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Examiners' report

CHEMISTRY B (SALTERS)

H433
For first teaching in 2015

H433/01 Summer 2018 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. 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 can be downloaded from OCR.

Paper H433/01 series overview

H433/01 is one of three examination components for the A Level examination for GCE Chemistry B Salters. This component covers knowledge and understanding across the full range of the specification in context-based questions, including structured and multiple choice questions. There are a certain proportion of extended answer questions, practical applications and questions requiring mathematical skills. To do well on this paper, candidates need to be able to apply their knowledge and understanding in a range of contexts, familiar and unfamiliar, practical and theoretical.

Chemical literacy is a greater feature of H433/02 and questions set in a practical context are a greater feature of paper H433/03.

Candidate Performance overview

Candidates who did well on this paper generally did the following:

- Read the question carefully so that they were able to make full use of the information in it and address its exact demands; for example the use of appropriate numbers of significant figures (36c), or correctly identifying products from acid or alkaline hydrolysis (32c(ii), 33a(i)).
- Were able to logically structure a description, such as a clear interpretation of spectroscopic evidence, building up to a correct structure or explanation of the steps involved in using chromatography to identify the products of protein hydrolysis, or use of electrode potential evidence (31g, 32d, 35e).
- Were able find and use numbers of moles when information was given in a variety of units such as tonnes and kilograms (31a, 36f(ii)).
- Could set out their calculations in a clear and logical way (31a, 31c, 34c, 35b, 35f(ii)).
- Could draw organic mechanisms in a clear way (31f).
- Were able to give practical details (33a(ii), 35a).

Candidates who did less well on this paper generally did the following.

- Found it difficult to apply their knowledge in unfamiliar situations (31d, 32c(ii), 33a(iii), 33b, 36f(ii)).
- Found it difficult to use moles in calculations.
- Found it difficult to structure arguments using data provided (31g, 34c, 36d).
- Found it difficult to balance half equations or give electron configurations (35c(i), 35d).
- Found it difficult to do multi-step calculations (34c).

This paper discriminated well with marks ranging from 7 to 104 with the expected distribution.50% of candidates scored 54 marks or above.

There are still some candidates who write on supplementary sheets instead of using the additional answer space in the question paper booklet.

There was evidence that a few candidates found it difficult to complete the paper as there were some with blanks in the last 2 parts of the last question. There were also occasional blanks in the multiple choice. It is important to follow the advice and not spend more than 40 minutes on the multiple choice section.

Section A overview

Multiple choice questions allow a wide range of topics to be tested. The intention is that the level of demand increases throughout the set.

Higher ability candidates scored over 20 marks in this section and had shown their working in the space next to the question.

Some answers were difficult to read, due to overwriting or B and D letter formation making them look similar. Candidates should be encouraged to write clearly and re-write the answer next to the box if they change their mind. In some instances, such as Q17 and 28-30, a number was written in the box instead of the letter. Credit was given if the answer matched the correct letter.

Most successfully answered questions	***Least successfully answered questions***
1, 4, 6, 7, 8, 11, 12, 14, 15, 16, 18, 23, 28, 30.	5, 10, 17, 20, 25, 26.

Question 1

1 Which equation represents a possible fusion reaction?

A ${}_1H + {}_1H \rightarrow {}_2H$

B ${}_1H + {}_3H \rightarrow {}_4He$

C ${}_1H + {}_1H \rightarrow {}_2He$

D ${}_1H + {}_2He \rightarrow {}_3Na$

Your answer ☐ **[1]**

This was generally well done, but B was a common incorrect response.

Question 2

2 Which solutions when mixed would give a solution of a salt?

A barium hydroxide and sulfuric acid

B lead nitrate and sulfuric acid

C silver nitrate and hydrochloric acid

D lithium hydroxide and hydrochloric acid

Your answer ☐ **[1]**

Slightly fewer than half the candidates scored here with incorrect responses covering all the possible answers, but A was seen most frequently.

Question 5

5 Which statement about a by-product of an industrial reaction is correct?

A It is formed in the same reaction as the product.

B It is formed when the reactants react in a different way.

C It is in the equation for the reaction.

D It is a minor reactant in the reaction.

Your answer ☐ **[1]**

This is a topic that candidates have found difficult on the previous occasions it has been asked. Response A was the most frequently seen incorrect answer.

Question 6

6 What is the volume of CO_2 (in dm^3) measured at RTP when 20 g $CaCO_3$ completely decompose?

A 0.20

B 2.4

C 4.8

D 24

Your answer ☐ **[1]**

It was good to see such a high proportion of correct answers here.

Question 8

8 Which formula has the correct systematic name?

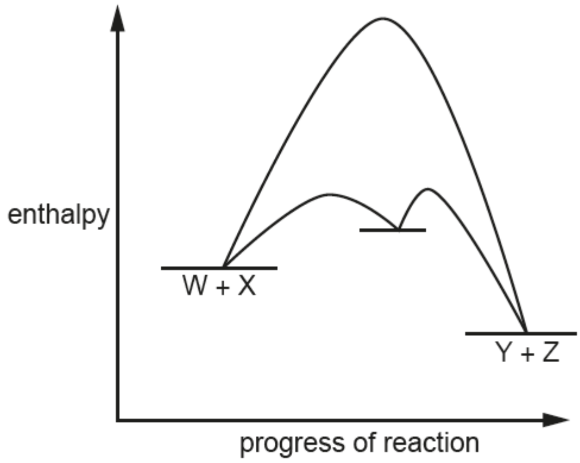
	Formula	Systematic name
A	Na_2SO_3	sodium sulfate(VI)
B	$NaClO_3$	sodium chlorate(III)
C	Cu_2S	copper(I) sulfide
D	$Pb(NO_3)_2$	lead(II) nitrate(III)

Your answer ☐ **[1]**

This was generally well done, but A and D were also frequently seen.

Question 9

9 The enthalpy profiles for the reaction W + X $\rightleftharpoons$ Y + Z are shown below, with and without a catalyst.



Which statement is correct?

