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Examiners' report

CHEMISTRY B (SALTERS)

H433

For first teaching in 2015

H433/01 Summer 2022 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers are also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 1 series overview

There was evidence of good candidate preparation in this session. The calculations were particularly well handled overall. Structure, bonding and properties and organic mechanisms proved more of a challenge and as in previous series, and as possible consequence of absences from centre, the practical aspects also proved more difficult for many students.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• Managed to set out all the steps in calculations in a clear and logical way. • Gave clear and detailed descriptions where required, e.g. in the extended response Questions, 34(c) and 35(g). • Were able to accurately describe practical procedures. • Had detailed knowledge of organic reaction mechanisms.	• Lacked ability in rearranging formulae, e.g. in Question 34(b)(ii). • Were not able to draw organic structures of products of a reaction. • Could not use mechanisms to explain observations. • Had difficulty determining structures from spectroscopic data.

Section A overview

The scores in this section ranged from 5/30 to 29/30 which shows it was a paper that tested candidates across all levels. In general, the performance in multiple choice questions has continued to improve and there was much evidence of careful working out in the spaces around the questions. Some of the questions were quite complex and many candidates had developed strategies to help them work out the answer.

Question 1

1 Which feature of the structure of the atom was deduced from the Geiger and Marsden experiment?

A Atoms consist of electrons, protons and neutrons.

B The nucleus is small and dense.

C Electrons exist in energy levels/shells.

D Electrons exist in atomic orbitals.

Your answer ☐ **[1]**

This question was generally well done; incorrect responses were equally distributed across the other possible answers.

Question 2

2 Which row gives the correct trends for the following properties of Group 2 elements and compounds going down the Group?

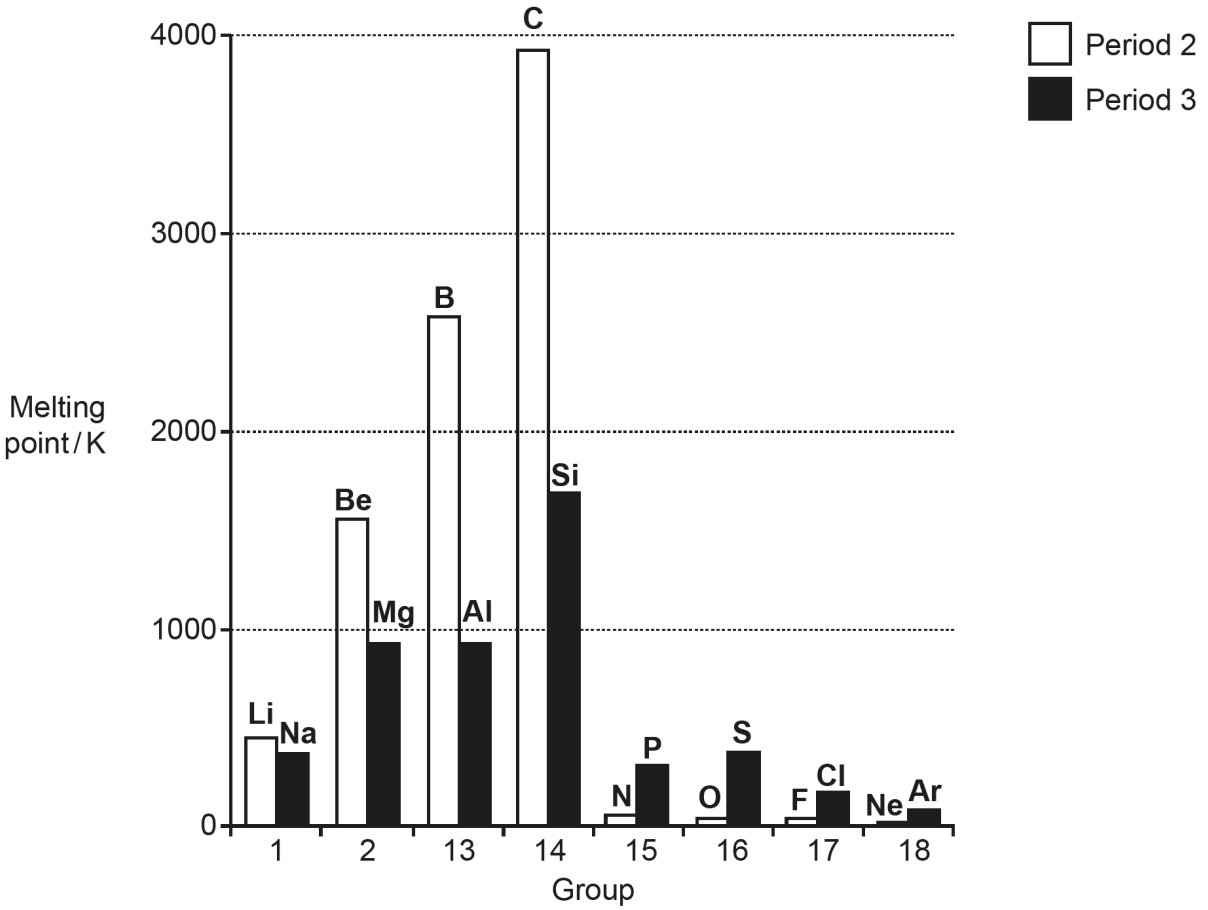
	First ionisation enthalpy of element	**Thermal stability of carbonate**
A	Increases	Increases
B	Increases	Decreases
C	Decreases	Increases
D	Decreases	Decreases

Your answer ☐ **[1]**

This was well-understood; over 60% of the responses were correct.

Question 3

3 The bar chart shows the melting points of the elements in Periods 2 and 3.
What is the correct reason for the large decrease in melting point after Group 14 in both Periods?



A The bonding of the elements changes from metallic to covalent.

B The elements change from metals to non-metals.

C The structure and bonding of the elements change from ionic to simple molecular.

D The structure of the elements changes from giant to molecular.

Your answer ☐ **[1]**

This was correctly answered by more than half of the candidates who interpreted the complex diagram well. Incorrect answers were generally A or C.

Question 4

4 What is the correct bond angle in the ammonia molecule?

A 90°

B 107°

C 109°

D 120°

Your answer ☐ **[1]**

Candidates showed their clear understanding of molecular shapes here, as they also did in Question 35 (b).

Question 5

5 In which of the following reactions is iodine oxidised?

A $2Na + I_2 \longrightarrow 2NaI$

B $I_2 + 2e^- \longrightarrow 2I^-$

C $I_2 + 2At^- \longrightarrow At_2 + 2I^-$

D $I_2 + F_2 \longrightarrow 2IF$

Your answer ☐ **[1]**

This question was very well answered.

Question 6

6 Which mixture forms a buffer solution?

A A mixture of a strong acid and a strong base

B A mixture of a strong acid with its salt

C A mixture of a strong base with its salt

D A mixture of a weak acid with its salt

Your answer ☐ **[1]**

This was well answered, with A and B the most frequently seen incorrect responses.

