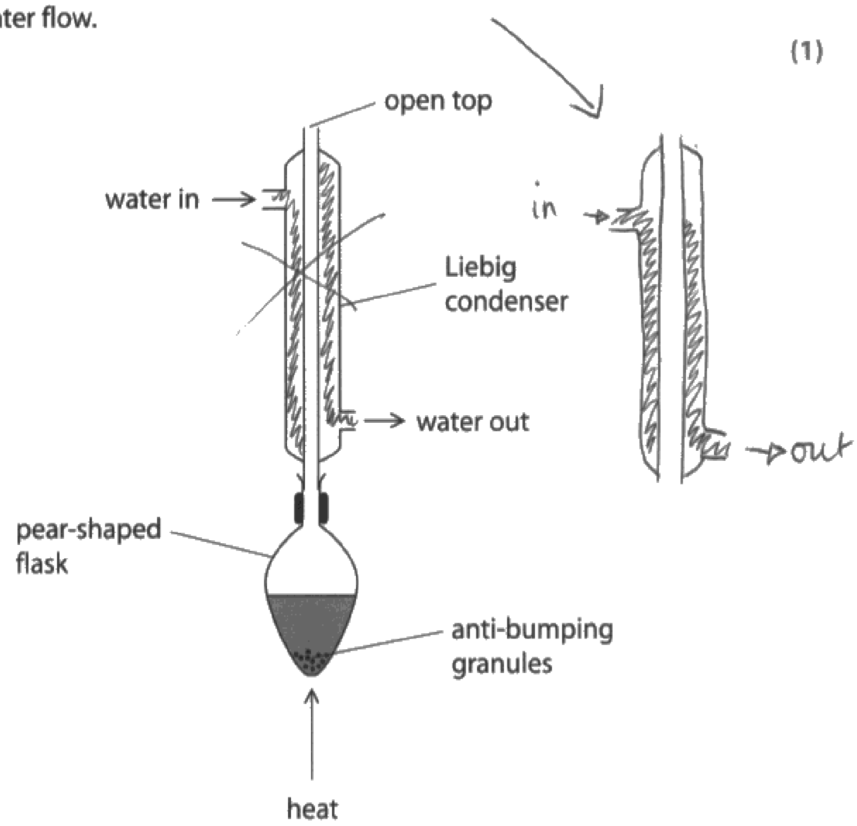
The most common reason for a lack of credit on this question was the absence of any attempt. It is most likely that these candidates missed the need to answer the question despite the fact that the following question is part (ii). This serves as a reminder to candidates to pay closer attention to the rubric of the question. Occasionally candidates did not answer with shading as requested but drew arrows which did not score.

Most of the candidates attempting this question did understand that the condenser would not completely fill with water and so any response with a practical shading was awarded credit.

(b) Reflux apparatus can be used to carry out the oxidation of alcohols.

(i) This Liebig condenser has been set up incorrectly. Add shading to the diagram to show the water in the condenser, illustrating the effect of the incorrect water flow.

(1)

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**Examiner Comments**

The response scored one mark for partial shading of the condenser.

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**Examiner Tip**

If you are unhappy with your answer then a clear crossing out, as shown here, and a replacement with an alternative answer is acceptable.

## *Question 5 (b) (ii)*

Three quarters of candidates failed to score and appeared to have no real idea of the function of the anti-bumping granules; in fact a lot of erroneous comments about these granules being sites for reactions or acting as catalysts were seen. Possibly centre-specific, some high-quality answers were seen referring to the granules serving as nucleation sites for smaller bubbles.

The function of chemical apparatus is an excellent revision activity for candidates

(ii) State how the granules prevent bumping.

(1)

These allow small bubbles / pockets of gas to form insted of large so the heating is more evenly distributed. This prevents bumping.

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**Examiner Comments**

There are two answers given here and both are suitable for the mark.

**ResultsPlus**
**Examiner Tip**

Only give one answer to a question because any incorrect answers will negate any correct answers.

## *Question 5 (d)*

The candidates were roughly evenly spread over the full marking range and proved an effective discriminator. The better candidates gave a good explanation of why an aldehyde produced would distil off before further oxidation due to its lower boiling temperature. The weaker candidates failed to mention the aldehyde product but gave vague or general comments about the difference between reflux and distillation.

(d) Using the apparatus for distillation instead of reflux is not an efficient way to produce ethanoic acid from ethanol. Explain why.

**(2)**

Distillation will only allow a certain degree of oxidation and will produce an aldehyde as ~~a~~ major product, and not a carboxylic acid

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**Examiner Comments**

This response scores one mark for the reference to the oxidation of the alcohol to an aldehyde. However there is no explanation why there is no oxidation from the aldehyde to the carboxylic acid.

**ResultsPlus**
**Examiner Tip**

Remember to check your answer for marking points so that if there are two marks for a response to a question then make sure that your answer has two clear marking points.

## Question 6 (a)

A significant number of candidates used sodium hydroxide instead of water for hydrolysis and so the reaction would be almost instantaneous. Hence no mark could be awarded for the timing factor of the experiment. Further, the addition of silver nitrate to a mixture of halogenoalkane and sodium hydroxide would form a precipitate of silver hydroxide instead of a silver halide precipitate. Thus the mark for the use of silver nitrate was not awarded without the neutralisation of the sodium hydroxide by an acid, commonly nitric acid.

It was pleasing to see high calibre candidates using ethanol as a co-solvent and a water bath to control temperature. Some responses did refer to controlling temperature but without the means to do so which did not score.

**6** This is a question about the hydrolysis of halogenoalkanes.

(a) Devise an experiment, giving outline details only, that would enable the relative rates of hydrolysis of halogenoalkanes to be compared.

**(5)**

- Set up warm water bath and warm up 3 test tubes containing NaOH.
- mix haloalkane with NaOH (warm).
- add dilute nitric acid then add silver nitrate.
- time the quickest to form precipitate.
- white = Cl

cream = Br

yellow = I

(order should be I faster than Br, faster than Cl).