A The catalyst increases the yield of Y.

B Increasing the temperature shifts the position of equilibrium to the products side.

C The catalyst does not take part in the reaction.

D The reverse reaction is speeded up by the catalyst.

Your answer ☐ **[1]**

C was a common incorrect answer here.

Question 10

10 The reaction below produces a chloroalkane.

$$R\text{–}OH + HCl \rightarrow R\text{–}Cl + H_2O$$

Which row shows the steps to purify the liquid product in the correct order?

A	Use a separating funnel	Distil	Dry	Remove unreacted HCl
B	Remove unreacted HCl	Use a separating funnel	Dry	Distil
C	Remove unreacted HCl	Use a separating funnel	Distil	Dry
D	Use a separating funnel	Remove unreacted HCl	Distil	Dry

Your answer ☐ **[1]**

This relates to a practical preparation that the candidates will likely have done, but C and D were very frequently seen.

Question 12

12 Colorimetry is used to find the concentration of an orange solution of iodine. Which statement is correct?

A The more concentrated the solution the more light is transmitted.

B A yellow coloured filter should be used.

C The absorbance of solutions of known concentration should be measured to get a calibration curve.

D Orange light is absorbed.

Your answer ☐ **[1]**

This practical technique was very well known.

Question 13

13 What is correct for the complex $[Fe(C_2O_4)_3]^{3-}$?

A The charge on each ligand is 2–.

B The co-ordination number of the metal ion is 3.

C The oxidation state of the iron is +2.

D The ligand is monodentate.

Your answer ☐ **[1]**

More than 50% of candidates scored this mark but B was a common incorrect answer.

Question 15

15 Which row is correct?

	Species	Protons	Neutrons in isotope	Electrons
A	F^-	9	10	11
B	Ne	10	10	10
C	Na^+	11	10	11
D	Mg^{2+}	14	10	12

Your answer ☐ **[1]**

This question was very well done.

Question 17

17 An unsaturated carboxylic acid has an M_r of 280.
70 g of the acid is saturated by 1.0 g of hydrogen.

How many C=C bonds are there in one molecule of the acid?

A 1

B 2

C 4

D 8

Your answer ☐ **[1]**

C was the most frequently seen answer as candidates did not use 2 as the molecular mass of hydrogen in calculating moles

Question 18

18 Sodium carbonate reacts with hydrochloric acid as shown in the equation.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$$

What mass (in grams) of Na_2CO_3 will react exactly with 50 cm^3 of 2.0 mol dm^{-3} HCl?

A 0.05

B 5.3

C 10.6

D 21.2

Your answer **[1]**

The majority of candidates scored here.

Question 19

19 Which compound will react with acidified potassium dichromate(VI)?

A $CH_3CH(OH)COOH$

B $(CH_3)_3COH$

C CH_3COOH

D CH_3COCH_3

Your answer **[1]**

More than half the candidates scored this mark. Option B, the tertiary alcohol, was the most frequently seen incorrect answer.

Question 20

20 Which statement is **not** correct about amines?

A The lone pair on the nitrogen allows them to act as nucleophiles.

B They react with carboxylic acids to form amides.

C They form hydrogen bonds with water.

D They accept protons from water molecules.

Your answer **[1]**

D was the most frequently seen incorrect answer.

Question 21

21 The methane concentration in the atmosphere has increased from 0.722 ppm in pre-industrial times to 1.80×10^{-4} % now.

What is the % increase in methane concentration?

A 40%

B 60%

C 67%

D 150%

Your answer [ ] **[1]**

Candidates did well on this quite difficult question. A was the most common incorrect answer, expressing 0.722 ppm as a percentage of 1.80×10^{-4}, rather than the % increase.

Question 24

24 Which statement about the Arrhenius equation is correct?

A A plot of ln *k* against *T* gives a straight line.

B When *T* is very large ln *k* almost equals ln *A*.

C E_a is the gradient of a plot of ln *k* against 1/*T*.

D A plot of *k* against 1/*T* gives a straight line.

Your answer [ ] **[1]**

Candidates were mostly confident enough to pick the correct answer here. A and C were the most frequently seen incorrect answers.

Question 25

25 Which molecule will **not** be made when water is eliminated from $CH_3CH_2C(CH_3)(OH)CH_2CH_2CH_3$?

A $CH_3C(CH_3)=CHCH_2CH_2CH_3$

B $CH_3CH=C(CH_3)CH_2CH_2CH_3$

C $CH_2=C(CH_2CH_3)CH_2CH_2CH_3$

D $CH_3CH_2C(CH_3)=CHCH_2CH_3$

Your answer [ ] **[1]**

Visualising the different ways this molecule could have water eliminated proved difficult for candidates. It was designed to be a high demand question.

Question 26

26 Which statement about a strong base at 298 k is correct?

A It is partially ionised.

B Its pH is given by pH = 14 + log[OH^-].

C It will not react with weak acids.

D It has the same pH as a weak base of the same concentration.

Your answer **[1]**

The unfamiliar way the pH of an alkali was expressed made this question difficult, but the other options are relatively easy to eliminate.

Question 27

27 Which row correctly shows the main products in electrolysis using graphite electrodes?

	Electrolyte	Product at the anode	Product at the cathode
A	$MgBr_2$(l)	bromine	magnesium
B	$CuSO_4$(aq)	oxygen	hydrogen
C	NaCl (aq)	chlorine	sodium
D	PbS(l)	hydrogen sulfide	lead

Your answer **[1]**

This is a new topic to the current specification and candidates found it relatively difficult.

Section B overview

Most candidates had clearly worked hard for this examination. In general energetics calculations and the extended response questions allowed them to show their knowledge.

They also understood chirality well and made sensible suggestions on green chemistry. They were less secure on hydrolysis of esters and proteins, equilibrium calculations and electrode potentials. Their knowledge on practical techniques was also not as detailed as it might be.

