National
Qualifications
SPECIMEN ONLY

S813/77/02

Chemistry
Section 1 — Questions

Date — Not applicable

Duration — 3 hours

Instructions for the completion of Section 1 are given on *page 02* of your question and answer booklet S813/77/01.

Record your answers on the answer grid on *page 03* of your question and answer booklet.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

S8137702

SECTION 1 — 25 marks

Attempt ALL questions

1. The energy associated with a photon of electromagnetic radiation is

A independent of the frequency

B proportional to the frequency

C inversely proportional to the frequency

D proportional to the square of the frequency.

2. An element X forms an ion, X^{3+}, which contains 55 electrons.

In which block of the periodic table would element X be found?

A s

B p

C d

D f

3. Which of the following lines in the table shows the quantum numbers for an outer electron in an atom of chlorine in its ground state?

	n	l	m_l	m_s
A	2	0	0	$+\frac{1}{2}$
B	2	1	1	$-\frac{1}{2}$
C	3	0	0	$+\frac{1}{2}$
D	3	1	1	$-\frac{1}{2}$

4. The following diagram represents a square-planar structure.

Where  and  represent bonding electron pairs

and  represents a non-bonding electron pair (lone pair).

Which of the following species could have the structure shown above?

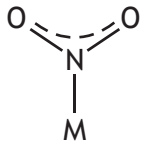
A SF_4

B NH_4^+

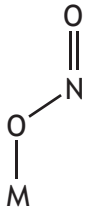
C XeF_4

D AlH_4^-

5. The nitrite ion, NO_2^-, can bind to transition metal ions, M^{3+}, in two different ways as shown.

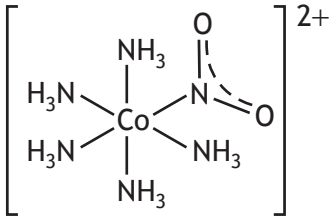


ligand name - nitro



ligand name - nitrito

Which line in the table is correct for the complex shown?



	Name	Formula
A	pentaamminenitrocobalt(III)	$[Co(NH_3)_5(NO_2)]^{2+}$
B	pentaamminenitritocobalt(III)	$[Co(NH_3)_5(ONO)]^{2+}$
C	nitropentaamminecobalt(III)	$[Co(NO_2)(NH_3)_5]^{2+}$
D	nitritopentaaminecobalt(III)	$[Co(ONO)(NH_3)_5]^{2+}$

6. The reaction

$$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$$

has an equilibrium constant of 3·9 at 950 °C.

The equilibrium concentrations of CO(g), $H_2(g)$ and $H_2O(g)$ at 950 °C are given in the table.

Substance	Equilibrium concentration (mol l^{-1})
CO(g)	$5{\cdot}0 \times 10^{-2}$
$H_2(g)$	$1{\cdot}0 \times 10^{-2}$
$H_2O(g)$	$4{\cdot}0 \times 10^{-3}$

What is the equilibrium concentration of $CH_4(g)$, in mol l^{-1}, at 950 °C?

A $4{\cdot}9 \times 10^{-1}$

B $3{\cdot}1 \times 10^{-5}$

C $4{\cdot}9 \times 10^{-5}$

D $2{\cdot}0 \times 10^{-7}$

7. Which of the following decreases when an aqueous solution of ethanoic acid is diluted?

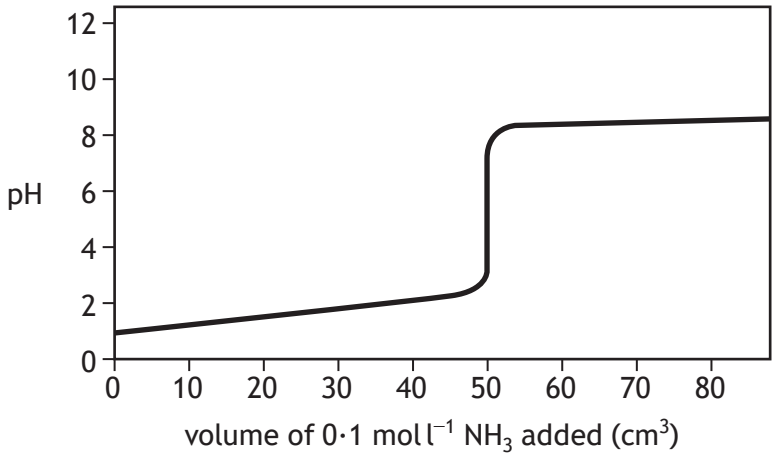
A pH

B $[H^+]$

C pK_a

D K_a

8. The graph below shows the pH changes when 0·1 mol l^{-1} ammonia solution is added to 50 cm^3 of 0·1 mol l^{-1} hydrochloric acid solution.



Which of the following indicators is **not** suitable for use in determining the equivalence point of the above reaction?

A Phenolphthalein

B Methyl orange

C Bromothymol blue

D Bromocresol purple

9. Which of the following statements is not true?

A 0·1 mol l^{-1} hydrochloric acid has a hydrogen ion concentration of 0·1 mol l^{-1}.

B 20·0 cm^3 of 0·1 mol l^{-1} sodium hydroxide is exactly neutralised by 20·0 cm^3 of 0·1 mol l^{-1} ethanoic acid.

C The pH of 0·1 mol l^{-1} hydrochloric acid is lower than that of 0·1 mol l^{-1} ethanoic acid.

D The K_a value for ethanoic acid is greater than that of hydrochloric acid.

10. The standard enthalpy of formation of strontium chloride is the enthalpy change for

A $Sr(s) + 2Cl(g) \rightarrow SrCl_2(s)$

B $Sr(s) + Cl_2(g) \rightarrow SrCl_2(s)$

C $Sr^{2+}(g) + 2Cl^{-}(g) \rightarrow SrCl_2(s)$

D $Sr^{2+}(aq) + 2Cl^{-}(aq) \rightarrow SrCl_2(s)$.

11. Which of the following alcohols would have the greatest entropy at 90 °C?

A Propan-1-ol

B Butan-1-ol

C Propan-2-ol

D Butan-2-ol

12. For any liquid, $\Delta S_{\text{vaporisation}} = \dfrac{\Delta H_{\text{vaporisation}}}{T_b}$

where T_b is the boiling point of that liquid.

For many liquids, $\Delta S_{\text{vaporisation}} = 88\ \text{J K}^{-1}\,\text{mol}^{-1}$.

Assuming this value is true for water and its $\Delta H_{\text{vaporisation}} = 40{\cdot}6\ \text{kJ mol}^{-1}$, then the boiling point of water is calculated as

A 461 K

B 373 K

C 2·17 K

D 0·46 K.

13. The order of a reactant in a reaction

A can only be obtained by experiment

B determines the speed of the overall reaction

C is determined by the stoichiometry involved

D is the sequence of steps in the reaction mechanism.

[Turn over

14. A suggested mechanism for the reaction

$2X + Y \rightarrow X_2Y$

is a two-step process

$X + Y \rightarrow XY$ (slow)

$XY + X \rightarrow X_2Y$ (fast)

Which of the following rate equations is consistent with this mechanism?