Question 7

7 What is correct about the greenhouse effect?

A Carbon dioxide is the only gas in the troposphere that acts as a greenhouse gas.

B Infrared radiation breaks bonds in molecules in the troposphere.

C The main way that the Earth is heated is by infrared radiation from the Sun.

D The Earth emits infrared radiation.

Your answer ☐ **[1]**

More than half the answers to this were correct, but B and C were frequently seen incorrect responses.

Question 8

8 What is correct about nitrogen chemistry?

A The ammonia molecule has a lone pair of electrons.

B The ammonium ion has a bond angle of 120°.

C The ammonium ion has four dative covalent bonds.

D The nitrogen molecule has a double bond.

Your answer ☐ **[1]**

A well answered question.

Question 9

9 Which row is correct?

	$Cu^{2+}(aq) + NaOH(aq)$	$Cu^{2+}(aq) + NH_3(aq)$
A	Blue precipitate soluble in excess NaOH(aq)	Blue precipitate insoluble in excess $NH_3(aq)$
B	Blue precipitate insoluble in excess NaOH(aq)	Blue precipitate insoluble in excess $NH_3(aq)$
C	Blue precipitate soluble in excess NaOH(aq)	Blue precipitate soluble in excess $NH_3(aq)$
D	Blue precipitate insoluble in excess NaOH(aq)	Blue precipitate soluble in excess $NH_3(aq)$

Your answer ☐ **[1]**

In common with many items based on practical activities, this was a difficult question. Fewer than half the candidates gave a correct answer.

Question 10

10 Ammonia is manufactured using the process shown in **Equation 10.1**.

A high pressure and moderate temperature are used.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\,kJ\,mol^{-1}$ **Equation 10.1**

What is correct about this manufacturing process?

A Creating a high pressure is expensive and dangerous.

B If the process were attempted at room temperature it would be quicker but give less ammonia.

C The nitrogen gas is expensive.

D The process is beneficial to society because it removes nitrogen from the air.

Your answer ☐ **[1]**

This question was well answered.

Question 11

11 Which of the following alcohols **cannot** undergo dehydration?

A $CH_3CH_2CH_2CH_2OH$

B $(CH_3)_2CHCH_2OH$

C $(CH_3)_3COH$

D $CH_3CH(OH)CH_2CH_3$

Your answer ☐ **[1]**

This question contained an error and any response, or lack of response was given the mark.

Question 12

12 Which equation represents the first ionisation enthalpy of phosphorus?

A $P(l) \longrightarrow P^+(g) + e^-$

B $P(s) \longrightarrow P^+(s) + e^-$

C $P(s) \longrightarrow P^+(g) + e^-$

D $P(g) \longrightarrow P^+(g) + e^-$

Your answer ☐ **[1]**

This question was well answered.

Question 13

13 Predict which row is correct for selenium, Se.

	melting point/°C	Structure	Bonding
A	217	Simple molecular	Covalent
B	1026	Giant	Metallic
C	–101	Simple molecular	Covalent
D	–157	Atomic	Instantaneous dipole-induced dipole

Your answer ☐ **[1]**

Most candidates identified the structure and bonding as simple molecular covalent but did not consider the trends in melting point down the group and the fact that sulfur is a solid at room temperature.

Question 14

14 What is the correct order of boiling points?

A CH_3CH_2COOH > $CH_3CH_2CH_2OH$ > CH_3CH_2CHO

B CH_3CH_2COOH > CH_3CH_2CHO > $CH_3CH_2CH_2OH$

C $CH_3CH_2CH_2OH$ > CH_3CH_2COOH > CH_3CH_2CHO

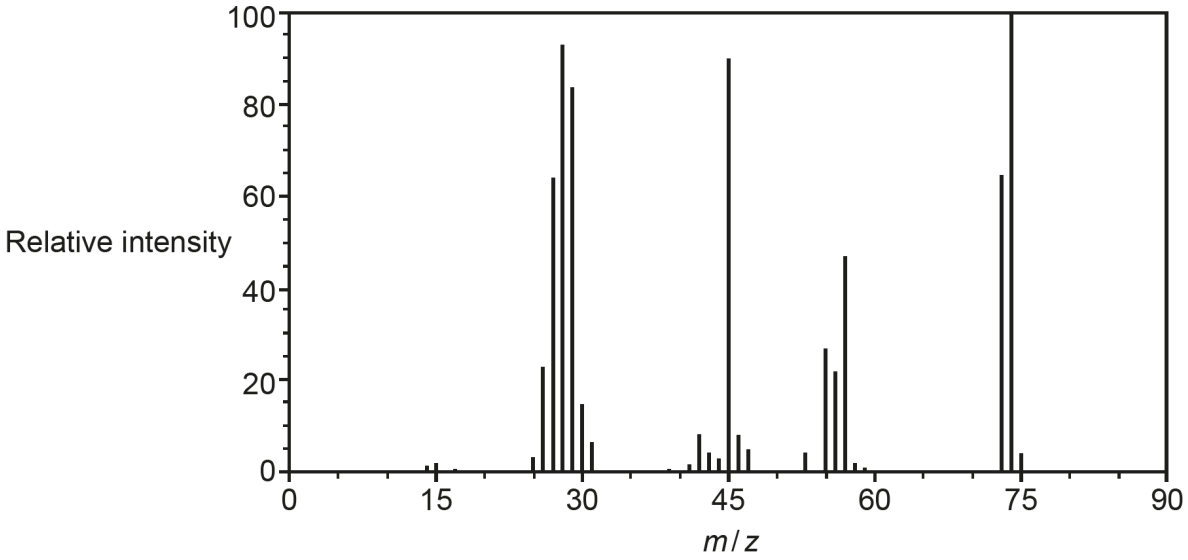
D CH_3CH_2CHO > CH_3CH_2COOH > $CH_3CH_2CH_2OH$

Your answer [ ] **[1]**

Slightly over a third of candidates gave the correct response.

Question 15

15 What is the correct M_r value of the organic molecule whose mass spectrum is shown below?



A 75

B 74

C 45

D 28

Your answer [ ] **[1]**

Candidates were able to interpret this mass spectrum to get the correct M_r.

Question 16

16 What is correct about the linking of DNA strands?

A Adenine forms three hydrogen bonds with thymine.

B Guanine forms three hydrogen bonds with cytosine.

C Guanine forms two hydrogen bonds with adenine.

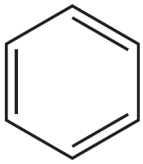
D Uracil forms two hydrogen bonds with adenine.

Your answer [ ] **[1]**

Candidates had a good knowledge of the base pairing in DNA.

Question 17

17 The Kekulé structure of benzene (C_6H_6) is shown below.



What is a correct statement about benzene if the Kekulé structure represented the actual structure and bonding in benzene?

A The molecule would have a regular hexagonal shape.

B The molecule would undergo electrophilic substitution reactions.

C The molecule would form several different compounds of formula $C_6H_4Br_2$.