Question 31 (a)

31 Long chain alkanes can be cracked to provide better fuels and raw materials for the chemical industry. One such cracking reaction is shown in **equation 31.1**.

$$C_{12}H_{26} \rightarrow 2C_3H_6 + C_6H_{14}$$ **Equation 31.1**

(a) In a cracking reaction 1.50 tonnes of dodecane ($C_{12}H_{26}$) produce 478 kg of hexane (C_6H_{14}).

Calculate the percentage yield of the reaction in **equation 31.1**.

percentage yield = ... % **[3]**

It was good to see a number of completely correct responses, but also a significant number that had just used masses, not moles. Most were able to convert the units successfully.

Question 31 (b) (i)

(b) Some students want to investigate the usefulness of hexane as a fuel.

(i) Describe an experiment they could use to determine the enthalpy change of combustion of liquid hexane in the laboratory.

....

....

.... **[1]**

Question 31 (b) (ii)

(ii) Show how the result would be calculated from the measurements made when carrying out the experiment in part **(b)(i)**.

....

.... **[1]**

Question 31 (b) (iii)

(iii) Describe **two** ways in which the students could make the basic experiment more accurate.

1 ....

....

2 ....

.... **[2]**

In these questions we wanted the idea of heating water with hexane for the first part which was well done. In part (ii) however we wanted the idea of $E=mc\Delta T$ for the energy transferred and then dividing by the number of moles for ΔH, including how the moles would be calculated, which was often not included. In part (iii) there were many possible improvements to the experimental procedure that were acceptable, nevertheless unacceptable answers were quite often given as seen in Exemplar 1.

Exemplar 1

Measure the temperature rise of a known volume of water using a thermometer when a known amount of liquid fuel is burned. use $q=mc\Delta t$ to find energy for that many moles [1]

(ii) Show how the result would be calculated from the measurements made when carrying out the experiment in part **(b)(i)**.

$q=mc\Delta t$, calculate energy (in joules) divide by 1000 and divide by the moles of fuel burned to get enthalpy in $kJ\ mol^{-1}$ [1]

accurate.

1 Place the water in a calorimeter (polystyrene cup) to prevent heat loss

2 Use a digital thermometer to measure temperature change [2]

In this answer the candidate does not say how the number of moles of fuel would be calculated in part (ii) and they have chosen inappropriate suggestions for improvements; the idea of a polystyrene cup was frequently seen, as were more precise forms of equipment such as balances, digital thermometers or pipettes to measure water. Doing the experiment under standard conditions was also seen.

Question 31 (c)

(c) The students are given some enthalpy changes of formation and use them to check the accuracy of their answer.

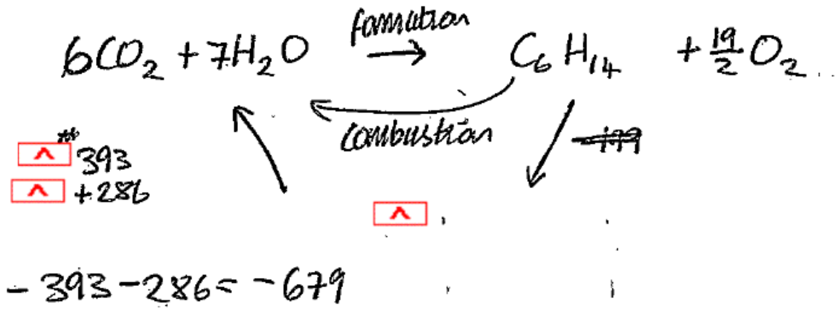
Calculate the standard enthalpy change of combustion of hexane from the data given.

Substance	$\Delta_f H^\ominus$ / kJ mol^{-1}
$CO_2(g)$	–393
$H_2O(l)$	–286
$C_6H_{14}(l)$	–199

$\Delta_c H^\ominus$ hexane = ...kJ mol^{-1} **[2]**

It was good to see so many perfectly correct answers here. Of those not getting full marks, the cycles were not clear enough to award 1 mark.

Exemplar 2



$\Delta_c H^\ominus$ hexane = ...-480.......... kJ mol^{-1} **[2]**

In this answer the value of -480 cannot be given 1 mark as the cycle is incomplete.

Question 31 (d)

(d) The propene produced in **equation 31.1** has many uses in the chemical industry.

Item removed due to third party copyright restrictions

Draw the **full** structural formula of the alcohol in the box below, giving your reasoning.

Reasoning ....

....

.... **[2]**

In this question there were some very good responses, but others lost marks through not thinking things through or not reading the question closely enough. Many got 2 carbon environments and then gave the structure as ethanol, forgetting that it had come from propene. Others gave propan-1-ol, neglecting the fact that there were only 2 carbon environments. A number omitted the H atom on the central C which shows the importance of checking drawn structures. Almost all the answers gave full structural formulae.

Question 31 (e)

(e) The alcohol from **(d)** can be oxidised to a carbonyl compound.

Give the reagents and conditions to carry out this oxidation.

Reagents ....

Conditions ....
[1]

In this question we wanted the reagents, so dichromate(VI) alone was insufficient. Sometimes the incorrect oxidation state was given. We wanted to see heat for the conditions and ignored reflux or distil as these would depend on which alcohol had been given in the previous part. A significant number of candidates lost the mark as a consequence of this. The number of candidates getting completely incorrect reagents were few.

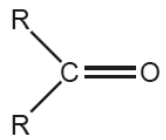
Question 31 (f)

(f) The carbonyl compound from **(e)** can be reacted further to produce other raw materials. For example, it reacts with HCN.

The formula of a carbonyl compound is shown below.

Give the mechanism for the reaction of this compound with cyanide ions followed by H^+. Show curly arrows, relevant dipoles and charges and give the formula of the product.

Name the type of reaction.



type of reaction .... **[4]**

It was clear that many candidates had revised this mechanism and gave very clear equations for it. Others did not include the dipoles, had arrows starting and finishing in vague places, had the initial attack by the nitrogen atom and a partial charge on the intermediate.