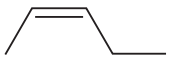
A Rate = $k[XY]$

B Rate = $k[X][Y]$

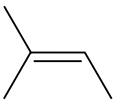
C Rate = $k[X]^2[Y]$

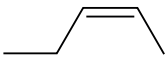
D Rate = $k[X][XY]$

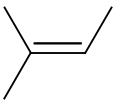
15.

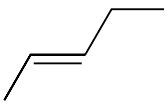


The trans isomer of the molecule represented above is

A 

B 

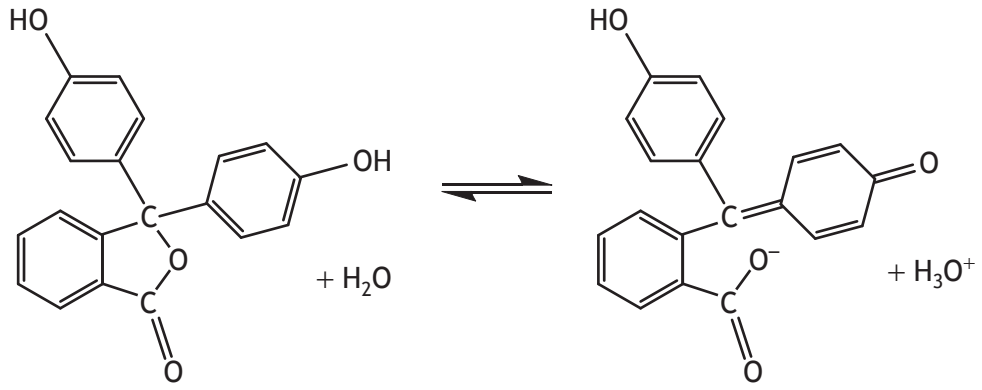
C 

D 

16. Which line in the table is correct for a molecule of ethyne?

	Hybridisation	Number of σ bonds	Number of π bonds
A	sp^2	2	3
B	sp^2	3	2
C	sp	2	3
D	sp	3	2

17.



colourless pink

Which line of the table is correct for the colourless form of the indicator solution above?

	Degree of conjugation	Explanation of colour
A	less than pink form	absorbs UV
B	more than pink form	emits UV
C	more than pink form	absorbs blue-green
D	less than pink form	no light absorbed

18. Which of the following has nucleophilic properties?

A Na

B Br^+

C CH_3^+

D NH_3

19. Which of the following compounds will react with both dilute hydrochloric acid and sodium hydroxide solution?

A C_6H_5OH

B $C_6H_5NH_2$

C HOC_6H_4COOH

D $H_2NC_6H_4COOH$

20. Which of the following is a tertiary haloalkane?

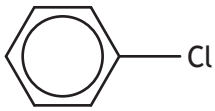
A $CHCl_3$

B $(CH_3)_3CCl$

C $(CH_2Cl)_3CH$

D $(CH_3)_3CCH_2Cl$

21.

Molecule	Structure
P	
Q	$CH_2{=}CHCl$
R	$CH_2{=}CHCH_2Cl$

Which of the above molecules is/are planar?

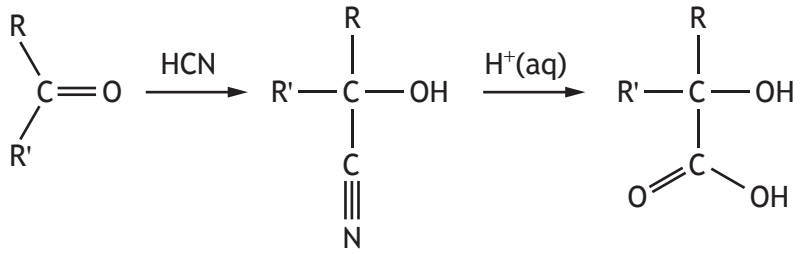
A P only

B Q and R only

C P and Q only

D P, Q and R

22. Carbonyl groups in aldehydes and ketones react with HCN and the product can then be hydrolysed forming a 2-hydroxycarboxylic acid as shown.



When the final product is 2-hydroxy-2-methylbutanoic acid, the starting carbonyl compound is

A butanal

B butanone

C propanol

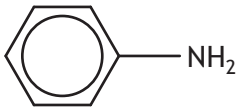
D propanone.

23. Which of the following amines shows no infrared absorption between 3300 cm^{-1} and 3500 cm^{-1}?

A $(CH_3)_3N$

B CH_3NHCH_3

C $H_2NCH_2NH_2$

D 

24. Sirolimus is a drug used in organ transplants. It works by binding to an enzyme and stopping the patient's immune system from rejecting the transplanted organ.

Sirolimus is acting as

A an agonist

B an antagonist

C an inhibitor

D a receptor.

[Turn over

25. What volume of 0·2 mol l^{-1} potassium sulfate is required to make, by dilution with water, one litre of a solution with a potassium ion concentration of 0·1 mol l^{-1}?

A 500 cm^3

B 400 cm^3

C 250 cm^3

D 100 cm^3

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET.]

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Mark

S813/77/01

Chemistry
Section 1 — Answer grid and Section 2

Date — Not applicable

Duration — 3 hours

S8137701

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

Total marks — 110

SECTION 1 — 25 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *page 02*.

SECTION 2 — 85 marks

Attempt ALL questions.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

S8137701 01

SECTION 1 — 25 marks

The questions for Section 1 are contained in the question paper S813/77/02.

Read these and record your answers on the answer grid on *page 03* opposite.

Use **blue** or **black** ink. Do NOT use gel pens or pencil.

1. The answer to each question is **either** A, B, C or D. Decide what your answer is, then fill in the appropriate bubble (see sample question below).

2. There is **only one correct** answer to each question.

3. Any rough working should be done on the additional space for answers and rough work at the end of this booklet.

Sample question

To show that the ink in a ball-pen consists of a mixture of dyes, the method of separation would be

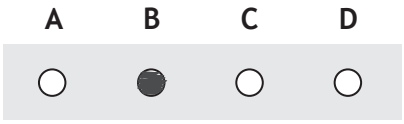
A fractional distillation

B chromatography

C fractional crystallisation

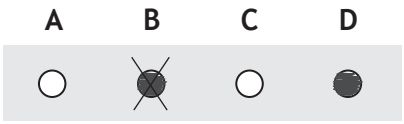
D filtration.

The correct answer is **B** — chromatography. The answer **B** bubble has been clearly filled in (see below).