**ResultsPlus**
**Examiner Comments**

This response is an example of one which used sodium hydroxide to accomplish the hydrolysis. The addition of nitric acid to neutralise the alkali meant that the mark for the use of the silver nitrate could be awarded but obviously not 'the time taken for the precipitate to form' mark. A second mark for the use of a water bath gives a total of 2 marks for this response.

## *Question 6 (b)*

Approximately two-thirds of candidates correctly stated the trend of hydrolysis of the halogenoalkanes and explained the reason in terms of the carbon-halogen bond strength. Candidates would benefit from making it clearer that a trend is involved by using comparative expressions such as 'faster' and 'weaker'.

(b) Explain the trend in the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

(2)

- the rate of hydrolysis of the 1-iodo butane would be fastest followed by 1-bromobutane and then 1-chlorobutane.
- this is because, the $C^{\delta+}-I^{\delta-}$ bond is the longest therefore has the weakest bond enthalpy - so is more easily broken and hydrolysed as a result. (the $C^{\delta+}-Cl^{\delta-}$ is the shortest bond length ∴ greater bond enthalpy ∴ requires more energy & time for it to be broken / hydrolysed overall).

**ResultsPlus**
**Examiner Comments**

A response which scored both marking points. The trend in the rate of hydrolysis is correctly stated and explained by referring to the difference in C-Hal bond enthalpy.

**ResultsPlus**
**Examiner Tip**

The number of lines or answer space should be a clear indicator of the depth of response required. This example illustrates the need to avoid repeating yourself and keep to the lines provided.

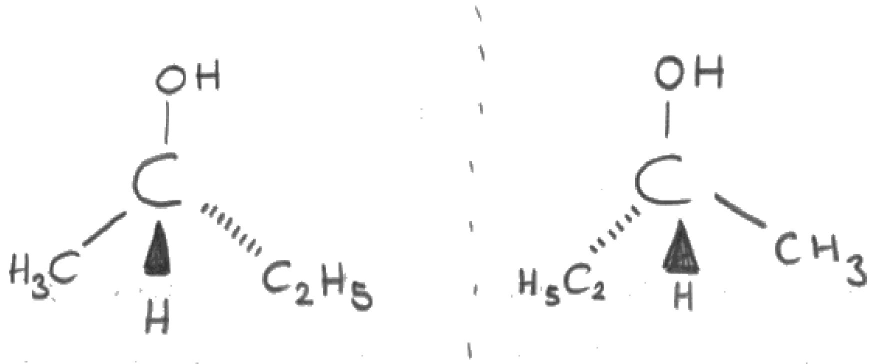
# Question 6 (c)

Candidates seem to have learnt from the similar question in last year's paper and very few non-3D diagrams were seen. Occasionally errors in the atoms/groups joined to the chiral carbon were seen, such as $CH_4$ and $C_2H_6$.


(c) The product of the hydrolysis of 2-bromobutane is butan-2-ol. Both molecules are chiral.

State what is meant by the term chiral, using three-dimensional diagrams of the enantiomers of butan-2-ol to illustrate your answer.

**(3)**




chiral ~~com~~ carbons are carbons ~~att~~ bonded to 4 different funtional groups. this means that they can form enantiomers that have the same molecular and structural formulae but are mirror images of each other and ~~th~~ can rotate plane ~~pla~~ polarised light different ways.

**ResultsPlus**
**Examiner Comments**

Two good 3D diagrams for two marks but the description refers to four functional groups which is incorrect as in this example there is a hydrogen atom joined to the chiral carbon and this is not a functional group.

## *Question 6 (d)*

If there was any evidence of structuring this response or some type of planning then invariably the response scored highly. This is something that candidates would be well-advised to do when answering the 6 mark extended open response type of question. This activity is more typical of the better candidates and the performance of the candidates on this question in general was likewise commensurate with their overall ability.

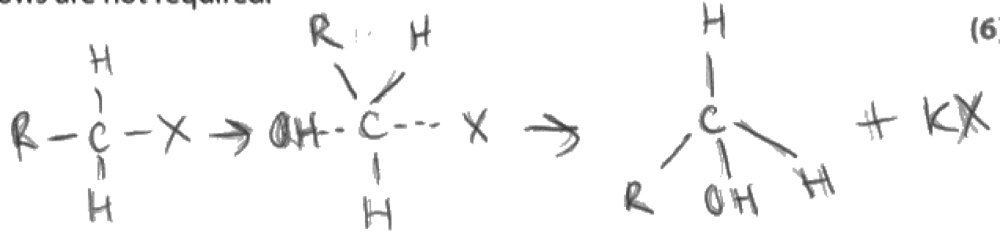
Attention to detail and care with terminology is always important and failure to do so resulted in frequent loss of marks. For example, many responses drew the transition state for the $S_N2$ primary halogenalkane mechanism but omitted the overall negative charge or the partial bonding between the incoming OH and outgoing Br. A further mark was often lost by incorrectly referring to the transition state as an intermediate or reference to the carbocation as a transition state. Another terminology error was to say that in the $S_N2$ mechanism there are two 'molecules' in the rate-determining step but one of the species is the hydroxide ion and so this was not credited. Likewise, when referring to the $S_N1$ mechanism it was not uncommon to see the response stating that only one reactant is in the rate-determining step but this is not the same as stating that only one species is in this step. One reactant could be the only one in the rate determining step but be second order.

Many candidates spent some time and effort discussing the difference in optical activity of the products of each type of reaction mechanism. Unfortunately this did not gain any credit because the example of the tertiary halogenoalkane given in the question was R3X and so all of the R groups could have been identical and so no optical activity would have been observed. It is worth reminding candidates that not all tertiary halogenoalkanes exhibit optical activity, only those with four different atoms/groups attached to the central carbon.

*(d) Compare and contrast the mechanism of hydrolysis, using aqueous potassium hydroxide, of the primary halogenoalkane, $RCH_2X$, with that of the tertiary halogenoalkane, $R_3CX$. Include diagrams of any intermediate or transition state.