Question 31 (g) (part one)

(g)* Compound **A** has six carbon atoms and can be made from propene using several steps.

The infrared, proton NMR and mass spectra for compound **A** are shown.

Item removed due to third party copyright restrictions

Question 31 (g) (part two)

Use the information on page 18 to work out the structure of **compound A**.

Explain your reasoning, using evidence from each spectrum.

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Structure of compound **A**

[6]

A significant number of candidates gave a Level 3 answer and an impressive number had the structure completely correct. An even greater number knew it was an ester. Of the lower scoring candidates, the C-H absorbance was wrongly attributed to O-H, and there were also suggestions of arenes not borne out by the spectroscopic data or the fact that it can be made from propene.

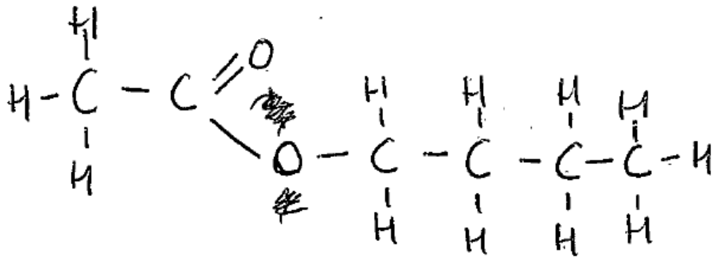
Exemplar 8

The IR shows no O-H peak due to the lack of a broad peak at 3000 but a less broad peak show C-H from alkanes are present.
The peak 1100 shows a C-O is present and at 1750 shows an ester C=O is present
The H'NMR peak at 4.0ppm shows there is 2 H on the adjacent carbon to the H-C-O of the ester, The multiplet HC-R suggests a ~~meth~~ CH_3 at the end of chain and CH_2 along side with the different shift show the different Hydrogen environment. The Quartet peak at 2.5ppm shows 3 Hydrogen on the carbon adjacent to the ~~CH~~ C=O meaning it is ~~en~~ a methyl at the the ester group.

L2

The Mass spec gives the Mr of 116 which when 6 carbons are known each have 12 Hydrogen an 2 oxygens present.

Structure of compound **A**



[6]

This candidate has correctly identified all the absorbances on the infra-red spectrum and did not confuse the C-H absorbance with O-H as some did. They have used the molecular ion peak on the mass spectrum with other data to get the molecular formula, although they have not considered the fragments. They have correctly identified the chemical shifts of protons next to the ester group and made an attempt at interpreting the splitting. They have deduced the structure is that of an ester, but they have not quite used the splitting pattern and the fact that it could be made from propene to get the correct ester. This response was therefore judged to be at Level 2, and credited 4 marks.

Question 32 (a)

32 Enzymes catalyse the breakdown of protein molecules in the digestive system. The tertiary structure of enzymes enables the substrate to bind to them.

(a) State the meaning of the term tertiary structure of a protein.

....

.... **[1]**

This was well done by the vast majority of candidates.

Question 32 (b)

(b) Give **two** ways a substrate can bind to an enzyme.

1 ....

2 ....

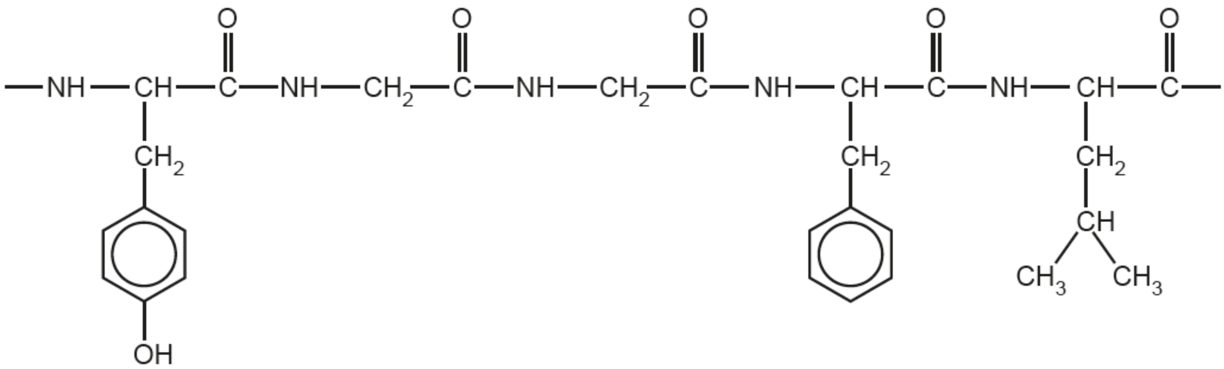
[1]

There were some answers that used 'lock and key theory', rather than naming the actual bonds between enzyme and substrate.

Question 32 (c) (i)

(c) Some students hydrolyse a protein in the laboratory by refluxing it with moderately concentrated hydrochloric acid.

(i) Circle **all** the chiral centres in the section of protein shown below. **[1]**



This was well done. Occasionally extra carbons were circled or incorrect ones such as the C=O groups.

Question 32 (c) (ii)

(ii) Give the organic products of the complete hydrolysis of this protein section with hydrochloric acid.

[4]

The things required here were: knowing how a protein is hydrolysed, getting the correct structures of the products, and modifying them appropriately to account for the acidic conditions. There were a number of perfect answers with all the NH_2 groups protonated and quite a few who lost one mark because they were not. Others lost all the marks because they had acid chlorides, aldehydes or other incorrect functional groups in the products.

Question 32 (d)

(d)* The students use paper chromatography to confirm that the products of hydrolysis are those in part **(c)(ii)**.

Describe how the students would **develop** and **analyse** the chromatogram to identify the products of hydrolysis.

You may include a diagram in your answer.