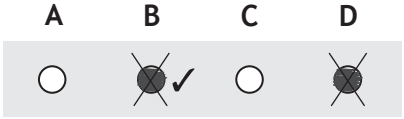


Changing an answer

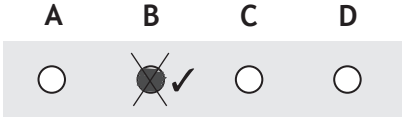
If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



If you then decide to change back to an answer you have already scored out, put a tick (✓) to the **right** of the answer you want, as shown below:



or



SECTION 1 — Answer grid

0BJ25AD1

	A	B	C	D
1	○	○	○	○
2	○	○	○	○
3	○	○	○	○
4	○	○	○	○
5	○	○	○	○
6	○	○	○	○
7	○	○	○	○
8	○	○	○	○
9	○	○	○	○
10	○	○	○	○
11	○	○	○	○
12	○	○	○	○
13	○	○	○	○
14	○	○	○	○
15	○	○	○	○
16	○	○	○	○
17	○	○	○	○
18	○	○	○	○
19	○	○	○	○
20	○	○	○	○
21	○	○	○	○
22	○	○	○	○
23	○	○	○	○
24	○	○	○	○
25	○	○	○	○

SECTION 2 — 85 marks

Attempt ALL questions

MARKS | DO NOT WRITE IN THIS MARGIN

1. In 2002, astronomers observed a flash of light 10 000 times brighter than normal. Its electromagnetic spectrum revealed an intense crimson line, wavelength, 671 nm.

(a) Identify an element that could be responsible for this intense crimson line in the emission spectrum. **1**

(b) Explain how the line of crimson light is produced. **2**

(c) Calculate the energy, in kJ mol^{-1}, associated with a wavelength of 671 nm. **2**

2. Most commercial bleaches contain hypochlorous acid. This acid dissociates as follows

$$HClO(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + ClO^-(aq)$$

(a) Complete the table to identify one of the acid-conjugate base pairs. **1**

Acid	
Conjugate base	

(b) Write the expression for the dissociation constant, K_a, for hypochlorous acid. **1**

(c) A solution of hypochlorous acid was titrated with sodium hydroxide solution.

The solution at the end point was alkaline.

Explain fully why the solution was alkaline at the end point. **2**

[Turn over

3. Manganese oxide, MnO_2, was used 30 000 years ago as a black pigment in cave paintings.

MARKS DO NOT WRITE IN THIS MARGIN

(a) (i) State the oxidation number of manganese in MnO_2. **1**

(ii) Using orbital box notation, write the electronic configuration for a manganese ion in MnO_2. **1**

(iii) Every electron in a manganese ion can be represented by a unique set of four quantum numbers.

One of these electrons can be represented by the quantum numbers $2,1,0,+\frac{1}{2}$.

(A) Draw the shape of an orbital containing this electron. **1**

(B) The electrons in a subshell of an isolated manganese ion are degenerate.

State the meaning of the term degenerate. **1**

(C) Write a set of four quantum numbers for an electron degenerate to the one represented by the quantum numbers $2,1,0,+\frac{1}{2}$. **1**

3. (continued)

(b) Small amounts of manganese are added to the aluminium used for drinks cans to improve their corrosion resistance.

The manganese in aluminium can be converted to an aqueous solution containing purple permanganate ions, $MnO_4^-(aq)$. The concentration of permanganate ions in this solution can be determined by colorimetry.

(i) A calibration graph is prepared using absorbance values from a series of different concentrations of standard solutions of permanganate ions. Prior to recording any absorbance values the colorimeter is switched on for around 5 minutes.

Suggest another two steps that must be carried out to set up the colorimeter before recording the absorbance value of any of the solutions. **1**

(ii) A student measured the absorbance of the sample solution. The absorbance reading gave a concentration of $MnO_4^-(aq)$ higher than any of the standard solutions used to prepare the calibration graph.

Suggest what should be done to determine the most accurate value for the concentration of $MnO_4^-(aq)$ in the sample solution. **1**

[Turn over

3. (b) (continued)

(iii) Manganese can have different oxidation states in different species. The table shows the colours of some of these species.

Species	Colour
Mn^{2+}	colourless
MnO_2	black
MnO_4^-	purple

Using your knowledge of chemistry, discuss the relationship between oxidation state and colour in these species of manganese. **3**

4. A student was investigating the percentage calcium carbonate content of an eggshell. **MARKS** DO NOT WRITE IN THIS MARGIN

0·390 g of ground eggshell was placed in a beaker containing 20·0 cm^3 of 1·00 mol l^{-1} hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(\ell)$$

Once the reaction was complete, the solution was quantitatively transferred to a 100 cm^3 standard flask and made up to the mark with distilled water.

10·0 cm^3 samples of the solution were titrated with 0·100 mol l^{-1} sodium hydroxide solution. The average titre was 11·65 cm^3.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$$

(a) Calculate the number of moles of hydrochloric acid left unreacted in the standard flask. **1**

(b) Using the results obtained by the student calculate the percentage, by mass, of calcium carbonate present in the eggshell. **3**

(c) This procedure gave a mass of calcium carbonate that was greater than expected.

Suggest a reason for this and describe an improvement that should be made to the procedure to give a mass closer to the expected value. **2**

5. The entropy, S, of a system is a measure of the degree of disorder of the system.

The standard entropy values, $S°$, for some substances at 298 K are listed in the table.

Substance	$S°$ (J K^{-1} mol^{-1})
$UO_2(s)$	77
HF(g)	174
$UF_4(s)$	152
$H_2O(g)$	189
$H_2O(\ell)$	70
$CCl_4(g)$	310
$CCl_4(\ell)$	216

(a) One of the reactions in the production of nuclear fuel from uranium oxide is

$$UO_2(s) + 4HF(g) \rightarrow UF_4(s) + 2H_2O(g) \quad \Delta H° = -244 \text{ kJ mol}^{-1}$$

(i) Calculate the entropy change, $\Delta S°$, in J K^{-1} mol^{-1}, at 298 K for this reaction. **1**

(ii) Determine, by calculation, whether this reaction is feasible at 298 K. **2**

(Clearly show your working for the calculation.)

(b) Suggest why the entropy change for $H_2O(\ell)$ to $H_2O(g)$ is greater than that for $CCl_4(\ell)$ to $CCl_4(g)$. **2**

DO NOT WRITE IN THIS MARGIN

MARKS

6. At 1000 °C, nitrogen monoxide can combine with hydrogen. **MARKS** DO NOT WRITE IN THIS MARGIN

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

The initial rate of this reaction was determined at different concentrations of NO(g) and $H_2(g)$. The results are shown in the table.

Experiment	[NO] (mol l^{-1})	[H_2] (mol l^{-1})	Initial rate (mol l^{-1} s^{-1})
1	$4{\cdot}00 \times 10^{-3}$	$1{\cdot}00 \times 10^{-3}$	$1{\cdot}20 \times 10^{-5}$
2	$8{\cdot}00 \times 10^{-3}$	$1{\cdot}00 \times 10^{-3}$	$4{\cdot}80 \times 10^{-5}$
3	$8{\cdot}00 \times 10^{-3}$	$4{\cdot}00 \times 10^{-3}$	$1{\cdot}92 \times 10^{-4}$

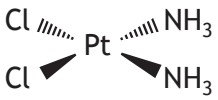
(a) (i) The reaction was found to be second order with respect to NO(g). Explain why this is consistent with the results shown in the table. **1**

(ii) Determine the order of the reaction with respect to $H_2(g)$. **1**

(b) Write the overall rate equation for the reaction. **1**

(c) Calculate the value for the rate constant, *k*, including the appropriate units. **2**

7. Cisplatin was the first member of a class of platinum-containing anti-cancer drugs. **MARKS** DO NOT WRITE IN THIS MARGIN



cisplatin

Clinical use of the drug is now limited since cancer cells can develop resistance to it.