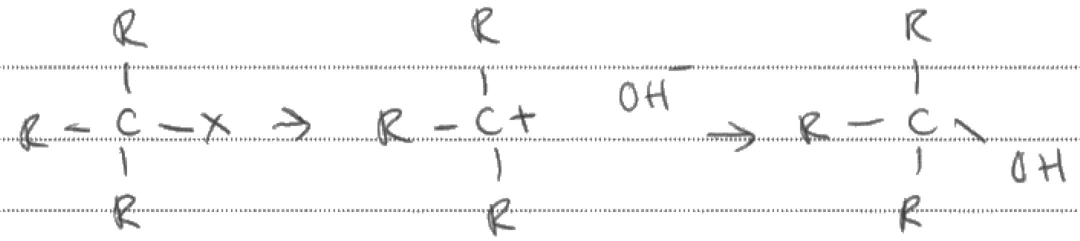
Curly arrows are not required.

**(6)**



Primary halogenoalkane - $RCH_2X$ - undergoes the $S_N2$ mechanism which has one step. As it is a primary halogenoalkane there isn't much steric hindrance this means the $OH^-$ nucleophile can attack the halogenoalkane from the opposite side to the halogen and it forms an intermediate. The Intermediate is unstable so the halogen breaks off and forms KX.

However the tertiary halogenoalkane - $R_3CX$ - undergoes the $S_N1$ mechanism ~~which only~~ which has 2 steps. First of all the halogen has ~~to~~ to break off to make room for the OH group as it is a tertiary halogenoalkane so it has more steric hindrance than a primary halogenoalkane. Unlike primary halogenoalkane hydrolysis this doesn't form an intermediate.




In the mechanism for ~~[illegible]~~ tertiary halogenoalkane the $OH^-$ can attach either side this means it form two enantiomers forming a raecimic mixture which means there is no optical activity.

**ResultsPlus**
**Examiner Comments**

This response unfortunately only scores one mark.

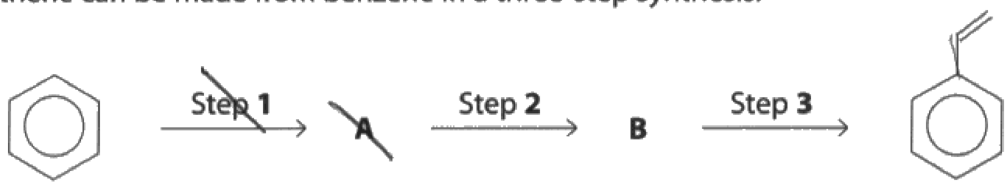
Note that the primary halogenoalkane $S_N2$ mechanism drawn at the start is missing the overall negative charge, presumably because the attacking hydroxide ion is also missing, and so loses M5. This transition state is also referred to incorrectly in the first paragraph as an intermediate and, so loses M2. There is no statement which states that the similarity is nucleophilic substitution, so no M1. The tertiary carbocation is given correctly on the second page and so this scores M6. There is no reference to the difference in the rate equation or rate determining steps of the two mechanisms and so there is no M3 nor M4.

# *Question 7 (a)*

Another question with discriminated across the ability range and thus produced a wide spread of marks. The decision was made to make the mark scheme strictly adhering to correct chemistry, so simply stating a suitable reagent did not score if it was given in an incorrect chemical context. This served to distinguish between candidates who were guessing from the table of reagents provided and those who deduced more carefully the appropriate reagent for the respective conversion.

Additionally the responses served to emphasise the need for double-checking of work once completed because some otherwise excellent reaction pathways were spoiled by structural errors such as missing hydrogen atoms or pentavalent carbon atoms.

**7** Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.

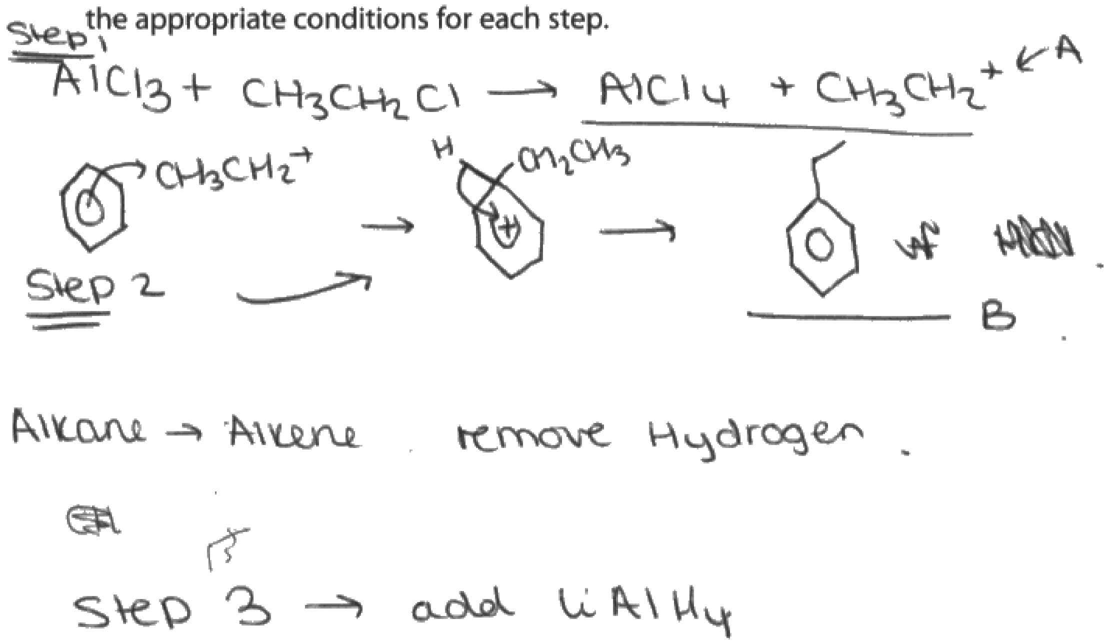



(a) Some of the following compounds can be used to make phenylethene from benzene.

| | | | |
|---|---|---|---|
| Aluminium chloride | Chloroethane | Ethanal | Ethanol |
| Ethanoic acid | Ethanoyl chloride | Ethene | Ether |
| Hydrochloric acid, concentrated | Lithium tetrahydridoaluminate(III) | Phosphoric acid, concentrated | Sulfuric acid, concentrated |

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step.