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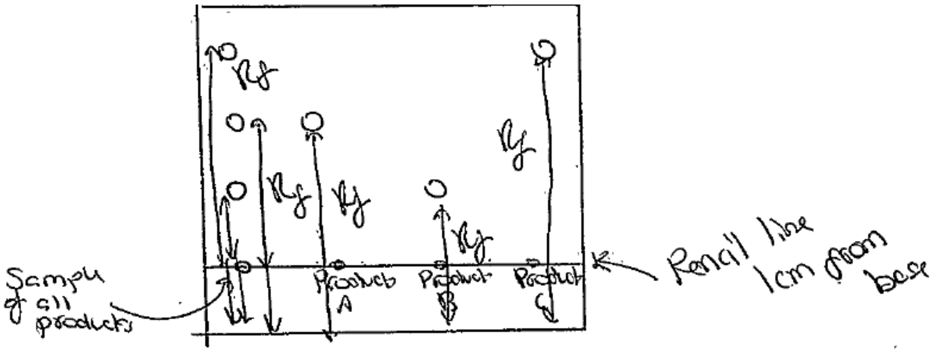
.... **[6]**

This was an experiment that candidates knew well and could describe logically. Many realised the advantages of annotated diagrams, both for setting up the experiment and calculating R_f values. In some cases, the incorrect or no locating agent was given. 'Iodine crystals' was a frequent incorrect answer. Some did not fully explain what R_f was and how it could be calculated, and others called it 'retention factor'.

Exemplar 9



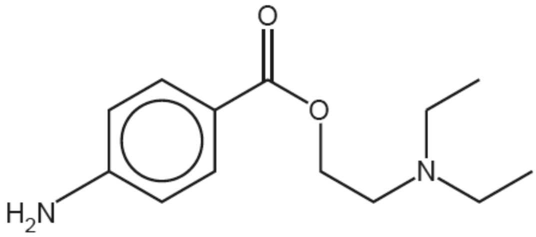
L2

A sample from the reaction containing all 3 products should be dotted onto the baseline, (drawn in pencil, 1cm from bottom of paper). Then a pure sample of each of the 3 products should be dotted onto the paper on the baseline. A suitable solvent should be chosen and placed in a beaker so it won't submerge the paper above the pencil line. The paper can then be placed in the beaker, and a lid must be placed on the becker to ensure the solvent does not evaporate. Once the solvent front nears the top of the paper, the paper can be removed and sprayed with Iodine vapour to reveal the dots. Rf values can then be measured by dividing the distance of the dot from the bottom of the paper by the height of the paper. Compare Rf values to identify the different products of hydrolysis. **[6]**

In this answer the candidate has given a good account of how to get the chromatogram, but the position of the solvent front is not marked. The developing section uses the incorrect locating agent, iodine, rather than ninhydrin and does not mention drying the chromatogram. The analysis section makes some points but is vague about how to calculate R_f values and what to compare them to. Overall we thought this was a Level 2 answer but the explanations did not include sufficient detail to give more than 3 marks. This candidate has included a diagram in the answer and it is possible to credit points made on a labelled diagram. Unfortunately in this case the detail on calculating R_f was absent here too.

Question 33 (a) (i)

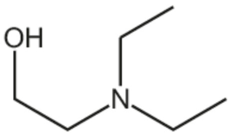
33 Procaine has been used as an anaesthetic in dentistry.

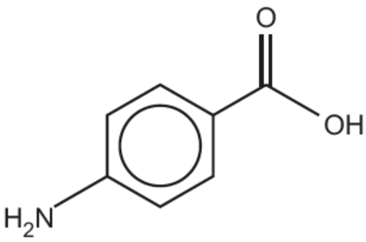


Procaine

Some students reacted procaine with various reagents to see if they could make other useful substances from it.

They hydrolysed procaine, producing a solution containing compound **B** and the **sodium salt** of compound **C**.





	compound B	**compound C**
State at room temperature:	liquid	solid

(a) **(i)** Suggest the reagent and conditions the students used for the hydrolysis.

.... **[1]**

Fewer than half the candidates scored here as they chose acid hydrolysis despite the sodium salt of C being formed. There were also quite a few instances of water as the reagent.

Question 33 (a) (ii)

(ii) Suggest how the students could obtain a sample of compound **C** from the solution they obtained.

....

....

....

.... **[2]**

Filtration was frequently seen, but acidification was much rarer. Distillation was a popular answer.

Question 33 (a) (iii)

(iii) The students reacted procaine with ethanoyl chloride.

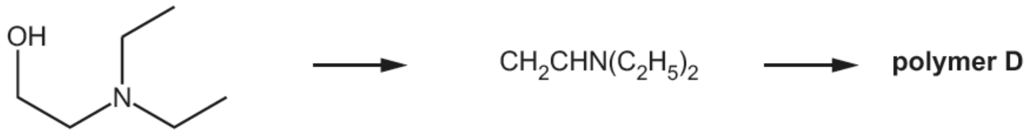
Give the formula of the organic product formed.

[1]

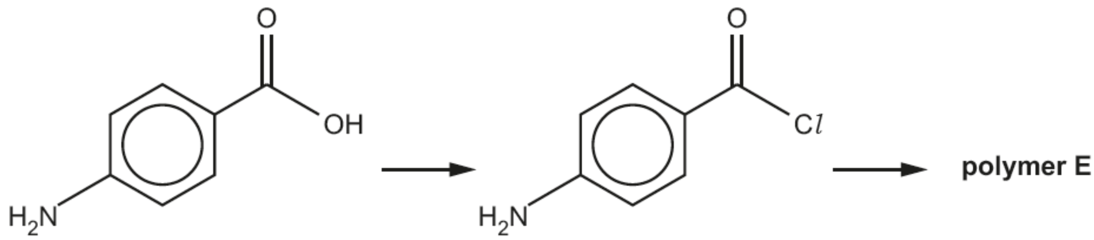
A significant number of candidates omitted this question as they found it difficult to apply their knowledge of simpler amines reacting with acid chlorides to this example.

Question 33 (b)

(b) Compounds **B** and **C** can be turned into monomers for polymerisation reactions.