(a) (i) Explain the meaning of **cis** in cisplatin. **1**

(ii) Cisplatin is the common name for this complex.

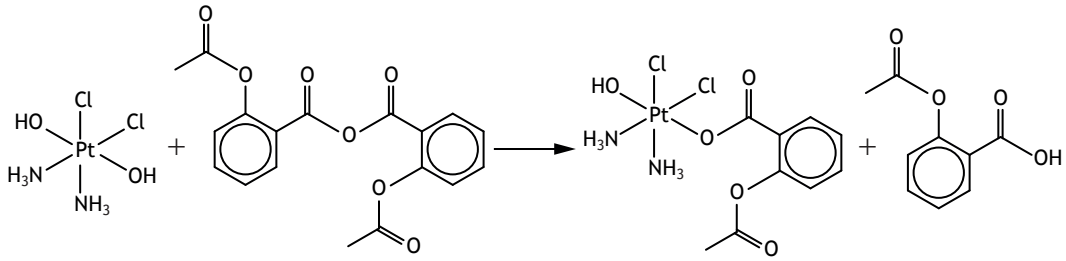
State the IUPAC name for this complex. **1**

MARKS

DO NOT WRITE IN THIS MARGIN

(b) A new drug being trialled, asplatin, may be capable of overcoming drug resistance in cancer cells.

Asplatin is synthesised by reacting oxoplatin with acetylsalicylic anhydride.



oxoplatin
GFM = 334·1 g

acetylsalicylic anhydride
GFM = 342 g

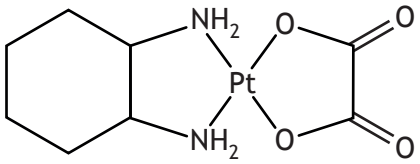
asplatin
GFM = 496·1 g

aspirin
GFM = 180 g

During a trial synthesis, 5·00 g of oxoplatin was reacted with excess acetylsalicylic anhydride to produce 6·36 g of asplatin.

Calculate the percentage yield. **2**

(c) Another platinum based anti-cancer drug, oxaliplatin, is shown.



oxaliplatin

(i) State the coordination number of platinum in oxaliplatin. **1**

(ii) The ligands in oxaliplatin bind to the platinum ion by dative covalent bonds.

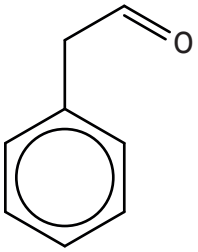
(A) State the **type** of ligand binding to platinum in this complex. **1**

(B) State what feature of ligands allows dative covalent bonds to form. **1**

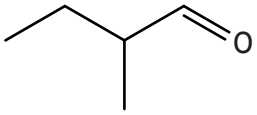
8. Chocolate contains more than 600 chemical compounds.

MARKS DO NOT WRITE IN THIS MARGIN

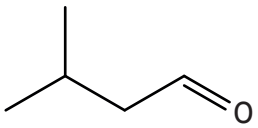
(a) Phenylethanal, 2-methylbutanal and 3-methylbutanal are three of the compounds responsible for the distinctive smell of chocolate.



phenylethanal



2-methylbutanal

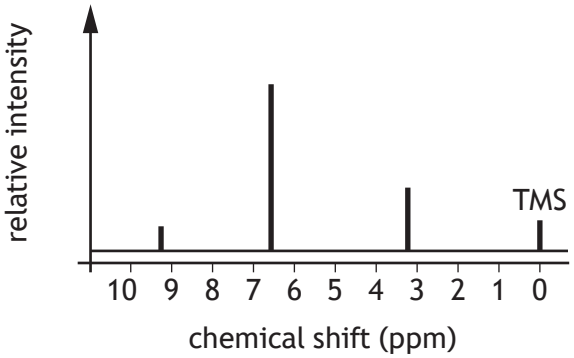


3-methylbutanal

(i) State which one of these compounds has optical isomers. **1**

(ii) Describe how separate samples of two enantiomers could be distinguished. **2**

(iii) The low resolution ^{1}H NMR spectrum for one of these compounds is shown.

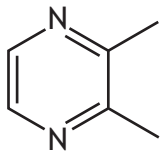


Explain which of the three compounds would give this ^{1}H NMR spectrum. **2**

MARKS

DO NOT WRITE IN THIS MARGIN

(b) A compound responsible for the nutty flavour of chocolate is 2,3-dimethylpyrazine.



2,3-dimethylpyrazine

(i) Write the molecular formula for 2,3-dimethylpyrazine. **1**

(ii) The ring structure of 2,3-dimethylpyrazine consists of carbon and nitrogen atoms with sp^2 hybridisation resulting in sigma and pi bonding.

(A) State how sp^2 hybridisation arises in an atom of nitrogen. **1**

(B) Explain fully how the sp^2 hybrid oribitals of nitrogen form sigma bonds with carbon atoms in 2,3-dimethylpyrazine. **2**

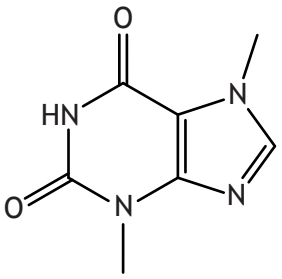
(c) Theobromine is another compound present in chocolate and has been linked to the 'feel-good' factor associated with eating chocolate. If consumed in large enough doses it is toxic.

(i) A bar of dark chocolate of mass 99·6 g contains 802 mg of theobromine. The lethal dose for a dog is 300 mg per kg of body weight.

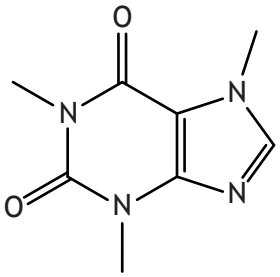
Calculate the mass of dark chocolate that would be lethal for a dog of 30·6 kg body mass to consume. **2**

8. (c) (continued)

(ii) Caffeine produces a similar 'feel-good' factor to theobromine.