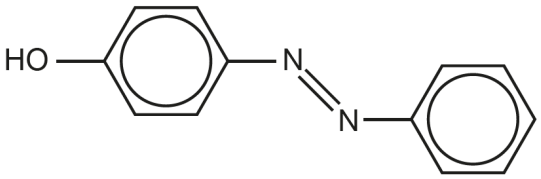
D The molecule would decolorise bromine water.

Your answer ☐ **[1]**

This was answered well showing good knowledge of molecular shapes and reaction mechanisms.

Question 18

18 A dye molecule is shown below.



What is correct about this dye molecule?

A Delocalisation extends over the whole dye molecule.

B The dye molecule will attach itself to fibres mainly by covalent bonds.

C Substitution of CH_3 groups onto a ring will increase the solubility of the dye in water.

D Substitution of NO_2 groups onto a ring will not affect the chromophore.

Your answer ☐ **[1]**

This question required the critical consideration of several aspects of dyes and was correctly answered by more than half the candidates.

Question 19

19 What is correct about a 0.1 mol dm^{-3} solution of a strong base?

A $[OH^-] << 0.1\,mol\,dm^{-3}$.

B The solution is weaker than a 0.5 mol dm^{-3} solution of the same base.

C The pH of the solution is given by $pH = 14 + \log_{10}(0.1)$ at 298 K.

D The solution will not react with weak acids.

Your answer ☐ **[1]**

The mathematical demands of questions on pH are quite high, nevertheless a substantial proportion of candidates selected the correct response.

Question 20

20 GCC is a mRNA triplet code for alanine.

What is correct?

A Alanine has a transfer RNA with the code CGG.

B GCC is the only code for alanine.

C Other amino acids as well as alanine are coded by GCC.

D The mRNA sequence is produced by GCC on a DNA strand.

Your answer ☐ **[1]**

As in Question 16, candidates showed a good knowledge of DNA and RNA structures.

Question 21

21 In the absence of water the following reaction occurs.

$CH_3COOH + H_2SO_4 \rightarrow CH_3C(OH)_2^+ + HSO_4^-$

What is correct about this reaction?

A CH_3COOH is a proton donor.

B CH_3COOH is acting as a base.

C $CH_3C(OH)_2^+$ is the conjugate base of CH_3COOH.

D HSO_4^- is the conjugate acid of H_2SO_4.

Your answer ☐ **[1]**

This question was very well answered.

Question 22

22 What is correct?

A A 0.10 mol dm^{-3} solution of a strong acid has a pH of 2.

B A 0.10 mol dm^{-3} solution of a strong base has a pH of 14.

C A 0.10 mol dm^{-3} solution of an acid with $K_a = 1.0 \times 10^{-5}$ mol dm^{-3} has a pH of 3.

D A half-neutralised solution of a weak acid has pH = 0.5 pK_a.

Your answer ☐ **[1]**

This question is challenging due to its mathematical nature, but a significant proportion of candidates answered well.

Question 23

23 10 cm^3 of 0.10 mol dm^{-3} HC*l*(aq) is added to 5 cm^3 of 0.10 mol dm^{-3} NaOH(aq).

What is the pH of the resulting solution?

A 1.0

B 1.2

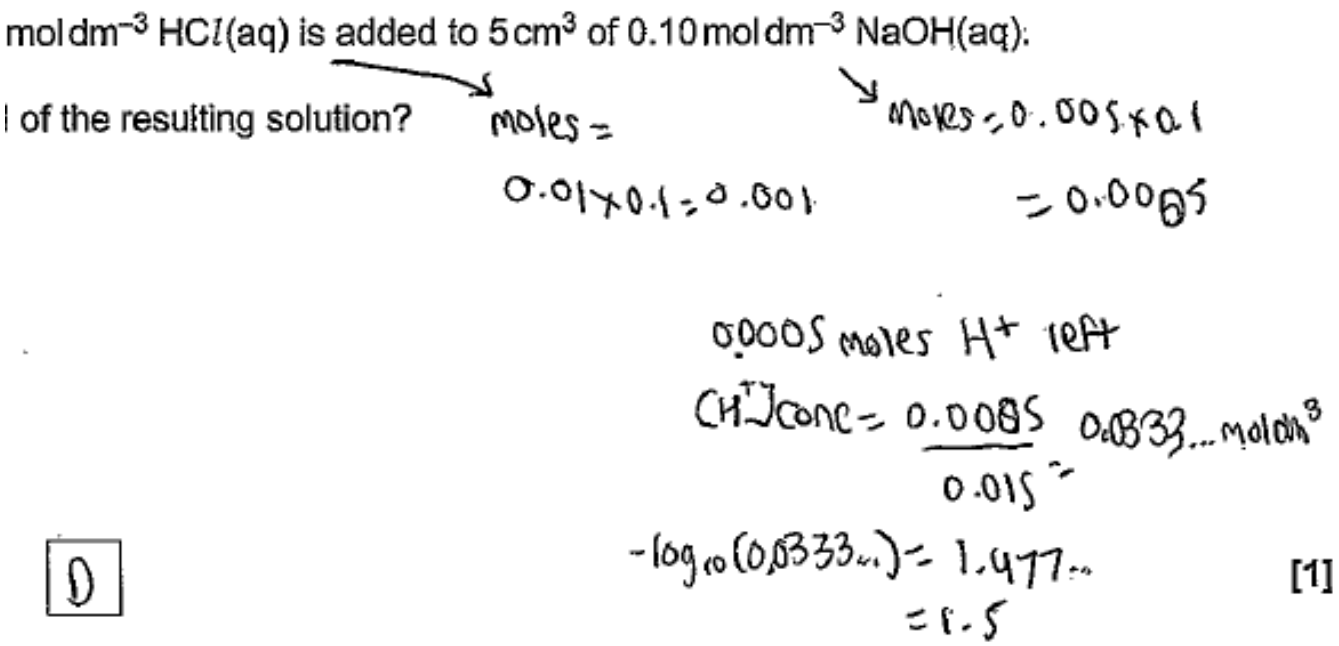
C 1.3

D 1.5

Your answer [ ] **[1]**

This question involved several steps. It is best to work out the correct answer and then look for it in the list of options

Exemplar 1



This response shows clear working around the question.

Question 24

24 Ethanoic acid is a weak acid and hydrochloric acid is a strong acid.

What is correct about 10 cm^3 of 0.1 mol dm^{-3} solutions of each acid?

A They both fizz at the same rate with equal sized pieces of magnesium.

B They both fizz at the same rate with equal sized pieces of $CaCO_3$.

C They both have the same effect on pH indicator paper.

