Oxford Cambridge and RSA

A Level Chemistry B (Salters)

H433/01 Fundamentals of Chemistry

Tuesday 5 June 2018 – Afternoon

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry B (Salters) (sent with general stationery)

You may use:
- a scientific or graphical calculator

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **110**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **36** pages.

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SECTION A

You should spend a maximum of 40 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which equation represents a possible fusion reaction?

A $_{1}H + _{1}H \rightarrow _{2}H$

B $_{1}H + _{3}H \rightarrow _{4}He$

C $_{1}H + _{1}H \rightarrow _{2}He$

D $_{1}H + _{2}He \rightarrow _{3}Na$

Your answer ☐ **[1]**

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]**

3 Which statement about an atomic emission spectrum is correct?

A It occurs when electrons absorb energy.

B The wavelength of a line is proportional to the energy lost by electrons.

C The wavelengths of the lines are the same as in an absorption spectrum of the same element.

D The lines in the emission spectrum of lithium give a yellow colour to a lithium flame.

Your answer ☐ **[1]**

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4 Which statement about NO_x pollution is correct?

A It is only produced in petrol engines.

B It can cause acid rain.

C It is not removed at all by catalytic converters.

D It consists mainly of NO_3 gas.

Your answer ☐ **[1]**

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]**

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]**

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7 Chlorine reacts with bromide ions in sea water, producing bromine.
Which statement about this process is **not** correct?

A Bromide ions are oxidised.

B The chlorine is obtained from sea water.

C Bromine forms because it is more reactive than chlorine.

D Chlorine molecules are reduced.

Your answer ☐ **[1]**

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]**

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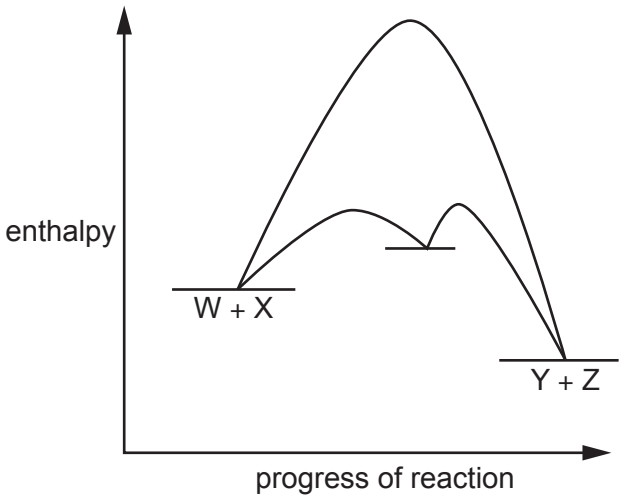
9 The enthalpy profiles for the reaction W + X $\rightleftharpoons$ Y + Z are shown below, with and without a catalyst.



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]**

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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 HC*l*
B	Remove unreacted HC*l*	Use a separating funnel	Dry	Distil
C	Remove unreacted HC*l*	Use a separating funnel	Distil	Dry
D	Use a separating funnel	Remove unreacted HC*l*	Distil	Dry

Your answer ☐ **[1]**

11 What is **not** correct for the reaction between aqueous OH^- ions and bromoethane?

A OH^- ions behave as nucleophiles.

B An alcohol is produced.

C The reaction is faster if chloroethane is used.

D The reaction occurs because of a polar C–Br bond.

Your answer ☐ **[1]**

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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]**

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]**

14 Which statement about p-orbitals is correct?

A A p-orbital is spherical in shape.

B A p-orbital can contain two electrons.

C There are six p-orbitals in a p-subshell.

D An element with outer configuration p^2 has both electrons in the same p-orbital.

Your answer ☐ **[1]**

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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]**

16 Which statement about the rate determining step of a reaction is correct?

A It is the fast step.

B It cannot involve a catalyst.

C It does not involve zero order reagents.

D It is always between two first-order reagents.

Your answer ☐ **[1]**

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]**

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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]**

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]**

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]**

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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]**

22 Which observation is correct?

A A solution of bromine water forms a purple layer when hexane is added.

B Aqueous silver nitrate forms a yellow precipitate when added to sodium bromide solution.

C When iodobutane and chlorobutane are separately refluxed with aqueous silver nitrate, a precipitate forms faster with iodobutane.

D Steamy fumes of hydrogen bromide are formed as the only gas when concentrated sulfuric acid is warmed with sodium bromide.

Your answer ☐ **[1]**

23 Which row gives the correct appearances of the products of the reactions?

	$[Fe(H_2O)_6]^{3+}$(aq) and sodium hydroxide solution	**$[Cu(H_2O)_6]^{2+}$(aq) and excess conc. ammonia solution**
A	Green precipitate	Green solution
B	Orange precipitate	Blue/violet solution
C	Orange precipitate	Green precipitate
D	Orange solution	Yellow solution

Your answer ☐ **[1]**

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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]**

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]**

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]**

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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]**

28 Which statement/s is/are correct about solutions of amino acids with the general formula $RCH(NH_2)COOH$?

1 They contain zwitterions.

2 They react with sodium hydroxide.

3 They react with hydrochloric acid.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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29 Which statement/s is/are a result of delocalisation in benzene?