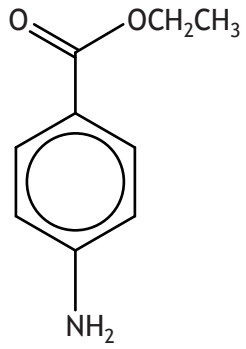
theobromine



caffeine

Using your knowledge of chemistry, suggest why these compounds produce a similar 'feel-good' factor when consumed. **3**

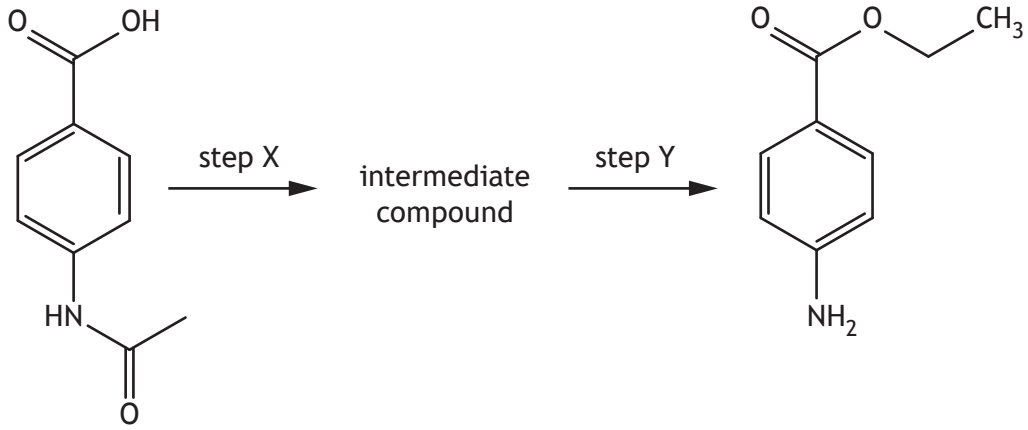
9. Benzocaine is used to relieve pain and itching caused by conditions such as sunburn, insect bites or stings. **MARKS** DO NOT WRITE IN THIS MARGIN



benzocaine

A student was carrying out a project to synthesise benzocaine.

(a) Two of the steps in the synthesis of benzocaine are shown in the reaction scheme below.



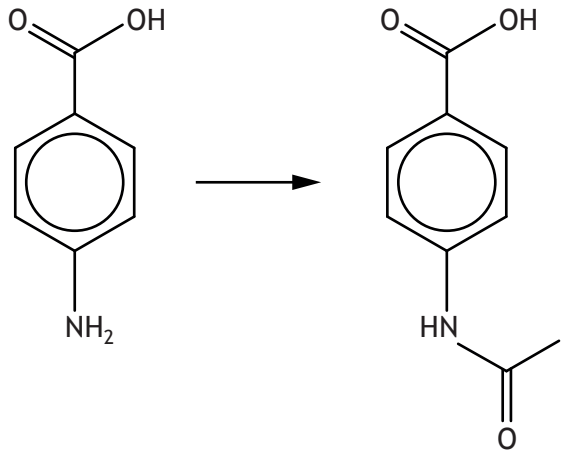
(i) Complete the table by identifying the type of reaction taking place in step X and in step Y. **2**

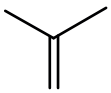
Step X	
Step Y	

[Turn over

9. (a) (continued)

(ii) The initial step in the synthesis is shown below.





The O group is used to protect the amine group and is removed again to make benzocaine.

Suggest why it is necessary to protect the amine group during this synthesis. **1**

9. (continued)

(b) The benzocaine produced in the reaction was recrystallised from ethanol to remove impurities.

(i) Explain why ethanol is a suitable solvent for this recrystallisation. **1**

(ii) Outline the steps that should be carried out to recrystallise benzocaine from ethanol. **2**

(c) The student analysed the recrystallised benzocaine by determining the melting point and by thin-layer chromatography (TLC).

(i) Pure benzocaine crystals are made up of molecules held together in a regular pattern by intermolecular attractions. This property allows melting point analysis to be used to determine if the synthesised product is pure.

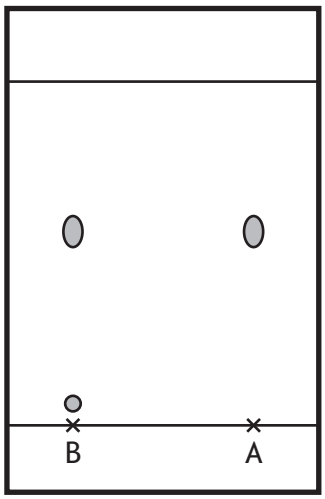
(A) State an effect impurities would have on the melting point of the recrystallised benzocaine. **1**

(B) Suggest why impurities lead to this effect on the melting point. **1**

[Turn over

9. (c) (continued)

(ii) TLC was used to confirm the identity of the recrystallised benzocaine. A sample was dissolved in a small volume of solvent and spotted onto a TLC plate. The following chromatogram was obtained.



B = recrystallised benzocaine

(A) State the name of the substance spotted at A on the TLC plate. **1**

(B) Calculate the R_f value of the spot showing the substance present in sample A. **1**

(C) Based on the results obtained in the TLC analysis, comment on the purity of the student's product. **1**

10. A student was researching ways to synthesise ethoxyethane and its isomer 2-methoxypropane and found two different methods.

(a) Method 1 uses an alcohol and an acid catalyst as shown below for ethoxyethane.

$$2CH_3CH_2OH \xrightarrow{H^+} CH_3CH_2OCH_2CH_3 + H_2O$$

ethanol ethoxyethane

(i) State the name given to this type of reaction. **1**

(ii) Suggest why this method would not be suitable to synthesise 2-methoxypropane. **1**

(b) Method 2 uses alkoxide ions and a haloalkane as shown below for ethoxyethane.

$$CH_3CH_2O^- + CH_3CH_2Br \rightarrow CH_3CH_2OCH_2CH_3 + Br^-$$

ethoxide ion bromoethane ethoxyethane

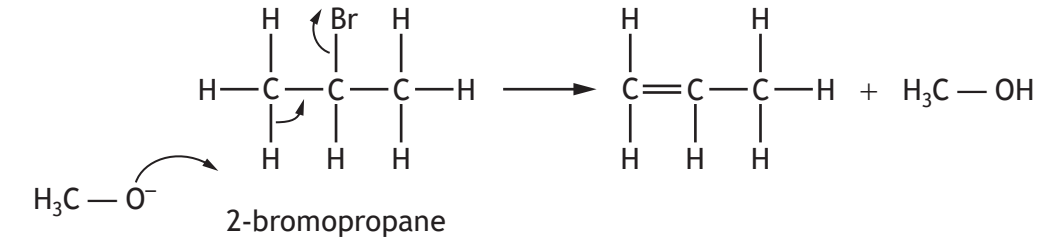
(i) Suggest why this reaction is more likely to follow an S_N2 mechanism rather than an S_N1 mechanism. **1**

(ii) Using structural formulae and curly arrow notation, outline a possible mechanism for this reaction. **2**

MARKS

DO NOT WRITE IN THIS MARGIN

(iii) When the student attempted to make 2-methoxypropane using methoxide ions and 2-bromopropane the major product of the reaction was found to be propene. A possible mechanism for this reaction is shown.