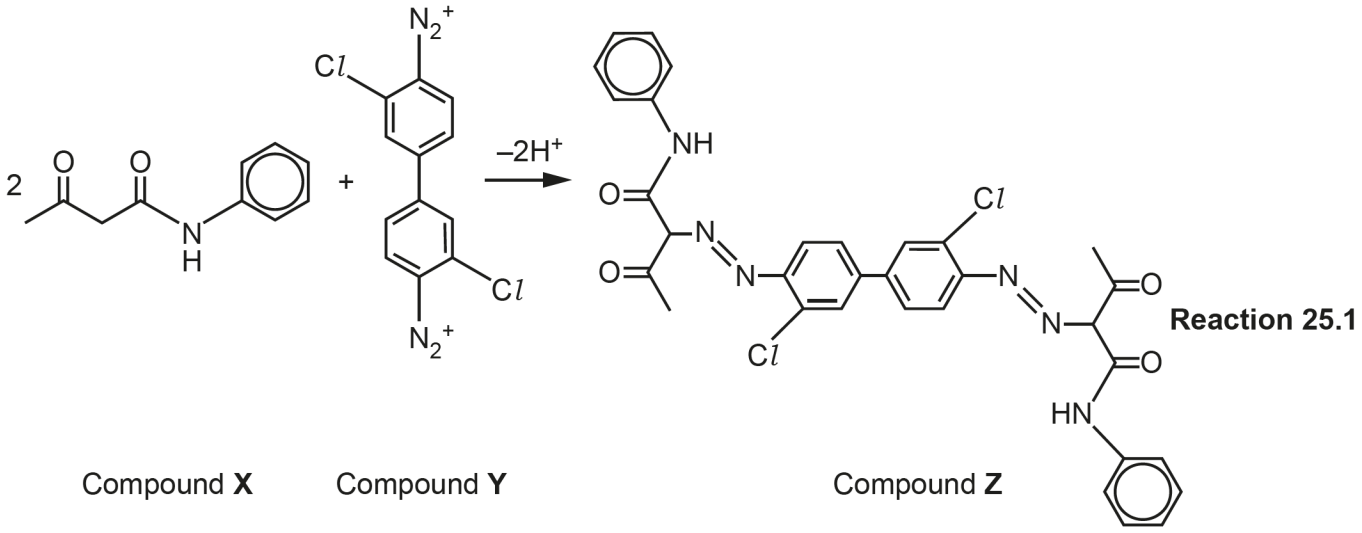
D They both neutralise 10 cm^3 of 0.1 mol dm^{-3} NaOH(aq).

Your answer ☐ **[1]**

All options were frequently seen as the answer which means that in many cases there was not a full understanding of the consequences of being a weak acid.

Question 25

25 The formation of an azo dye is shown in **Reaction 25.1** below.

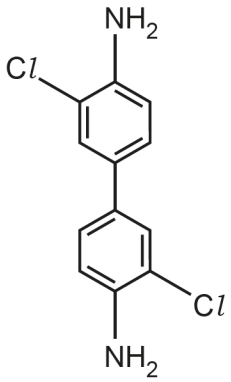


Reaction 25.1

Compound **X** Compound **Y** Compound **Z**

What is correct about this reaction and the compounds involved?

A Compound **Y** can be formed by a diazotisation reaction on the compound below.



B **Reaction 25.1** is a coupling reaction between diazonium groups and NH groups.

C **Reaction 25.1** is an addition reaction.

D **Reaction 25.1** needs cold HNO_2.

Your answer [ ] **[1]**

This question was difficult by design. There is a lot to consider, and a detailed knowledge of the topic is needed.

Question 26

26 Manganate(VII) ions react with sulfate(IV) ions as shown in the **unbalanced** equation below.

$MnO_4^-(aq) + SO_3^{2-}(aq) + H^+(aq) \rightarrow Mn^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$

What is the ratio of $SO_4^{2-}(aq)$: $H_2O(l)$ in the balanced equation?

A 1:1

B 1:3

C 3:4

D 5:3

Your answer ☐ **[1]**

In this question a little less than a quarter of the answers were correct; in many cases B was chosen that balanced the hydrogen and oxygen without considering the balancing of the gain and loss of electrons in MnO_4^- and SO_3^{2-}.

Question 27

27 Iodine is formed from iodide ions by reaction with copper(II) ions as shown in the following ionic equation.

$2Cu^{2+} + 4I^- \rightarrow I_2 + 2CuI$

The iodine formed can be titrated with sodium thiosulfate as shown in the following ionic equation.

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

25.0 cm^3 of a copper(II) solution forms iodine that reacts with 22.5 cm^3 of 1.50×10^{-2} mol dm^{-3} sodium thiosulfate solution.

What is the concentration of copper(II) ions (in mol dm^{-3}) in the solution?

A 3.38×10^{-4}

B 6.75×10^{-3}

C 1.35×10^{-2}

D 2.70×10^{-2}

Your answer ☐ **[1]**

This question was well attempted with more than half the answers correct.

Question 28

28 Which statement(s) is/are correct about an orange dye?

1 Blue light is absorbed when electrons rise to higher energy levels.

2 Orange light is emitted when electrons drop to lower energy levels.

3 The dye absorbs orange light.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

Most candidates were clear that orange light was not absorbed so statement 3 was incorrect, but many were unclear about the difference between transmitted and emitted so selected statement 2 as correct when it isn't.

Question 29

29 Two half-cell equations are shown with their standard electrode potentials.

$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$ $\quad E^{\ominus} = -0.26\,V$

$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$ $\quad E^{\ominus} = +0.34\,V$

Which statement(s) is/are correct?

1 A solution of V^{3+} will change into V^{2+} and VO^{2+}.

2 The cell made from these two half-cells has an $E^{\ominus}_{cell}$ value of 0.60 V.

3 $VO^{2+}(aq)$ will not oxidise $V^{2+}(aq)$ unless acid is present.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

Most candidates knew that statement 1 was incorrect and statement 2 was correct but were unsure about statement 3. They were nevertheless able to eliminate all but option C.

Question 30

30 Which statement(s) is/are correct about nitrogen chemistry?

1 Ammonium compounds give off ammonia when warmed with alkalis.

2 The oxide N_2O is brown.

3 Nitrate(V) ions can be oxidised to nitrate(III) ions.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

This question was well answered, often based on the confidence that statement 2 is incorrect.

Section B overview

The calculations were well attempted, however, it remains the case that working could be more clearly laid out, to make it easier to follow and award marks for steps where an error has been carried forward. Practical techniques remain a difficulty as clarity and detail are not often sufficient to gain all the marks. Organic structures and mechanisms similarly proved difficult to gain full marks on this session.

Question 31 (a)

31 Bromine is currently extracted from the Dead Sea.

(a) Bromine is made from the sodium bromide present in sea water.

Complete the table showing the structure, bonding and properties of bromine and sodium bromide.

Substance	Structure	Bonding	Melting point	Electrical conductivity in liquid state
Bromine	simple molecules			poor
Sodium bromide			high	

[2]

This question was well answered with the majority of candidates scoring full marks. There was some uncertainty in describing the structure of sodium bromide; ionic or ionic molecules were seen, the commonly seen ionic lattice was able to score and 'giant' was comparatively rarely seen.

Question 31 (b)

(b) The extraction process for bromine involves bubbling chlorine gas through sea water.

The equation for the reaction is shown below.

$2Br^-(aq) + Cl_2(g) \rightarrow Br_2(aq) + 2Cl^-(aq)$

Explain in terms of electrons why chlorine can displace bromine from bromide ions.

.....

.....

.....