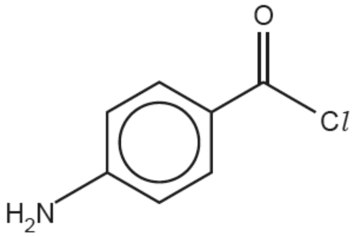


compound B



compound C

Give the structural formula for the repeat units of polymers **D** and **E** and give the **type** of polymerisation occurring in each case.

Monomer	Repeat unit of the polymer	Type of polymerisation
$CH_2CHN(C_2H_5)_2$	**Polymer D**	
	**Polymer E**	

[2]

The type of polymerisation was often correct, but candidates often struggled to give correct repeat units. Joining polymer **D** from the nitrogen or even retaining the double bond were both seen. For polymer **E** 2 repeat units were sometimes given.

Question 34 (a)

34 The use of cars can affect the concentration of ozone in the troposphere. Tropospheric ozone causes respiratory problems and photochemical smog.

Tropospheric ozone is formed in a series of reactions involving carbon monoxide, oxides of nitrogen and volatile organic compounds, all of which are present in exhaust emissions.

(a) NO is a radical.

Draw a '*dot-and-cross*' diagram of NO and explain why it is called a radical.
Show outer electron shells only.

....

.... **[1]**

Marks were mostly lost due to incorrect dot and cross diagrams in this question, especially those with the unpaired electron on the oxygen.

Question 34 (b) (i)

(b) A series of reactions producing ozone from carbon monoxide, hydroxyl radicals and NO are shown in **equations 34.1 – 34.5** below.

$OH + CO \rightarrow HOCO$ **Equation 34.1**

$HOCO + O_2 \rightarrow HO_2 + CO_2$ **Equation 34.2**

$HO_2 + NO \rightarrow OH + NO_2$ **Equation 34.3**

$NO_2 + hv \rightarrow NO + O$ **Equation 34.4**

$O + O_2 \rightarrow O_3$ **Equation 34.5**

(i) Explain why the reaction in **equation 34.3** is classed as a propagation step.

....

.... **[1]**

This questions was well answered.

Question 34 (b) (ii)

(ii) Write in the box the overall equation for the reaction sequence in **equations 34.1 – 34.5**.

[1]

This was well answered by the majority, although a few had extra species on both sides of the equation. A few guessed it was $O + O_3 \rightarrow 2O_2$

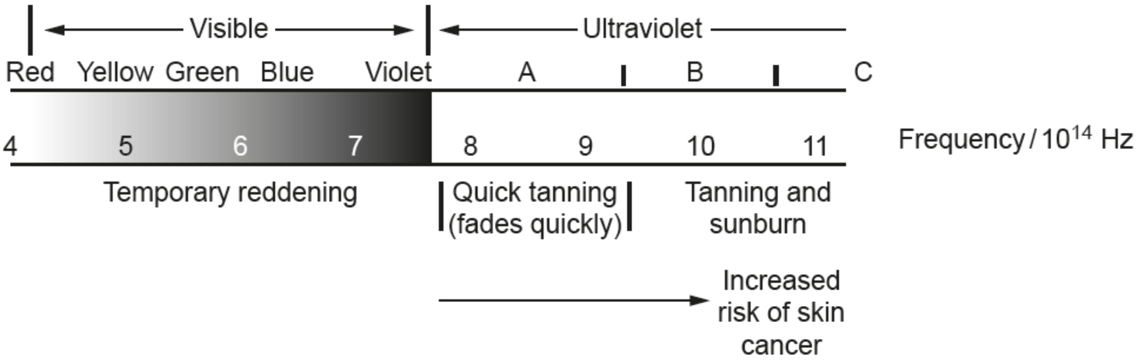
Question 34 (c)

(c) Years ago, the air conditioning in cars used CFC-12, CCl_2F_2.

CFC-12 absorbs some UV radiation when it breaks down.

The most harmful UV radiation from the Sun that causes damage to cells is in the range 10.1×10^{14} to 14.0×10^{14} Hz. Ozone in the stratosphere absorbs radiation in this range.

The diagram below shows the effects of different frequencies of UV on human skin.



Carry out some calculations, using the bond enthalpies below, and comment on the ability of CFC-12 to remove harmful UV when it breaks down.

Bond	Bond enthalpy / $kJ\,mol^{-1}$
C–Cl	+346
C–F	+467

....

....

....

.... **[3]**

This question proved challenging for many candidates and although there were some excellently, clear and logical answers there were others who struggled. A common misconception was that all 4 bond enthalpies were added up before performing the calculation. If this was the case, 1 mark was credited for a successful conversion of enthalpy to frequency. The comments were often unclear.

Exemplar 3

Bond	Bond enthalpy / kJ mol^{-1}
C–Cl	+346
C–F	+467

$E = h\nu$

~~346 6·63×10^-34~~

$10{\cdot}1\times10^{14} \times 6{\cdot}63\times10^{-34} = 6{\cdot}7\times10^{-20}$ kJ.

403 kJ mol^{-1}

The least ~~most~~ dangerous UV at $10{\cdot}1\times10^{14}$ won't break the C–F bond but will break the C–Cl bond. However the most lethal UV **[3]** will break both bond meaning not all the UV will be stopped.

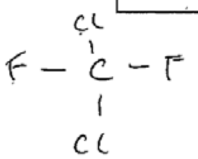
This is an example of an acceptable alternative approach. The candidate has converted one end of the range of harmful UV radiation to a bond enthalpy and compared it with the bond enthalpies in CFC-12.