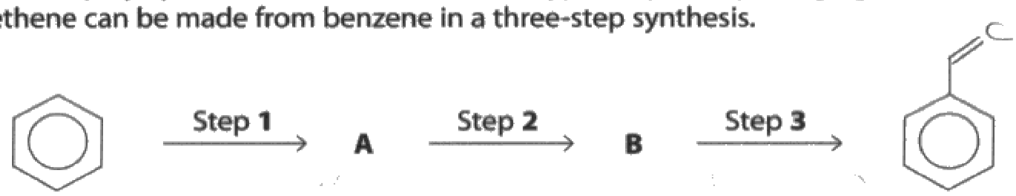
**(5)**



**ResultsPlus**
**Examiner Comments**

This is an example of a response which was given credit for some correct chemistry. Aluminium chloride is the required halogen carrier for the first step in the reaction pathway but was only awarded the mark when part of a Friedel-Crafts reaction. In this instance it is and so the mark was awarded. It is not possible to remove the hydrogen atoms from ethylbenzene from the reagents given in the table and so this is the only mark available.

7 Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.



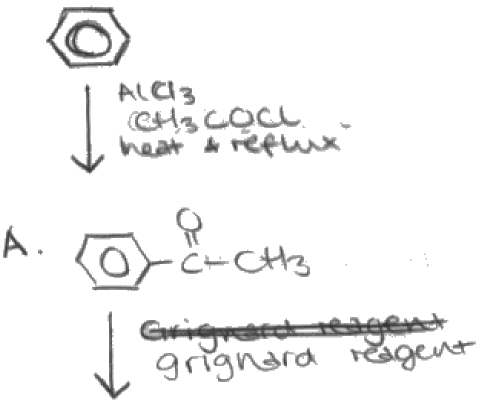

(a) Some of the following compounds can be used to make phenylethene from benzene.

| | | | |
|---|---|---|---|
| Aluminium chloride | Chloroethane | Ethanal | Ethanol |
| Ethanoic acid | Ethanoyl chloride | Ethene | Ether |
| Hydrochloric acid, concentrated | Lithium tetrahydridoaluminate(III) | Phosphoric acid, concentrated | Sulfuric acid, concentrated |

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step. **(5)**

$AlCl_3$ + CH

Nitrile → carboxylic acid




ResultsPlus
Examiner Comments

This response scores two marks for the correct first step using ethanoyl chloride with aluminium chloride. Although the candidate does not know how to proceed further the marks gained from this first step were no doubt valuable in the overall total score.

ResultsPlus
Examiner Tip

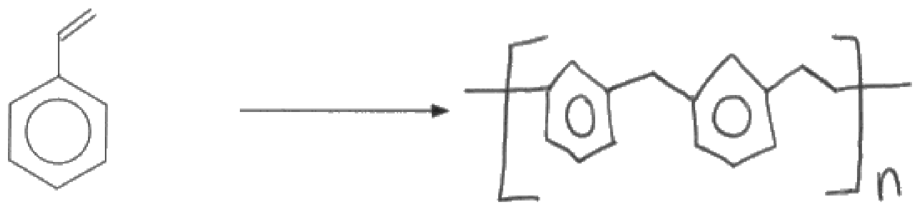
Never leave an answer space blank. It is always worth having a guess.

## Question 7 (c)

Polymerisation and the drawing of repeat units continues to prove challenging for candidates with only about a third scoring the mark for this question. The use of skeletal formulae was an issue for many candidates because often the two repeat units drawn were either missing $CH_2$ units or had too many. The weaker candidates drew the benzene ring as part of the main carbon chain. In all instances further practise would be beneficial for candidates.

(c) Draw a section of the polymer, polystyrene, showing **two** repeat units.

**(1)**




ResultsPlus
Examiner Comments

Note the two errors in this response. Firstly the benzene rings are part of the main carbon chain. Secondly there is one $CH_2$ drawn skeletally between the two rings but then there are two $CH_2$ groups drawn after the second ring.

ResultsPlus
Examiner Tip

Skeletal formulae can prove very challenging and so if the question does not require this type of formulae then write out displayed formulae which is generally easier to get correct.

# Question 7 (d)

Vague responses such as stating that the products of incineration are 'harmful' are always unlikely to gain credit and the better candidates referred to reasons for their stated advantages. There remains some confusion in some candidates' minds between the global warming and the ozone layer so this may be an area for centres to spend some time on in order to clarify the topic in their candidates' minds.

It was surprising to see some candidates refer to a disadvantage of acid rain due to the production of sulfur oxides or that toxic products containing chlorine would be made when neither sulfur nor chlorine is present in phenylethene. A reminder then to perhaps re-read the question and to appreciate the context rather than write a 'stock' answer.

(d) Give one advantage and one disadvantage of the disposal of polystyrene by incineration.

(2)

one advantage of incineration is that it is very quickly disposing of the polystyrene but due to combustion $CO_2$ is produced which contribute to global warming.

**ResultsPlus**
**Examiner Comments**

No credit was given for the 'speed' of disposal as an advantage but the disadvantage of the production of carbon dioxide was awarded the mark as long as it was connected with global warming as seen here.

## *Question 7 (e)*

Interpreting the molecular formulae of skeletal formulae remains a very real challenge for many candidates as seen by the wide range of molar masses suggested for phenylethene. Another worthwhile revision exercise task for candidates.

The second mark of the calculation was allowed if the candidates' own molar mass was correctly used as long as an appropriate number of significant number of figures was used.

**(e) Calculate the percentage by mass of carbon in phenylethene, giving your answer to an appropriate number of significant figures.**

**(2)**

14 H
8 × 12 = 96 + 14 = 110.    C 8.

$\frac{96 \times 100}{110}$ = 87.27%.
= 87%

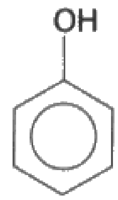
**ResultsPlus**
**Examiner Comments**

An example of a response which loses the first mark for an incorrect molar mass value but scores the second mark for 'transferred error' for a suitable final answer determined from the candidate's value.