..... **[2]**

Many candidates knew the answer to this but were not able to express their ideas clearly enough. Many were able to say that chlorine is better able to attract electrons but were not so clear about the reason. Some answers were in terms of electronegativity which is not appropriate in this context.

Question 31 (c)

(c) Bromine can also be produced by the electrolysis of aqueous sodium bromide.

Write the ionic half-equation for the production of bromine at the anode.

[1]

This was generally well done, but about a third of candidates reversed the equation or had the electrons on the incorrect side.

Question 31 (d)

(d) A solution contains 2.57 g dm^{-3} of sodium bromide.

Calculate the minimum volume of chlorine gas (in cm^3) required at 20 °C and 101 kPa to displace all the bromine from 100 cm^3 of this solution.

$2Br^-(aq) + Cl_2(g) \rightarrow Br_2(aq) + 2Cl^-(aq)$

volume = ... cm^3 **[4]**

Many answers were fully correct here. The most common error was not applying the mole ratio to determine the number of moles of chlorine. Others included using the M_r of Br^- instead of NaBr or not converting to moles at all. There were also some instances of incorrectly converting from m^3 to cm^3.

Question 31 (e) (i)

(e) Three test-tubes, labelled as **A**, **B** and **C**, contain solutions of sodium chloride, sodium bromide and sodium iodide but not necessarily in that order.
A student adds an equal volume of silver nitrate solution to each tube.

Tubes **A** and **B** both give precipitates that are not white but are not clearly distinguishable from each other. Tube **C** gives a white precipitate.

(i) Write an ionic equation for the reaction that has occurred in tube **C**.

Show state symbols.

[1]

This was well answered. There were instances of $AgCl_2$ and not following the instruction to show state symbols.

Question 31 (e) (ii)

(ii) Describe what the student would do to the precipitates to distinguish between the halide ions in tubes **A** and **B**.

State the expected results.

.....

.....

.....

..... **[2]**

There were instances where candidates did not know the answer and suggested adding hexane. Of those who did know the test, a number did not give evidence that the ammonia had to be concentrated.

Question 31 (f) (i)

(f) Another student tries to prepare a sample of pure hydrogen bromide by adding concentrated sulfuric acid to solid sodium bromide. A brown vapour is produced as well as fumes of HBr.

(i) Write an equation to show why a brown vapour is produced when hydrogen bromide reacts with sulfuric acid.

[1]

This is an area of the specification that was not generally well known and only a small proportion of candidates scored the mark here.

Question 31 (f) (ii)

(ii) State how the student can produce pure hydrogen bromide.

.....

..... **[1]**

Again, this area of the specification was not well answered.

Question 32 (a)

32 The Montreal Protocol was established to phase out ozone-depleting CFCs. CFC molecules contain carbon, fluorine and chlorine atoms only. When CFCs reach the stratosphere they decompose, releasing atoms that cause ozone to break down.

(a) A student says that when CFCs decompose they release F atoms. This is because the C–F bond is more polar than the C–C*l* bond and breaks more easily.

Comment on the statements made by the student. Give and explain the correct chemistry where necessary.

.....

.....

.....

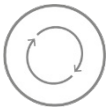
.....

.....

..... **[3]**

The most common scores on this question were 1 or 2. Many candidates agreed that the C-F bond was more polar but did not say why and many correctly said the C-Cl bond would break as it had a lower bond enthalpy but did not say it would release chlorine atoms or radicals.

Assessment for learning



It is important to be clear and detailed in evaluating the ideas provided, giving clear reasons. Marks can be lost by not explaining fully. This was also seen in Question 34(a) where incorrect statements given are identified but not clearly corrected.

Question 32 (b)

(b) Nitrogen oxides from aircraft exhausts can also play a part in ozone depletion.

Nitrogen dioxide undergoes photodissociation by homolytic bond fission according to the following equation.

$NO_2(g) \rightarrow NO(g) + O(g)$

Photodissociation occurs with ultraviolet radiation with a wavelength of 3.96×10^{-7} m.

Calculate the enthalpy of the N–O bond (in $kJ\,mol^{-1}$) that breaks in NO_2.

Give your answer to an **appropriate** number of significant figures.

enthalpy of N–O bond = ... $kJ\,mol^{-1}$ **[4]**

Almost half of all candidates scored full marks. A few did not follow the instruction to give the answer to an appropriate number of significant figures and some did not multiply by N_A or Planck's constant.

Question 32 (c) (i)

(c) The NO radical can act as a homogeneous catalyst in a catalytic cycle that depletes ozone.

(i) Explain what is meant by the term **homogeneous** as applied to a catalyst.

..... **[1]**

Almost all correct responses for this question.

Question 32 (c) (ii)

(ii) The NO radical depletes ozone in a catalytic cycle.
The first reaction in the cycle is shown below.

Suggest an equation to complete the cycle.

$NO + O_3 \rightarrow NO_2 + O_2$

[1]

Many of the answers had equations involving O_3.

Question 32 (c) (iii)

(iii) Explain how a catalyst increases the rate of a reaction.

.....

..... **[1]**

The answer to this was widely evidenced with only occasional answers not gaining marks as they did not include a full description.

Question 32 (d) (i)

(d) Radical reactions are also important in making haloalkanes.

The reaction between methane and chlorine to make chloromethane occurs according to the following equation:

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ **Reaction 32.1**

The product mixture is also found to contain other compounds, including small amounts of a chloroalkane **D** with M_r = 85 and a hydrocarbon **E** with M_r = 30.

(i) Identify the compounds **D** and **E**.

D is ..... **E** is ..... **[1]**

The compounds were generally correctly identified.

Question 32 (d) (ii)

(ii) Use your knowledge of the stages of the mechanism of **Reaction 32.1** to suggest equations showing how **D** and **E** are formed.

[3]

Many candidates were able to account for the formation of ethane (E), fewer could do so for dichloromethane (F). A significant number of candidates had not realised this was a radical mechanism and scored no marks as a consequence. Recognising radicals were involved and showing the formation of ethane in a termination step involving 2 methyl radicals, meant only 2 marks were scored.

Question 33 (a)

33 Parabens are used as antifungal preservatives in cosmetic products like shaving gel. Parabens are esters of 4-hydroxybenzoic acid, HOC_6H_4COOH (4-HBA).

4-HBA is a white solid.

(a) The antifungal properties of parabens are linked to their solubility in fats (esters of propane-1,2,3-triol).

Suggest the intermolecular bonds that cause parabens (esters of 4-HBA) to be soluble in fats.

..... **[1]**

This was a low scoring question as hydrogen bonds was a frequently seen answer due to the 2 OH groups in the molecule, but there are few hydrogen bonding opportunities in fats. Other reasons for not achieving the mark were incorrect names for the forces or abbreviations.

Question 33 (b)

(b) A student shakes some 4-HBA with sodium hydroxide solution.

A reaction occurs forming a soluble product.

Write the equation for the reaction of solid 4-HBA, HOC_6H_4COOH, with excess sodium hydroxide solution.

Show state symbols.