2-bromopropane

methoxide ion

(A) State the role of the methoxide ions in this mechanism. **1**

(B) Draw the structures of two reactants that would react to make 2-methoxypropane using method 2. **2**

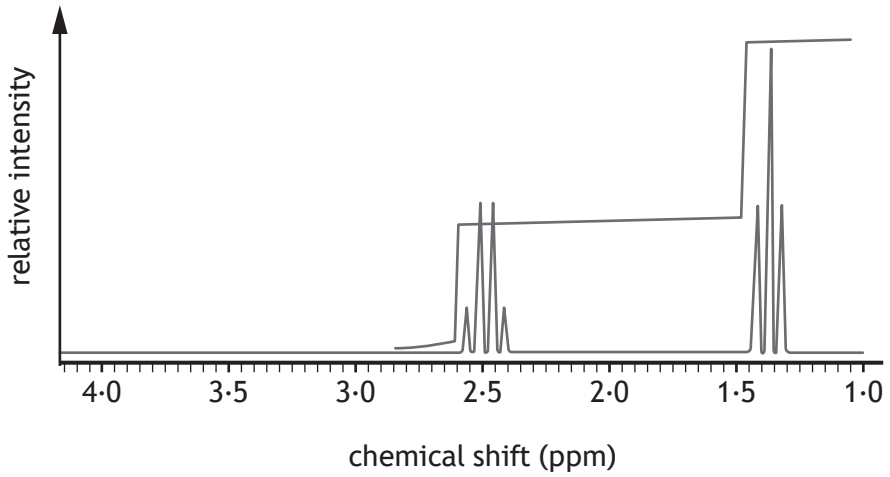
(c) The student analysed a sample of ethoxyethane using elemental microanalysis and high resolution ^{1}H NMR spectroscopy.

(i) 2·50 g of ethoxyethane was burned producing 5·95 g of CO_2 and 3·04 g of H_2O as the only products.

Using the information above, show by calculation that the sample was ethoxyethane. **2**

10. (c) (continued)

(ii) The high resolution ^{1}H NMR spectrum of ethoxyethane is shown.



(A) The two peaks in this spectrum are split into multiplets.

Explain fully why this splitting pattern helps to confirm the sample is ethoxyethane. **2**

(B) Explain why the integration curve also helps to confirm the sample is ethoxyethane. **1**

[Turn over

11. 250 cm^3 of buffer solution was prepared by dissolving a weighed sample of ammonium chloride in 0·96 mol l^{-1} ammonia solution. After preparation the buffer was found to have a pH of 10·23.

(a) Explain fully how this solution would resist a change in pH if a few drops of dilute acid solution were added. **2**

(b) The pH of a basic buffer can be calculated using the pK_a value for the dissociation constant of the conjugate acid.

$$\text{pH} = \text{p}K_a - \log\frac{[\text{conjugate acid}]}{[\text{base}]}$$

(i) Calculate the concentration, in mol l^{-1}, of ammonium ions in the buffer solution using the pK_a value for ammonium ions given in the data booklet. **2**

(ii) As the equilibrium position for ammonia solution lies to the left, the concentration of ammonium ions is assumed to be entirely from the presence of the ammonium chloride salt.

Calculate the mass, in g, of the weighed sample of ammonium chloride that was used to make this buffer solution. **1**

[END OF SPECIMEN QUESTION PAPER]

MARKS | DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

MARKS DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

National
Qualifications
SPECIMEN ONLY

S813/77/02 **Chemistry**

Marking Instructions

These marking instructions have been provided to show how SQA would mark this specimen question paper.

SQA
©

General marking principles for Advanced Higher Chemistry

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(b) If a candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Do not award half marks.

(d) Award full marks for the correct response to a calculation (including units, if appropriate) without working. An exception to this is when candidates are asked to 'Find, by calculation' or 'Clearly show your working for the calculation'.

(e) Ideally, numerical values should be given to the correct number of significant figures as shown in the **detailed marking instructions**. Full marks can be awarded for values that have one significant figure fewer and up to two more significant figures than the expected answer. Exceptions to this rule will be given in the **detailed marking instructions**. Incorrect significant figures would only be penalised once in any paper.

(f) Where a candidate makes an error at an early stage in a multi-stage calculation, award partial marks, as shown in the **detailed marking instructions**, for correct follow-on working in subsequent stages, unless the error significantly reduces the complexity of the remaining stages. Apply the same principle for questions that require several stages of non-mathematical reasoning. The exception to this rule is where the marking instructions for a numerical question assign separate 'concept marks' and an 'arithmetic mark'. In such situations, the marking instructions will give clear guidance on the assignment of partial marks.

(g) Ideally, calculated intermediate values should not be rounded. If the candidate has correctly rounded, the calculated intermediate values can have one significant figure fewer than the data given in the question but no fewer. For example, if the data in the question is given to three significant figures, the intermediate value should have no fewer than two significant figures.

(h) In many questions, the unit in which the answer is to be expressed is given. In these questions, the candidate does not need to state a unit in their answer; but if they do, the unit must be correct. The full mark allocation cannot be awarded if an incorrect unit is shown. In these questions, incorrect units would only be penalised once in any paper and cannot be applied if marking instruction **(e)** has already been applied in the paper.

(i) Candidates may fully access larger mark allocations whether their responses are in continuous prose, linked statements, or a series of developed bullet points.

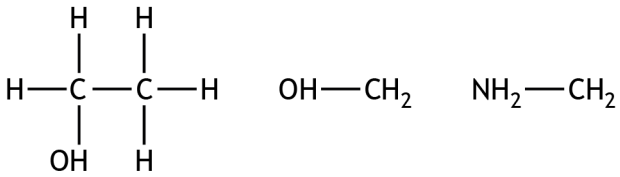
(j) Do not deduct marks for inaccurate or unconventional spelling or vocabulary as long as the meaning of the word(s) is conveyed. **For example**, responses that include 'distilling' for 'distillation', or 'it gets hotter' for 'the temperature rises', are acceptable. Exceptions to this rule will be given in the **detailed marking instructions**.

(k) If a correct response and a wrong response are given, award no marks. **For example** in response to the question, 'State the colour seen when blue Fehling's solution is warmed with an aldehyde', do not award marks for the response 'red green'. However, if a correct response is followed by additional information which does not conflict with that, ignore the additional information, whether correct or not. **For example** in response to a question

concerned with melting point, 'State why the tube should not be made of copper', the response 'Copper has a low melting point and is coloured grey' **would** gain marks.

(l) Ignore the omission of one H atom from a full structural formula provided the bond is shown. Ignore the omission of one bond provided the attached atom is shown.

If a structural formula is asked for, award marks only if the bond points to the appropriate atom. **For example**, the structural formulae shown below would not be awarded marks



This marking instruction must only be applied a maximum of once per question.

(m) Award marks for a symbol or correct formula in place of a name **unless stated otherwise in the detailed marking instructions.**

(n) When formulae of ionic compounds are given as responses, candidates only need to show ion charges if these have been specifically asked for. However, if ion charges are shown, they must be correct. If incorrect charges are shown, do not award marks.

(o) If an answer comes directly from the text of the question, do not award marks. **For example**, in response to the question, 'A student found that 0·05 mol of propane, C_3H_8 burned to give 82·4 kJ of energy. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$. Name the kind of enthalpy change that the student measured', do not award marks for 'burning' since the word 'burned' appears in the text.

(p) A guiding principle in marking is to give credit for correct elements of a response rather than to look for reasons not to give marks.

Example 1: If a structural formula is asked for, CH_3 and CH_3CH_2 are acceptable as methyl and ethyl groups respectively unless the question asks for a skeletal structural formula.

Example 2: If a name is asked for such as 3-methylhexane, then 3, methyl-hexane would be acceptable although the use of comma and dashes is not correct.