## *Question 8 (a) (i)*

Substitution of a benzene ring is a good test of candidates' appreciation that there are hydrogen atoms on each of the carbon atoms in the ring, although they are rarely drawn. The responses to this question revealed those candidates who were aware of this because only they could gain the second mark for balancing the equation.

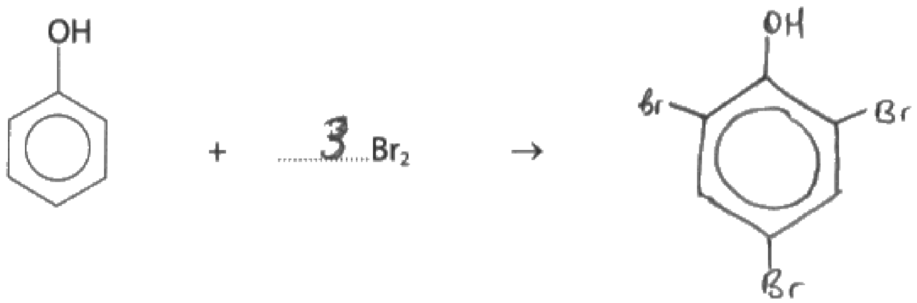
**8** Phenol is a feedstock in the production of many organic molecules.




(a) Phenol reacts with bromine water.

(i) Complete the equation for the reaction of phenol with excess bromine water, using the **skeletal** formula of the organic product.

**(2)**




**ResultsPlus**
**Examiner Comments**

One mark awarded for the correct tribromo product but the response is missing the 3HBr bi-product.

**ResultsPlus**
**Examiner Tip**

Remember to balance equations for atoms and double-check such responses. Even a cursory check would highlight the fact that in this response there are 6 bromine atoms on the reactant side but only 3 bromine atoms on the product side.

## Question 8 (a) (ii)

A 'compare and contrast' question will always require one or more differences and one or more similarities. In this question candidates frequently wrote about the differences and only the better candidates spared a thought for the similarity. Furthermore some candidates lost a possible mark for the use of incorrect terminology, for example stating that phenol has three bromine atoms "added" compared to benzene only having one "added".

(ii) Compare and contrast the bromination of phenol with the bromination of benzene.

**(3)**

Benzene will not react with bromine the solution will remain colourless. This is due to the stability of the benzene ring caused by the electron pi cloud. ~~Phenol~~ However Phenol will react with bromine water and turn it colourless, it lacks the stability of benzene due to the OH group which pulls and slightly distorts the pi electron cloud.

**ResultsPlus**
**Examiner Comments**

An example of a response which stated a number of points but none sufficiently to score.

It is true that phenol will react with bromine water and that benzene won't but to score the mark the contrast of benzene will react with liquid bromine was required.

There was one mark awarded for an explanation of the greater reactivity of phenol which is attempted here but there needed to be reference to the lone pair of electrons on the oxygen of the OH group interacting with the delocalised ring of electrons and making it more susceptible to electrophilic attack which is not stated.

(ii) Compare and contrast the bromination of phenol with the bromination of benzene.

**(3)**

✓ Bromination of benzene requires a catalyst of $FeBr_3$ phenol doesn't.

✓ Bromination of benzene with $FeBr_3$ will result in only one Br attached phenol will result in 3

✓ ~~Phenol will react~~ Both ~~are~~ are types of ~~the~~ electrophilic substitution reactions

✓ Phenol will react more quickly and vigorously than than with benzene

**ResultsPlus**
**Examiner Comments**

A response which scored all three marks. The use of bullet points is fine and helps the candidate to see more clearly the points that they are making.

**ResultsPlus**
**Examiner Tip**

Note that there are three marks available for this question and so two for contrasts and one for a similarity. This response has three contrasts which is unnecessary and uses up valuable time in the exam so make sure that your answer matches the demand of the question.

## Question 8 (b) (i)

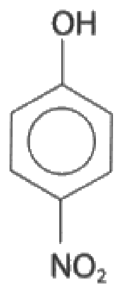
The mechanism was mostly well-understood with marks lost by careless placements of arrows/charges/atoms or by omissions.

It is worth reminding candidates that the hydroxide ion is usually drawn $OH^-$ but it is clearly understood that the negative charge is really on the oxygen and not on the hydrogen. Likewise in a nitronium ion that is written as $NO_2^+$ the charge is on the nitrogen and not on the oxygen which means that the curly arrow should go to the nitrogen. Furthermore candidates should appreciate that the curly arrow is showing the movement of two electrons in the formation of a covalent bond and so should be between the two atoms that will be joined in that bond. Hence a curly arrow that went from the ring to the oxygen or to the positive charge did not score.

It was surprising to see a significant minority of candidates draw their curly arrow to a lone pair of electrons which had been added to the nitrogen atom. This was not awarded the first mark. Candidates need to remember that the curly arrow represents the movement of electrons and so would not go towards a lone pair of electrons as there would be repulsion.

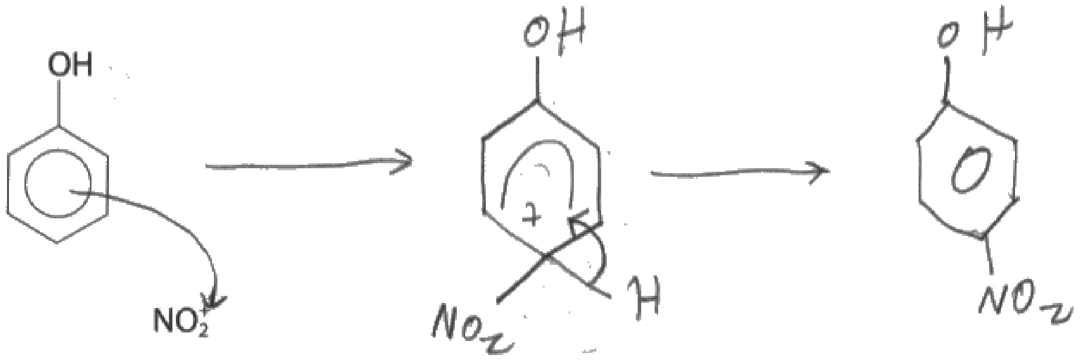
The structures seen of the intermediate ion were generally correct and it was pleasing to see few drawings with the positive charge on the tetravalent carbon or the broken delocalised ring facing the wrong carbon. However there remain a small number of candidates that are still drawing the second curly arrow for the reformation of the delocalised ring from the hydrogen atom instead of from the carbon-hydrogen bond.