[2]

Many answers lost marks as the state symbols were absent or incorrect despite the clues given in the stem of the question.

Other answers only formed the salt with the carboxylic acid group, despite the clue in the question saying excess sodium hydroxide was used.

Assessment for learning

It is important that candidates understand the reactions of phenols; only a few candidates knew that sodium hydroxide would react with the phenol group as well as the carboxylic acid group. In Question 33(c)(ii), where the reaction is with sodium carbonate only reacts with the carboxylic acid group.

Question 33 (c) (i)

(c) The student places some aqueous sodium carbonate into a test-tube and adds small quantities of 4-HBA.

(i) Describe **two** things that the student would observe.

1 .....

.....

2 .....

.....

[1]

Many candidates did not realise the solid 4-HBA would disappear, although the bubbling due to the production of CO_2 was recognised.

Question 33 (c) (ii)

(ii) Write a formula for the organic product that is formed when 4-HBA reacts with aqueous sodium carbonate.

[1]

The answers to this were generally correct, although sometimes spoiled by giving the full equation which was not asked for with an incorrect formula for sodium carbonate.

Question 33 (d)

(d) The student prepares an impure sample of ethyl paraben by reacting 4-HBA with ethanol.

Describe how the student could purify the ethyl paraben.

You should make use of the solubility data for ethyl paraben in **Table 33.1** below.

Solvent	Solubility in solvent at room temperature	Solubility in solvent when hot
Water	Insoluble	Slightly soluble
Propanone	Very slightly soluble	Moderately soluble
Ethanol	Very slightly soluble	Very soluble

Table 33.1

.....

.....

.....

.....

.....

..... **[5]**

A few answers scored 5 marks and all scores between 0 and 5 were seen. Mostly the choice of ethanol for the recrystallisation was recognised, but the details of the process were incomplete or lacked detail. Some answers used different methods such as a separating funnel and distillation.

Exemplar 2

Table 33.1

ethyl paraben.

$HOC_6H_4COOH + C_2H_5OH \rightarrow HOC_6H_4COOC_2H_5$

Ethanol used as solvent as ethyl paraben is soluble in it at high temperatures, but relatively insoluble when cold. It is also inert.

Add ethyl paraben to the minimum amount of hot solvent.

- Hot filtration with Buchner funnel to remove insoluble impurities.
- ~~Cool slowly so that~~ Cool slowly.
- Add cooled mixture to a separating funnel, and add water. Shake. [5]

~~soluble~~ impurities should filter off aqueous layer and add HCl to remove any additional aqueous layer.

Dry with anhydrous $CaCl_2$

Dry in

In this response the techniques the candidate has used are confused.

Assessment for learning

Practical procedures are not always remembered in sufficient detail, this has been seen in other series too, although could be the result of less time for practical due to lock downs.

Question 33 (e) (i)

(e) 4-HBA reacts with thionyl chloride to make HOC_6H_4COCl.

(i) Give the name of the functional group $COCl$ that is formed in this reaction.

..... **[1]**

This was well answered.

Question 33 (e) (ii)

(ii) Give the structural formula of the aromatic product formed in the reaction between HOC_6H_4COCl and CH_3NH_2.

[1]

Some structures attached the CH_3 group to the ring, either separately from the NH_2 or together.

Question 34 (a)

34 Methanol is an important alcohol that can be used for making various plastics and it can also be used as a fuel. It can be produced industrially by reacting carbon monoxide with hydrogen according to the equilibrium in **Equation 34.1**.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1}$ **Equation 34.1**

(a) Student **F** says that dynamic equilibrium is reached when the forward and back reactions are still occurring and the concentrations of the reactants and products are equal.

Student **G** says that equilibrium is reached when the forward and back reactions have stopped.

Evaluate these two statements giving correct chemistry where necessary.

.....

.....

.....

..... **[2]**

As with Question 32 (a) the evaluation of students' statements tended to say where they were incorrect, but not always to give the correct chemistry in sufficient detail.

Question 34 (b) (i)

(b) (i) Write the expression for the equilibrium constant K_c for the reaction in **Equation 34.1**.

$K_c =$

[1]

Candidates had an excellent knowledge of equilibrium constants.

Question 34 (b) (ii)

(ii) The value of K_c at 657 K is $4.75 \times 10^3\,dm^6\,mol^{-2}$.

The reaction in **Equation 34.1** is carried out at 657 K in a flask of volume $9.40 \times 10^3\,cm^3$.

An equilibrium mixture is found to contain 0.452 mol of CO and 0.273 mol CH_3OH.

Calculate the amount (in mol) of H_2 in this equilibrium mixture.

amount of H_2 = ... mol **[4]**

The most frequently seen mark for this was 4/4, the candidates did very well in navigating the rearrangement of the equilibrium constant expression, remembering to take the square root and accounting for the volume of the container.

Question 34 (c)

(c)* The most economic operating conditions for the manufacture of methanol are a temperature of 525 K and a pressure of 40 atm with a copper-based catalyst.

Discuss these conditions.

Use the principles of equilibrium and rates of reaction and give the supporting chemistry.

.....

.....

.....

.....

.....

..... **[6]**

Most candidates were able to respond appropriately to this question, showing good understanding of the principles governing equilibrium and reaction rate. Good use of accurate terminology gave, for many, a good response. Answers in most parts were well structured. The obvious difficulty which only the most able candidates overcame was the impact of the catalyst on yield.

Question 34 (d) (i)

(d) Another important industrial process is the one that produces hydrogen from methane as shown in **Equation 34.2**.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206\,kJ\,mol^{-1}$ **Equation 34.2**

(i) State and explain the sign of $\Delta_{sys}S$ for the reaction in **Equation 34.2**.

.....

..... **[1]**

Many Candidates focused on the feasibility of the reaction, rather than the relative number of moles of gas in the reactants and products.

Misconception

A significant number of candidates had confused entropy with enthalpy.

Exemplar 3

The sign will be positive as the reaction is endothermic

In this response the candidate has confused entropy with enthalpy and due to this was given no marks.

Question 34 (d) (ii)

(ii) Calculate the temperature (in K) at which the reaction in **Equation 34.2** is just feasible.

You should make use of the data in **Table 34.1** below.

Substance	$\Delta S°$/J K^{-1} mol^{-1}
$CH_4(g)$	+186.2
$H_2O(g)$	+188.7
$CO(g)$	+197.6
$H_2(g)$	+130.7

Table 34.1

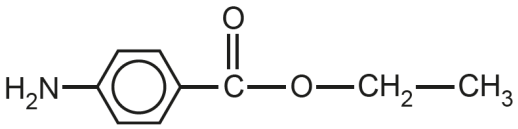
temperature = ... K **[4]**

The most frequently seen mark was 4, although some answers only got as far as finding the entropy change of the system.

Question 35 (a)

35 Benzocaine is a local anaesthetic used to relieve toothache.

Benzocaine has the following structure:



benzocaine

(a) Local anaesthetics work by binding to certain receptors in cells in order to inhibit pain.