Exemplar 4

Bond	Bond enthalpy / kJ mol^{-1}
C–Cl	+346
C–F	+467

$c = \lambda\nu$

$E = hf$



Cl–C ×2 = 692 kJ mol^{-1}

C–F ×2 = 934 kJ mol^{-1}

C–F → $\frac{934000}{6{\cdot}02\times10^{23}} \div 6{\cdot}63\times10^{-34} = 2{\cdot}34\times10^{15}$ Hz $= 23{\cdot}4\times10^{14}$

Cl–C → $\frac{692000}{6{\cdot}02\times10^{23}} \div 6{\cdot}63\times10^{-34} = 1{\cdot}73\times10^{15}$ Hz $= 17{\cdot}3\times10^{14}$ Hz ECF

CFC-12 ~~can~~ breaks down with frequency greater than 14×10^{14} Hz, ∴ will not remove this radiation **[3]**

This is an example where bond enthalpies have been added and the calculation is worth 1 mark.

Question 35 (a)

35 A company was investigating the corrosion of metal parts used in oil rigs in the North Sea.

Chemists took two identical bolts. One was unused and the other had been exposed to the seawater for several weeks. They reacted each bolt with dilute sulfuric acid. All the unreacted iron was converted to Fe^{2+}(aq) ions and the rust reacted to form Fe^{3+}(aq).

(a) Describe how the chemists would dissolve one bolt and make the solution up to 1.00 dm^3.

....

....

....

.... **[2]**

This was a question that proved one of the most difficult, both in terms of low scores and omission rates. The ideas we were looking for were practical points on how to dissolve the bolt. The first was dissolving the bolt, many candidates selected a solvent other than sulfuric acid despite it being given in the stem of the question, some even chose water. Very few realised that heat would be needed. The second point was making the solution up to 1 dm^3. We expected the use of a volumetric flask here and making up to the line.

Question 35 (b)

(b) The chemists then titrated 10.0 cm^3 portions of their solutions with a solution of 0.200 mol dm^{-3} potassium manganate(VII).

The MnO_4^- ions oxidise the Fe^{2+} to Fe^{3+} and the Fe^{3+} ions do not react.
The equation for the reaction is given below.

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Use the titration results below to find the mass of the bolt that had rusted away.

Type of bolt	**Average volume of 0.200 mol dm^{-3} $KMnO_4$ used in the titration / cm^3**
Unused bolt	17.92
Rusted bolt	9.75

mass of bolt that had rusted away = ... g **[3]**

Most candidates were able to score some of the marks here. The most frequently scored was the multiplication of the moles of MnO_4^- by 5. Other marks were lost because the final answer was not multiplied by 100 (to account for the fact that 10cm^3 portions were titrated), or the difference between the titration results was not used. Sometimes 2 calculations were done with the subtraction as the final step – this was an acceptable alternative route.

Exemplar 5

Type of bolt	**Average volume of 0.200 mol dm^{-3} $KMnO_4$ used in the titration / cm^3**
Unused bolt	17.92
Rusted bolt	9.75

$\frac{9.75}{1000} \times 0.2 = 1.95 \times 10^{-3}$ moles $KMnO_4$ (rusted)

$\times 5 = 9.75 \times 10^{-3}$ moles Fe $\times 55.8 = 0.54405$ g

$\frac{17.92}{1000} \times 0.2 = 3.584 \times 10^{-3}$ moles $KMnO_4$ (unused bolt)

$\times 5 = 0.01792 \times 55.8 = 0.999...$ (1)

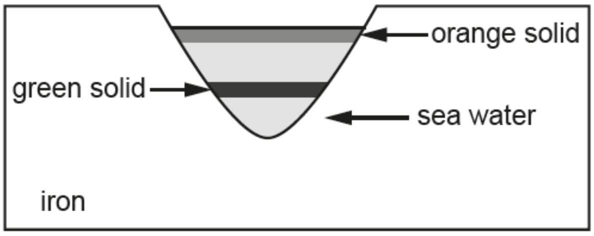
$1 - 0.54405 = \cancel{0.4526}\ 0.4559$

mass of bolt that had rusted away = ...0.4559...... g **[3]**

This is an example where the subtraction has been done at the end. The final mark is not scored as the mass has not been scaled up to 1dm^3.

Question 35 (c) (i)

(c) The iron rusted in small dips in the surface. The chemists noticed a green solid that turned orange at the surface of the water.



(i) Give the half-equations for the processes occurring during the rusting.

[2]

The process of rusting was not well known, and d block chemistry in general proved challenging. Sometimes correct half equations were contradicted by extra ones.

Question 35 (c) (ii)

(ii) What are the **formulae** of the green and orange solids?

Green solid ....

Orange solid .... **[1]**

This was well answered and we accepted the formulae of iron(III) oxide or hydroxide for the orange solid.

Question 35 (c) (iii)

(iii) Suggest why rusting takes place faster in seawater than in rainwater.

....

.... **[1]**

Very few candidates knew the answer to this. A few had memorised the definition provided in text books..

Question 35 (d)

(d) Give the electron configuration of the Fe^{2+} ion.

.... **[1]**

More than half of the candidates scored here. The main reason for not getting the mark was ending the electron configuration with $4s^2$, $3d^4$. There were a significant number with the numbers as subscripts.

Question 35 (e)

The chemists investigated making the bolts from a nickel-copper alloy that has high strength and resistance to corrosion.

They reacted the alloy with sulfuric acid and filtered off the unreacted solid, which they found was copper.

(e) Use the electrode potentials in the table below to explain why only the nickel reacts.

Half reaction	$E^{\ominus}$/V
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	– 0.25
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+ 0.34

....

....

....

....

.... **[2]**

This was a difficult question. Many answers compared the electrode potentials of nickel and copper with each other rather than with hydrogen. They also answered in terms of Cu^{2+} ions being reduced, when the point of the exercise is that there are none.

Exemplar 6

Nickle only reacts Because ~~the~~ the Ni/Ni^{2+} has a ~~more~~ more negative $E^{\ominus}$ than $2H^+/H_2$ So is oxidised because electrons flow from negative to positive **[2]**

This is an example has a very clear explanation of why nickel reacts but has not mentioned copper.