(b) Phenol can be nitrated to produce 4-nitrophenol.




(i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, $NO_2^+$, and phenol to produce 4-nitrophenol.

**(3)**



ResultsPlus
Examiner Comments

The first mark is lost because the curly arrow clearly goes to the oxygen of the nitronium ion. The second mark is awarded for the formula of the intermediate ion. The third mark is not awarded because although the second curly arrow is correct, there is no hydrogen ion product.

ResultsPlus
Examiner Tip

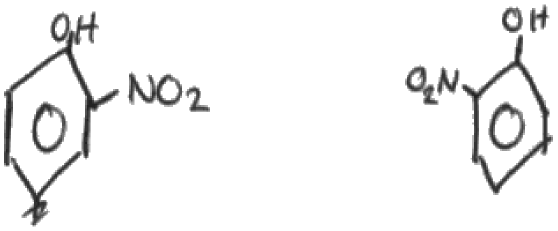
When writing reaction mechanisms do make sure that bi-products such as a $Cl^-$ or in this instance an $H^+$ are included.

## *Question 8 (b) (iii)*

Just over 55% of candidates could correctly draw the two structural isomers of 4-nitrophenol. The most common error was drawing the 4-nitro isomer again.

(iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

**(1)**




**ResultsPlus**
**Examiner Comments**

These structures are both the same but drawn from different perspectives. Hence the mark for two different structural isomers was not awarded as only one is actually given.

**ResultsPlus**
**Examiner Tip**

Try to mentally turn your structures to determine if they are actually different or the same.

## *Question 9 (a)*

This was a question aimed at the grade A/A* candidate and so it proved to be with only the top 5% of candidates scoring the mark by appreciating how unlikely it would be for five iodide ions to collide simultaneously.

A worrying common response was to state that the reaction order can only be 0,1 or 2. This appears to reflect a misunderstanding of the specification. Topic 16 refers to reaction orders 0, 1 or 2 so that this complex area of chemistry is simplified to these few reaction orders but it does not mean that these are the only reaction orders.

It was frustrating to see the occasional correct reference to how unlikely it was for five iodides to collide, ruined by stating that the iodides were "molecules".

**9** This question is about the reaction kinetics of an 'iodine clock' reaction.

One example of an 'iodine clock' reaction that involves the iodate(V) ions and iodide ions in acidic solution is

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

(a) State why the order of reaction with respect to iodide ions cannot be five, even though 5 mol of iodide ions are shown in the equation.

**(1)**

The balancing numbers do not affect the order of the reaction.

**ResultsPlus**
**Examiner Comments**

Whilst a true statement this does not state why this is the case.

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(a) State why the order of reaction with respect to iodide ions cannot be five, even though 5 mol of iodide ions are shown in the equation.

**(1)**

It can only be 1st 2nd or 0th order

ResultsPlus
**Examiner Comments**

An example of a response highlighted in the introduction to this question.

## *Question 9 (b) (i)*

This was another very challenging question with just under 10% of candidates gaining the mark. The point required was the fact that the volume is kept the same so that volume is proportional to concentration. Only the better candidates were able to clearly make this point.

(b) A series of experiments was carried out by a student to determine the order of reaction with respect to iodate(V) ions. The concentrations of the iodide ions and the acid were in large excess and the volume of the iodate(V) solution was varied.
The total volume of the reaction mixture was kept constant by the addition of suitable volumes of deionised water.
The following results were obtained:

| Experiment Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Volume of iodate(V) solution / $cm^3$ | 10.0 | 7.0 | 5.0 | 3.0 | 2.0 | 1.0 |
| Time (t) / s | 180 | 260 | 357 | 606 | 900 | 800 |
| (1000/t) / $s^{-1}$ | 5.56 | 3.85 | 2.80 | 1.65 | 1.11 | 1.25 |

(i) In experiment 6, the student forgot to add deionised water to keep the total volume the same for each experiment.
State why the total volume should be kept the same.

(1)

changing the volume changes the concentration of the reactants.

**ResultsPlus**
**Examiner Comments**

Changing the volume does change the concentration but when the volume is kept the same the concentration of one of the reactants is also changed. Hence this type of response did not score.

## Question 9 (b) (ii) - (iii)

The full spectrum of marks was awarded, although most of the candidates scored either 4, 5 or 6 for both parts (i) and (ii).