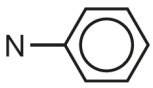
Name the part of a molecule that binds to a receptor in a cell in the body.

..... **[1]**

Only about half the answers were correct here, other answers including 'active site', 'chromophore' or specific parts of the benzocaine molecule.

Question 35 (b)

(b) Complete the diagram below to show the molecular shape around the nitrogen atom in the part of benzocaine shown. Use lines and wedges as appropriate.



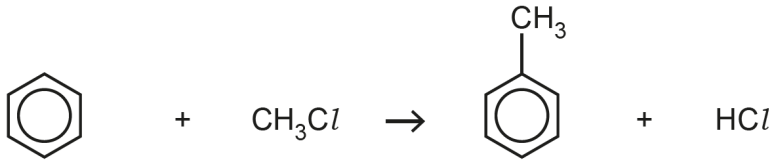
[1]

This was very well answered.

Question 35 (c) (i)

(c) A synthesis of benzocaine occurs in several stages.

A first step involves the conversion of benzene into methylbenzene as shown in the equation below:



The benzene is heated with chloromethane and aluminium(III) chloride as a catalyst in anhydrous conditions.

(i) Explain why this reaction must be carried out in anhydrous conditions.

.....

..... **[1]**

This practical detail was not at all well known, many of the answers suggested the chloromethane would react with water or a phenol would be produced.

Question 35 (c) (ii)

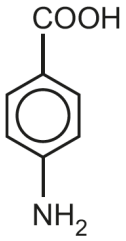
(ii) Name the mechanism of the reaction involved in this first step.

..... **[1]**

More than half of the candidates knew the mechanism.

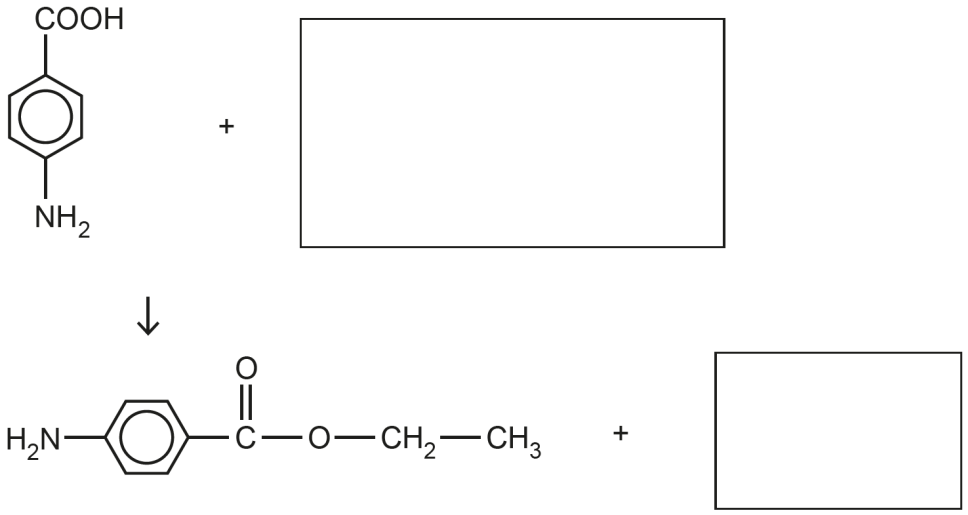
Question 35 (d)

(d) Further reactions are then carried out to convert methylbenzene into 4-aminobenzoic acid.



4-aminobenzoic acid

Complete the following equation to show a synthesis of benzocaine from 4-aminobenzoic acid.

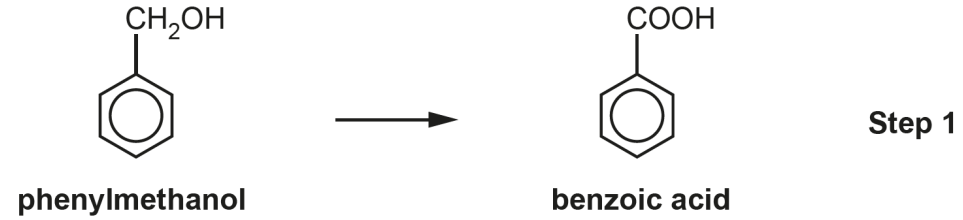


[2]

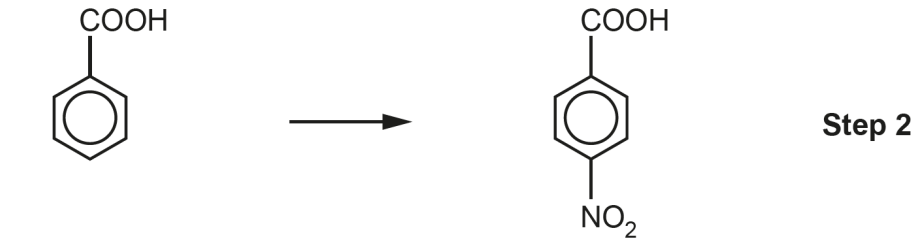
This was very well answered.

Question 35 (e) (i)

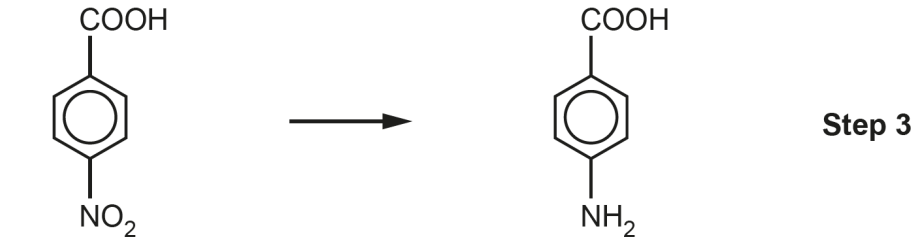
(e) An alternative route to 4-aminobenzoic acid involves the following three-step reaction sequence.



phenylmethanol **benzoic acid**



benzoic acid **4-nitrobenzoic acid**



4-nitrobenzoic acid **4-aminobenzoic acid**

(i) Give the reagents and conditions that a student could use to bring about the reaction in **Step 1**.

.....

..... **[1]**

This was well remembered as in most cases the dichromate was acidified and heated under reflux.

Question 35 (e) (ii)

(ii) The conversion in **Step 1** occurs through the intermediate formation of benzaldehyde.

benzaldehyde

Describe a test-tube reaction that a student could carry out to test for the aldehyde group in benzaldehyde.

.....

.....

..... **[2]**

Most candidates knew a test for an aldehyde but did not always include details like warming or that a precipitate is produced from Fehlings solution, meaning they did not get all the marks.

Question 35 (e) (iii)

(iii) The reaction of benzaldehyde with hydrogen cyanide can be written as follows:

$C_6H_5CHO + HCN \rightarrow C_6H_5CH(OH)CN$

Write out the two-step mechanism for this reaction.

Use 'curly arrows' and partial and full charges.

[3]

This question was not answered well and half the answers scored no marks at all.

Question 35 (e) (iv)

(iv) In **Step 2**, the benzoic acid is reacted with a nitrating mixture of concentrated nitric and concentrated sulfuric acids.