Exemplar 7

Half reaction	$E^\ominus$/V
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	– 0.25
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+ 0.34

Cu^{2+}/Cu half cell is more positive than the Ni^{2+}/Ni half cell. This means Cu^{2+} is reduced to Cu and Ni oxidised to Ni^{2+}. ~~Ni^{2+} can react~~ Ni^{2+} can react with H_2SO_4 more. **[2]**

This is an example where neither of the metal electrode potentials has been compared with the hydrogen half-cell.

Question 35 (f) (i)

(f) The solution they obtained was green due to $[Ni(H_2O)_6]^{2+}$. The chemists added some $EDTA^{4-}$ solution and the colour changed to blue. $EDTA^{4-}$ is a polydentate ligand.

(i) Suggest why the colour changes as the $EDTA^{4-}$ is added and name the type of reaction taking place.

....

....

.... **[1]**

Most candidates knew this was ligand substitution, but the explanations were less clear. Some thought the blue was due to Cu^{2+}.

Question 35 (f) (ii)

(ii) In a separate experiment, 25.0 cm^3 of a 0.250 $mol\,dm^{-3}$ $[Ni(H_2O)_6]^{2+}$ solution is found to react exactly with 41.7 cm^3 of 0.150 $mol\,dm^{-3}$ $EDTA^{4-}$ solution.

Calculate the formula of the complex ion that nickel forms with $EDTA^{4-}$.

formula of the complex ion = ... **[2]**

The majority of candidates scored at least 1 mark on this question for getting the mole ratios as 1:1. The second mark may not have been scored due to extra water ligands in the final complex, incorrect charges or an incorrect number of EDTA ligands despite the 1:1 ratio having been calculated.

Question 36 (b) (i)

(b) The hydrogen needed to manufacture ammonia can be produced from steam and methane as shown in **equation 36.1** below.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206\,kJ\,mol^{-1}$$ **Equation 36.1**

(i) Use the entropy values in the table below to calculate $\Delta_{sys}S$ for the forward reaction in **equation 36.1**.

Substance	**Entropy S / $J\,K^{-1}\,mol^{-1}$**
$CH_4(g)$	186.2
$H_2O(g)$	189.0
$CO(g)$	197.6
$H_2(g)$	130.6

$\Delta_{sys}S$ = ... $J\,K^{-1}\,mol^{-1}$ **[1]**

Quite a few candidates lost the mark as they omitted the sign.

Question 36 (b) (ii)

(ii) Explain how the sign of your answer to **(i)** is predicted by **equation 36.1**.

....

....

.... **[1]**

The answer was simply the number of moles on each side of the equation. Some candidates commented on feasibility of reaction.

Question 36 (c)

(c) Calculate the minimum temperature required for the forward reaction in **equation 36.1** to be feasible.

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

temperature = ... K **[2]**

The ability to answer this type of question has greatly improved over the years and teachers are to be congratulated on it. Marks were lost due to an incorrect number of significant figures in some cases.

Question 36 (d)

(d) $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206\,kJ\,mol^{-1}$ **Equation 36.1**

Another source of hydrogen is from the reaction shown in **equation 36.2**.

$CH_4(g) + CO_2(g) \rightleftharpoons 2CO(g) + 2H_2(g) \quad \Delta H = +247\,kJ\,mol^{-1}$ **Equation 36.2**

This is claimed to be a much greener process than that in **equation 36.1**.

Comment on the validity of this statement, considering:

- the raw materials used
- the operating conditions
- the mole ratios.

....

....

....

....

....

.... **[3]**

There were some very good answers, but others were vague and concentrated on the wrong things. Many identified the advantage of using CO_2 as a raw material but did not say why or used vague terms such as 'pollutant'. A lot focused on the CO produced, rather than the moles of hydrogen produced or atom economy.

Question 36 (e)

(e) The Haber process for the manufacture of ammonia is shown in **equation 36.3**.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\,kJ\,mol^{-1}$$ **Equation 36.3**

At a certain temperature, a mixture of nitrogen and hydrogen was allowed to reach equilibrium in a container of fixed volume. Chemists found the concentrations shown in the table.

Substance	Concentration at the start / $mol\,dm^{-3}$	Concentration at equilibrium / $mol\,dm^{-3}$
N_2	1.00	0.90
H_2	1.00	
NH_3	0.00	

Calculate the equilibrium concentrations of H_2 and NH_3.
Use these values to calculate a value for K_c at the temperature of the experiment and give the units.

K_c = ... units ....**[3]**

There were a large number of perfectly correct answers here. Others were not able to get the correct equilibrium concentrations but were able to use their values to find a value for K_c.

Question 36 (f) (i)

(f) In order to make the ammonium nitrate fertiliser, some of the ammonia is oxidised to nitric acid in several stages shown by **equations 36.4–36.6**.

$.......NH_3 + ...O_2 \rightarrow ....NO + ...H_2O$ **Equation 36.4**

$2NO + O_2 \rightarrow 2NO_2$ **Equation 36.5**

$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ **Equation 36.6**

The nitric acid formed is reacted with more ammonia.

$NH_3 + HNO_3 \rightarrow NH_4NO_3$ **Equation 36.7**

(i) Use oxidation states or some other method to balance **equation 36.4**. **[1]**

Question 36 (f) (ii)

(ii) The overall yield of the reactions **in equations 36.4 – 36.6** is 77%.
The yield of ammonium nitrate in **equation 36.7** can be taken as 100%.

What mass (in tonnes) of ammonia is needed to make 25 tonnes of ammonium nitrate?

mass of ammonia needed = ...tonnes **[4]**

This was designed to be a high demand question and relatively few scored the full 4 marks. However, there were scores of 1-3 on many occasions. The first mark was relatively easy, but to get the correct number of moles of ammonium nitrate the tonnes had to be converted to grams and this was not always done.

Question 36 (f) (iii)

(iii) Describe a test that would identify nitrate ions.

....

....

.... **[2]**

There were instances where candidates had simply forgotten this factual information. In other cases, marks were lost for omitting one of the reagents or not heating. Sometimes the colour change of the litmus paper was the incorrect way round.

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