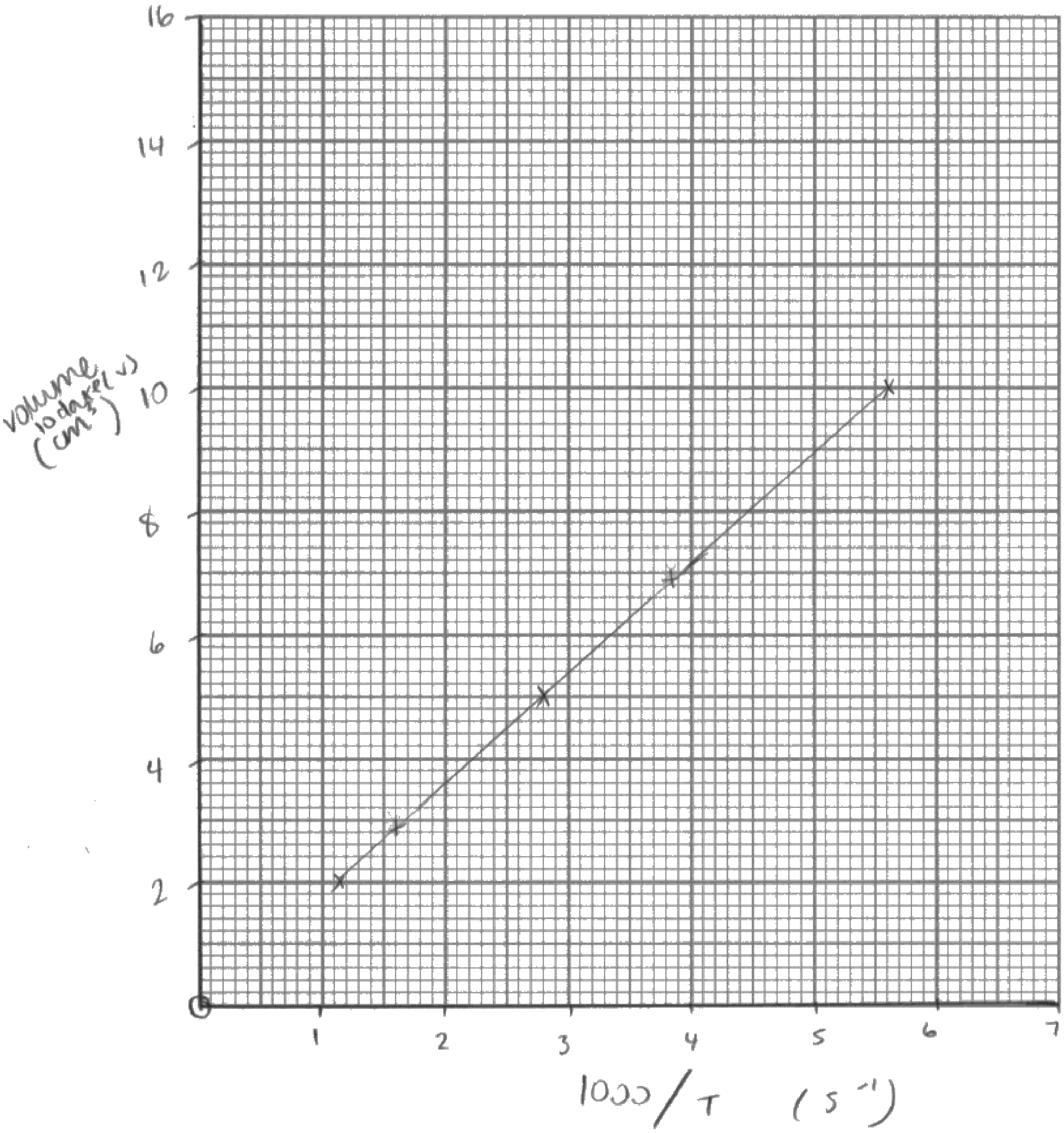
It was pleasing to see very few incorrect plotting of points and scales used were normally suitable. The common errors were axes written the wrong way round, omission of units, use of 'T' (which is temperature) instead of 't' and failure to extend the straight line through the origin.

In part (ii) most candidates correctly deduced that the order with respect to iodate (V) ions was 'first'. However the justification was less well-answered with a simple statement that the line was a straight one being insufficient. A horizontal line is a straight one but obviously true of a zero order reactant.

| Experiment Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Volume of iodate(V) solution / $cm^3$ | 10.0 | 7.0 | 5.0 | 3.0 | 2.0 | 1.0 |
| Time (t) / s | 180 | 260 | 357 | 606 | 900 | 800 |
| (1000/t) / $s^{-1}$ | 5.56 | 3.85 | 2.80 | 1.65 | 1.11 | 1.25 |

(ii) Complete the table and use the results from experiments 1, 2, 3, 4 and 5 to plot a graph of 1000/t against volume of iodate(V) ions.

**(4)**




(iii) Deduce the order of reaction with respect to the iodate(V) ions. Justify your answer.

**(2)**

As volume is proportional to concentration, it is first order - as rate ~~time~~ is proportional to the concentration of $IO_3^-$ (straight line, constant gradient)

**ResultsPlus**
**Examiner Comments**

In part (i) two marks were awarded. The values in the table are correct for M1. The axes are the wrong way round and there is no line through the origin so no M2 nor M4. The scale is correct for M3.

In part (ii) one mark was awarded for the reference to first order but the justification is not sufficient. The proportionality is between the rate and concentration/volume and not between volume and concentration.

## *Question 9 (c) (i)*

Only 45% of candidates scored both marks for a suitable value and units. A very common error was to give a value to excessive number of significant figures. Candidates would be well-advised to consider carefully the number of significant figures given in the table for the calculation.

(c) A different version of the 'iodine clock' reaction involves mixing hydrogen peroxide with aqueous solutions of potassium iodide, sodium thiosulfate and starch.

The main reaction is

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

The reaction is first order with respect to hydrogen peroxide and iodide ions but zero order with respect to hydrogen ions.

(i) In one experiment, the following data were obtained:

| Reactants | Initial concentration / mol dm$^{-3}$ |
|---|---|
| $H_2O_2(aq)$ | $1.50 \times 10^{-3}$ |
| $I^-(aq)$ | $2.10 \times 10^{-3}$ |
| $H^+(aq)$ | $2.10 \times 10^{-3}$ |

Initial rate = $1.24 \times 10^{-3}$ mol dm$^{-3}$ s$^{-1}$

Write the rate equation and hence deduce the value of the rate constant, *k*, from these data. Include units and give your answer to an appropriate number of significant figures.

**(2)**

$r = k[H_2O_2][I]$

$k = \frac{rate}{[H_2O_2][I]} = k = \frac{1.24 \times 10^{-3}}{[1.50 \times 10^{-3}][2.10 \times 10^{-3}]} = \frac{mol\,dm^{-3}s^{-1}}{[mol\,dm^{-3}s^{-1}]^2}$

$k = 393.65\ mol^{-1}\,dm^{3}\,s^{-1}$

**ResultsPlus**
**Examiner Comments**

Note that the numerical answer is to an inappropriate number of significant figures so does not score. The units are correct for one mark.