Write an equation to show the formation of the electrophile in this reaction.

[1]

This question was not answered well

Question 35 (e) (v)

(v) The conversion in **Step 3** is brought about by heating 4-nitrobenzoic acid with tin and concentrated hydrochloric acid under reflux.

Explain why the heating is carried out under reflux.

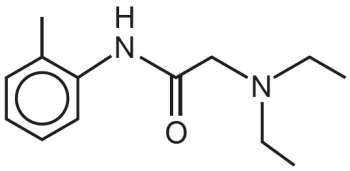
.....

..... **[1]**

There were some good clear answers here, but also some which missed the point of refluxing.

Question 35 (f)

(f) The skeletal formula for another local anaesthetic, lidocaine, is shown below.



lidocaine

Draw the skeletal formulae of the two products formed from the alkaline hydrolysis of the amide group in lidocaine.

Product 1 **Product 2**

[2]

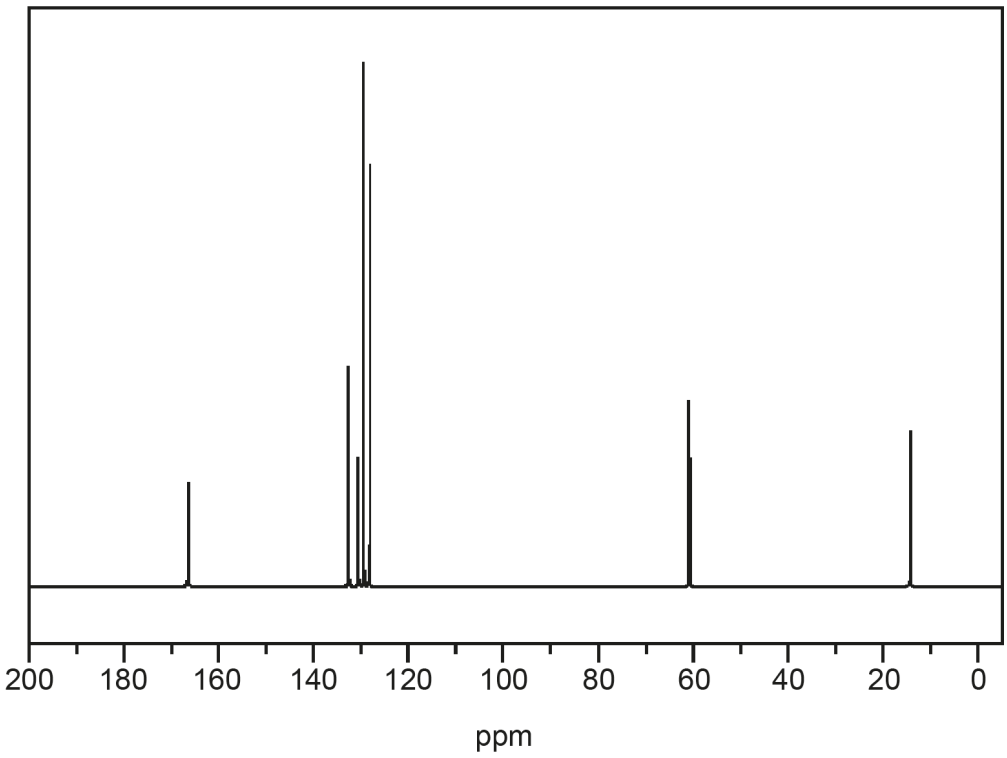
The most frequently seen mark was 2 here, other answers may have given the carboxylic acid group instead of the anion due to alkaline conditions.

Question 35 (g)*

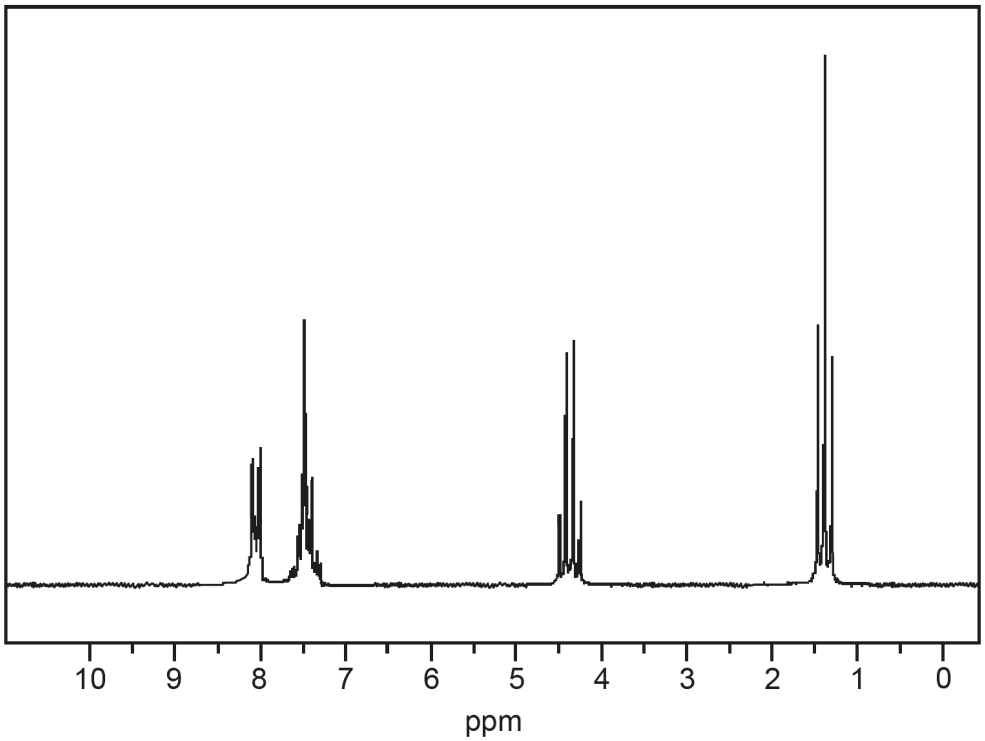
(g)* A molecule of another aromatic compound **H** is found to contain 72.0% carbon, 6.67% hydrogen and 21.3% oxygen by mass.

The M_r of **H** is 150.

The ^{13}C NMR spectrum of **H** is shown below.



The ^{1}H NMR spectrum of **H** is shown below.



You may do working on this page but it will not be marked.

Use the data on page 34 to identify compound **H**.

Give evidence from the percentage composition and the two spectra.

.....

.....

.....

.....

.....

..... **[6]**

Many candidates were able to interpret the spectra peaks and determine through calculation the molecular formula of molecule H, however, their ability to then piece such evidence together proved problematic. The majority of candidates were unable to arrive at the correct structure for H. This discriminated well, and it was often only those who could understand and account for the significance of the H NMR splitting patterns that were able to experience greater success. The non-substitution of the benzene ring was not mentioned at all (based on C NMR).Many candidates simply listed the shifts and didn't use them to explain how the structure could be 'built' from this. Lots of workings on and around the spectra but not then included in space for answer.

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