(q) Unless the question is clearly about a non-chemistry issue, for example costs in an industrial chemical process, do not award marks for a non-chemical response.
For example, in response to the question, 'Why does the (catalytic) converter have a honeycomb structure?', do not award a mark for 'To make it work'. This response may be correct but it is not a chemical response.

(r) Only award marks for a valid response to the question asked. Where candidates are asked to:

- **identify, name, give** or **state**, they must only name or present in brief form.
- **describe**, they must provide a statement or structure of characteristics and/or features.
- **explain**, they must relate cause and effect and/or make relationships between things clear.
- **compare**, they must demonstrate knowledge and understanding of the similarities and/or differences between things.
- **complete**, they must finish a chemical equation or fill in a table with information.
- **determine** or **calculate**, they must determine a number from given facts, figures or information.
- **draw**, they must draw a diagram or structural formula, for example 'Draw a diagram to show the part of a poly(propene) molecule formed from two propene molecules.'

- **estimate**, they must determine an approximate value for something.
- **predict**, they must suggest what may happen based on available information.
- **evaluate**, they must make a judgement based on criteria.
- **suggest**, they must apply their knowledge and understanding of chemistry to a new situation. A number of responses are acceptable: award marks for any suggestions that are supported by knowledge and understanding of chemistry.
- **use their knowledge of chemistry or aspect of chemistry to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). Candidates gain marks for the breadth and/or depth of their conceptual understanding.
- **write**, they must complete a chemical or word equation, for example 'Write the word equation for the complete combustion of ethanol.'

Marking instructions for each question

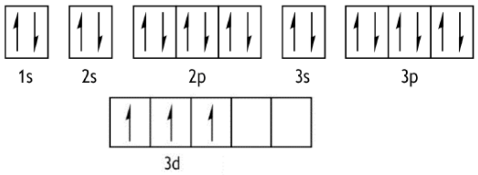
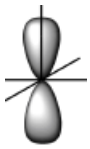
SECTION 1

Question	Answer	Max mark
1.	B	1
2.	D	1
3.	D	1
4.	C	1
5.	A	1
6.	C	1
7.	B	1
8.	A	1
9.	D	1
10.	B	1
11.	C	1
12.	A	1
13.	A	1
14.	B	1
15.	D	1
16.	D	1
17.	A	1
18.	D	1
19.	D	1
20.	B	1
21.	C	1
22.	B	1
23.	A	1
24.	C	1
25.	C	1

SECTION 2

Question				Expected response	Max mark	Additional guidance
1.	(a)			Lithium	**1**	
	(b)			(Excited) electrons fall to lower energy levels **(1)** Energy corresponding to the energy of the gap is emitted in the form of a photon whose wavelength corresponds to red light **(1)**	**2**	
	(c)			178 (kJ mol^{-1}) **(2)** Partial marking $E = Lhc/(1000)\lambda$ **OR** correct substitution of values **(1)**	**2**	Units not necessary but must be correct if given. 180/178·4/178·45 also acceptable

Question				Expected response	Max mark	Additional guidance
2.	(a)			<table><tr><td>Acid</td><td>HClO (aq)</td></tr><tr><td>Conjugate base</td><td>ClO^- (aq)</td></tr></table> **OR** <table><tr><td>Acid</td><td>H_3O^+ (aq)</td></tr><tr><td>Conjugate base</td><td>H_2O (ℓ)</td></tr></table>	1	State symbols not required but if given must be correct. Charges must be shown.
	(b)			$K_a = \frac{[H_3O^+][ClO^-]}{[HClO]}$	1	$[H^+]$ acceptable in place of $[H_3O^+]$
	(c)			$ClO^-(aq) + H^+(aq) \rightleftharpoons HClO(aq)$ **OR** the H^+ ions are removed by the conjugate base from the water equilibrium **(1)** $H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$ **AND** equilibrium moves to right **OR** this causes the water equilibrium to shift to the right hand side producing excess OH^- and hence pH >7 **OR** produces an excess of OH^- ions **(1)**	2	

Question				Expected response	Max mark	Additional guidance
3.	(a)	(i)		+4, 4, 4+, IV, four	**1**	–4, 4– not acceptable
		(ii)			**1**	Labels are required Must have one arrow in each of any of the 3d boxes and arrows must be either all pointing up or all pointing down.
		(iii)	(A)	Any p orbital 	**1**	Axes not required
			(B)	Of equal energy	**1**	
			(C)	Any of $2,1,-1,+\frac{1}{2}$ $2,1,-1,-\frac{1}{2}$ $2,1,0,-\frac{1}{2}$ $2,1,+1,+\frac{1}{2}$. $2,1,+1,-\frac{1}{2}$.	**1**	
3.	(b)	(i)		Filter complementary to colour of solution **AND** blank measured	**1**	
		(ii)		Dilute the sample **OR** prepare new standard solutions of greater concentration	**1**	

Question				Expected response	Max mark	Additional guidance
3.	(b)	(iii)		**Award 3 marks** where the candidate has demonstrated, at an appropriate level, a good understanding of the chemistry involved. They show a good comprehension of the chemistry of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the chemistry within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the chemistry involved. There is no evidence that they have recognised the area of chemistry involved, or they have not given any statement of a relevant chemistry principle. Award this mark also if the candidate merely restates the chemistry given in the question.	**3**	Candidates may use a variety of chemistry arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question				Expected response	Max mark	Additional guidance
4.	(a)			0·0117 moles HCl unreated Average titre = 11·65 cm^3 No moles of NaOH 0·1 × 0·01165 = 1·165 × 10^{-3} moles HCl unreacted in 10 cm^3	**1**	0·012/0·01165
	(b)			107 (%) Partial marking Up to 2 marks may be awarded for any two of the following. No moles HCl reacting (0·02 − 0·01165 =) 8·35 × 10^{-3} **OR** correct subtraction of incorrectly calculated moles **OR** correct calculation of mass of $CaCO_3$ **OR** correctly calculating a % from a calculated mass of calcium carbonate	**3**	Mass $CaCO_3$ = (4·175 × 10^{-3} × 100·1 =) 0·418 g is awarded 2 marks

Question				Expected response	Max mark	Additional guidance
4.	(c)			Concentration of NaOH greater than stated on bottle **(1)** **AND** standardise NaOH **(1)** **OR** Mass of egg shell used was less than recorded **(1)** **AND** repeat experiment with new mass of egg shell **(1)** **OR** Concentration of HCl less than stated on bottle **(1)** **AND** standardise the HCl **(1)** **OR** HCl reacted with other impurities in egg shell **(1)** **AND** carry out a control experiment with a known mass of pure calcium carbonate **(1)**	**2**	