## *Question 9 (c) (ii)*

Two-thirds of candidates scored one mark for reference to either starch being an indicator or a description thereof. Occasionally the mark was negated either by reference to the complex being produced by the wrong species, such as iodide, or by the wrong colour change stated. Only the better candidates went on to explain that it would be the timing of the appearance of the blue-black complex that could be used to calculate reaction rate.

(ii) Explain the purpose of the starch present in the reaction mixture when starch is neither in the rate equation, nor in the reaction equation.

**(2)**

The starch is required to detect the end point. It turns blue, black when all of the $H_2O_2$ has reacted with $2I^-$. turns blue black in the presence of iodine

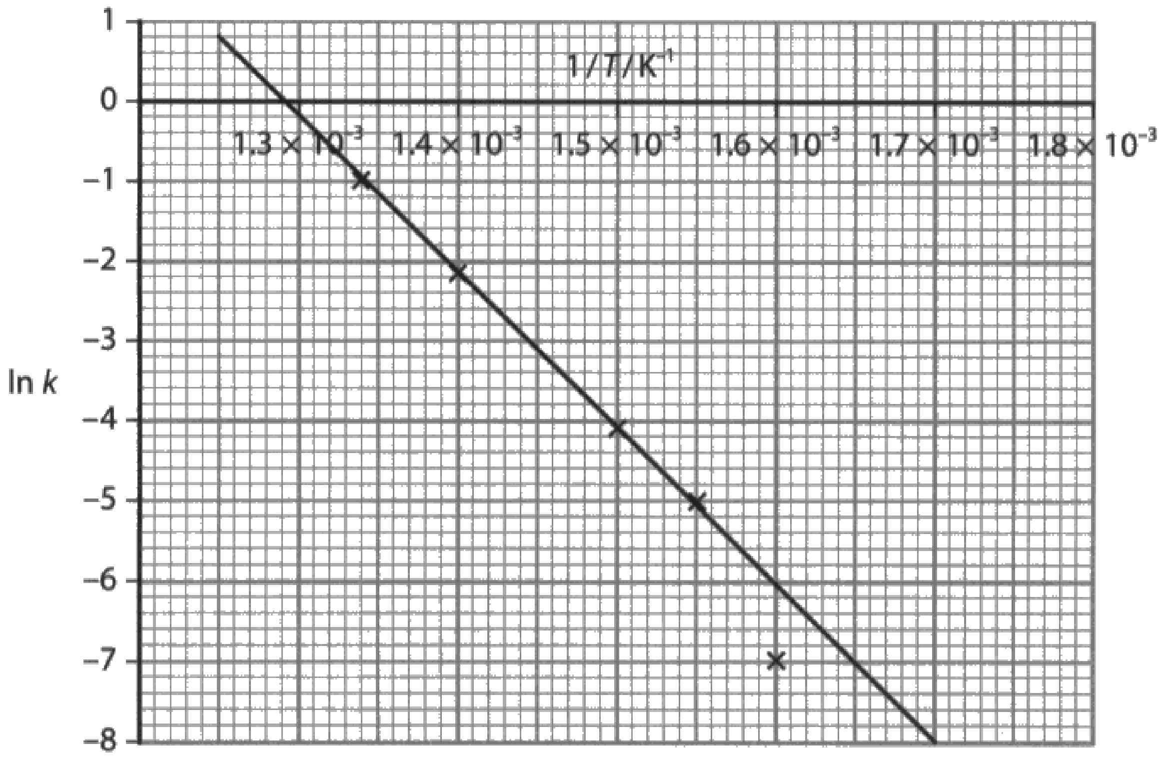
**ResultsPlus**
**Examiner Comments**

An example of a response which scores the first mark for the reference to starch being an indicator but there was no reference to the 'timing factor'.

## Question 9 (d) (i)

At least 20% of candidates scored each of the different marks possible for this question and so it was a very effective discriminator. The majority of candidates knew how to determine the gradient from the graph and could go on to process the value to determine the activation energy. The most common score was 2 marks which was frequently due to one mark lost because of a missing '+' sign or incomplete units.

(d) Another 'iodine clock' reaction produced data that enabled the following graph of ln *k* against 1/*T* to be drawn.




(i) The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \left[\frac{1}{T}\right] + \text{constant}$$

y = m x + c

From the gradient of the graph, determine the activation energy, $E_a$, for this reaction.

Include a sign and units in your answer.

**(3)**

$$M = \frac{-8-0.8}{1.7\times10^{-3} - 1.25\times10^{-3}}$$

$$M = -19555.6 = \frac{-Ea}{8.31}$$

Ea = 163 kJmol⁻¹

**ResultsPlus**
**Examiner Comments**

An example of a response which loses a mark for the omission of the '+' sign for the answer.

**ResultsPlus**
**Examiner Tip**

Make sure that the answer given includes all of the requirements in the question.

## *Question 9 (d) (ii)*

About 90% of candidates scored the mark for their answer to this question. The spelling of 'anomaly' was very varied but fortunately it couldn't be confused with a contradictory term and so most were accepted.

(ii) Give a reason for the point at $\ln k = -7$ **not** being included in the line drawn on the graph.

(1)

It is an anomallouy | outlier result.
Likely caused by random error

**ResultsPlus**
**Examiner Comments**

The mark was awarded for use of the term 'anomalous', 'outlier' or a description thereof. In this response all of these are given but obviously only one mark can be awarded.

# Paper Summary

Based on their performance on this paper, candidates are offered the following advice:

- $RTQ^2$ or 'Read The Question Twice' and make sure that the answer written matches the demands of the question
- $RYA^2$ or 'Read Your Answer Twice' to double-check that your answer does meet all of the requirements of the question
- Use specialist chemical terms carefully and in the correct context to ensure that they are appropriate to the topic area being discussed
- Plan your answer to the extended open response question so that the response is organised, covers the necessary points and is focused on the demands of the question
- In extended calculations make sure that the 'workings' are clearly shown so that if necessary credit can be given
- Practise writing different types of chemical formulae such as skeletal and structural repeatedly so that it becomes error-free

# Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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