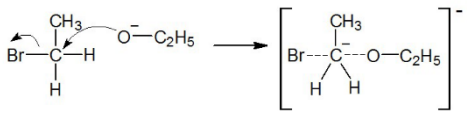
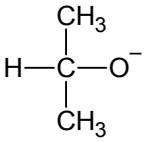
Question				Expected response	Max mark	Additional guidance
5.	(a)	(i)		−243 (J K^{-1} mol^{-1})	**1**	−240 also acceptable Units not necessary but must be correct if given.
		(ii)		−171·6 (kJ mol^{-1}) **OR** −171600 (J mol^{-1}) **AND** yes reaction is feasible **(2)** Partial marking One partial mark may be awarded for one of the following. $\Delta G^{o} = \Delta H^{o} - T\Delta S^{o}$ **OR** = (-244) - 298(-0.243) **OR** −171·6 (kJ mol^{-1}) **OR** −171600 (J mol^{-1}) **OR** incorrect value with correct feasibility for incorrect value	**2**	Working must be shown Follow through applies Units not necessary but must be correct if given.
	(b)			Entropy of $H_2O(\ell)$ is much lower than that of $CCl_4(\ell)$ and so $H_2O(\ell)$ is more ordered (due to hydrogen bonds) **(1)** The change from an ordered system of $H_2O(\ell)$ to free molecules results in a greater change in entropy than that in CCl_4 **(1)**	**2**	

Question				Expected response	Max mark	Additional guidance
6.	(a)	(i)		When the concentration is doubled the rate increases by a factor of four	**1**	
		(ii)		1/ first/1st/one	**1**	
	(b)			Rate = $k[NO]^2[H_2]$	**1**	Must be lowercase k R or r in place of rate is not acceptable Square brackets are required State symbols not required but if given must be correct.
	(c)			750 **(1)** $mol^{-2}\ l^2\ s^{-1}$ **(1)**	**2**	
7.	(a)	(i)		Both substituents are on same side of Pt **OR** both chlorine /both ammonia ligands on same side of Pt	**1**	
		(ii)		Diamminedichloridoplatinum(II)	**1**	
	(b)			85·7 (%) **(2)** Partial marking One mark may be awarded for Mass asplatin 7·424 (g) **(1)**	**2**	86/85·66/85·663
	(c)	(i)		4	**1**	
		(ii)	(A)	Bidentate	**1**	
			(B)	Lone /non-bonding pairs of electrons	**1**	

Question				Expected response	Max mark	Additional guidance
8.	(a)	(i)		2-methylbutanal	**1**	
		(ii)		Plane polarised light **(1)** rotated in equal and opposite directions **(1)**	**2**	
		(iii)		Phenylethanal **(1)** Peak at 6·5 has shift value in region of aromatic protons **OR** height ratios show that peak at 6·5 due to 5 protons **OR** only compound with only 3 environments **(1)**	**2**	
	(b)	(i)		$C_6H_8N_2$	**1**	C, H and N can be in any order.
		(ii)	(A)	One s orbital and two p orbitals combine to make three degenerate sp^2 hybrid orbitals	**1**	
			(B)	End-on overlap **(1)** With sp^2 orbital from C **(1)**	**2**	
	(c)	(i)		1140 g **(2)** **OR** 1·14 kg **(2)** Partial marking One partial mark may be awarded for one of the following 1140 **OR** 1·14 **OR** correct unit of a calculated final mass **(1)**	**2**	1100/1140·1 1·1/1·140/1·1401 Unit is required

Question				Expected response	Max mark	Additional guidance
8.	(c)	(ii)		**Award 3 marks** where the candidate has demonstrated, at an appropriate level, a good understanding of the chemistry involved. They show a good comprehension of the chemistry of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the chemistry within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the chemistry involved. There is no evidence that they have recognised the area of chemistry involved, or they have not given any statement of a relevant chemistry principle. Award this mark also if the candidate merely restates the chemistry given in the question.	**3**	Candidates may use a variety of chemistry arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question				Expected response	Max mark	Additional guidance
9.	(a)	(i)		<table><tr><td>Step 1</td><td>condensation</td></tr><tr><td>Step 2</td><td>hydrolysis</td></tr></table>	**2**	Any order
		(ii)		Nitrogen of amine group could also react **OR** Nitrogen of amine group is a nucleophile	**1**	
	(b)	(i)		Benzocaine is completely soluble in ethanol at high temperatures but only slightly soluble/ insoluble in ethanol at low temperatures	**1**	
		(ii)		• Minimum/small (volume) • Hot solvent/hot ethanol/hot ethanol (aq) • Filter (to remove impurities) • Cool	**2**	All four points for 2 marks. Two or three points for 1 mark.
	(c)	(i)	(A)	Lower melting point **OR** wider melting point range **(1)**	**1**	
			(B)	Weaker intermolecular attractions in benzocaine	**1**	
		(ii)	(A)	Benzocaine	**1**	
			(B)	Rf = 0·53–0·6	**1**	Only one single value is acceptable and must be within the range given.
			(C)	(Student's product) has impurity	**1**	

Question				Expected response	Max mark	Additional guidance
10.	(a)	(i)		Condensation	**1**	
		(ii)		Only works for symmetrical ether **OR** mix of products produced	**1**	
	(b)	(i)		Less stable carbocation would form	**1**	
		(ii)		 Five membered TS with square brackets and negative charge **(1)** Correct curly arrows **(1)**	**2**	
		(iii)	(A)	Base	**1**	
			(B)	 **(1)** $CH_3Br/CH_3Cl/CH_3I$ **(1)**	**2**	Answers relating to propan-2-ol alkoxide are not acceptable Full structural formula also acceptable
	(c)	(i)		Mass of C 1·623 g H 0·338 g O 2·50 − 1·623 − 0·338 = 0·539 g All three masses **(1)** Correct mole ratio calculated **(1)**	**2**	

Question				Expected response	Max mark	Additional guidance
10.	(c)	(ii)	(A)	Peak at 1·4 is a triplet and so is a proton environment next to a carbon atom with two protons on it **(1)** **AND** Peak at 2·5 is a quartet and so is a proton environment next to a carbon atom with three protons on it **(1)** Partial marking One mark may be awarded for Mention of n+1 rule **OR** quartet shows a CH_3 group present and triplet shows CH_2 group present	**2**	
			(B)	Ratio 2:3 which agrees with 4 ($2CH_2$) :6 ($2CH_3$)	**1**	

Question				Expected response	Max mark	Additional guidance
11.	(a)			OH^- ions would react with added H^+ ions **OR** $OH^- + H^+ \rightarrow H_2O$ **(1)** Ammonia equilibrium will shift to right to replace OH^- ions removed **(1)**	**2**	
	(b)	(i)		0·098 (mol l^{-1}) **(2)** Partial marking $10{\cdot}23 = \frac{9{\cdot}24 - \log\left[NH_4^+\right]}{0{\cdot}96}$ **OR** $0{\cdot}99 = \frac{-\log\left[NH_4^+\right]}{0{\cdot}96}$ **OR** $0{\cdot}1023 = \frac{\left[NH_4^+\right]}{0{\cdot}96}$ **(1)**	**2**	0·1/0·0982/0·9823 0·10/0·1006/0·10061 Units not necessary but must be correct if given.
		(ii)		1·3 (g)	**1**	1·31/1·311/1·3108 Units not necessary but must be correct if given.

[END OF SPECIMEN MARKING INSTRUCTIONS]