1 Benzene undergoes substitution reactions.

2 Benzene reacts faster with bromine than alkenes do.

3 The enthalpy change of hydrogenation of benzene is three times that of cyclohexene.

A 1, 2 and 3

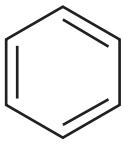
B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

30 Kekulé represented benzene as:



Which statement/s follow/s from this structure?

1 All the carbon-carbon bonds are of equal length in benzene.

2 The C–C–C bond angle in benzene is 120°.

3 Benzene has a planar structure.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

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SECTION B

Answer **all** the questions.

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]**

(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.

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.....

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

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

.....

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

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

1 .....

.....

2 .....

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

(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]**

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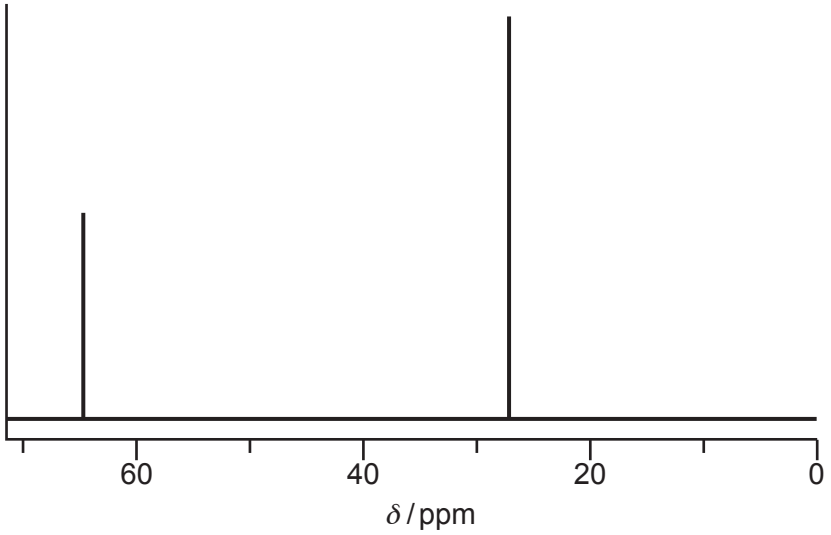
(d) The propene produced in **equation 31.1** has many uses in the chemical industry.

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

One of the substances produced from propene is an alcohol used as a cleaner and de-icer.

The ^{13}C NMR spectrum of this alcohol is shown below.



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

Reasoning .....

.....

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

(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]

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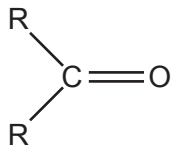
(f) The carbonyl compound from **(e)** can be reacted further to produce other raw materials. For example, it reacts with HCN.

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]**

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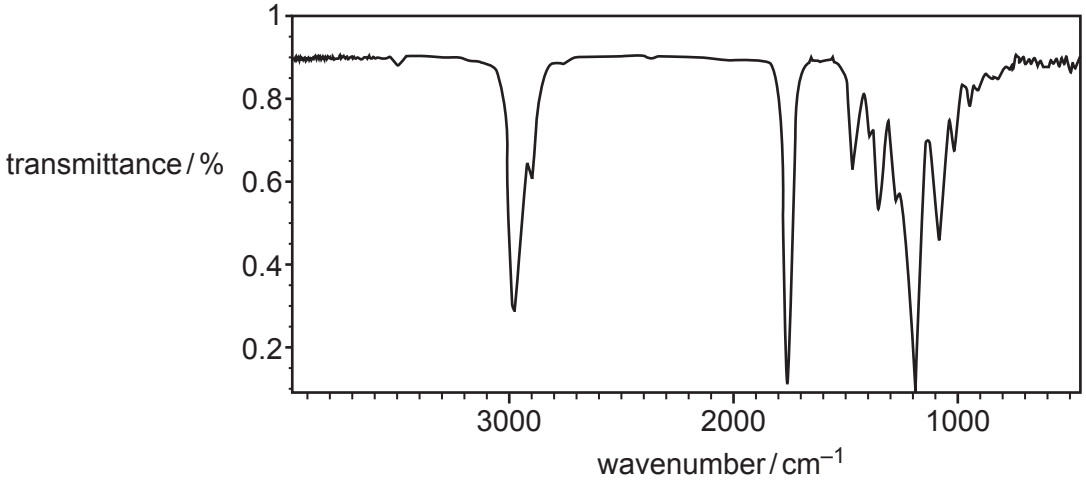
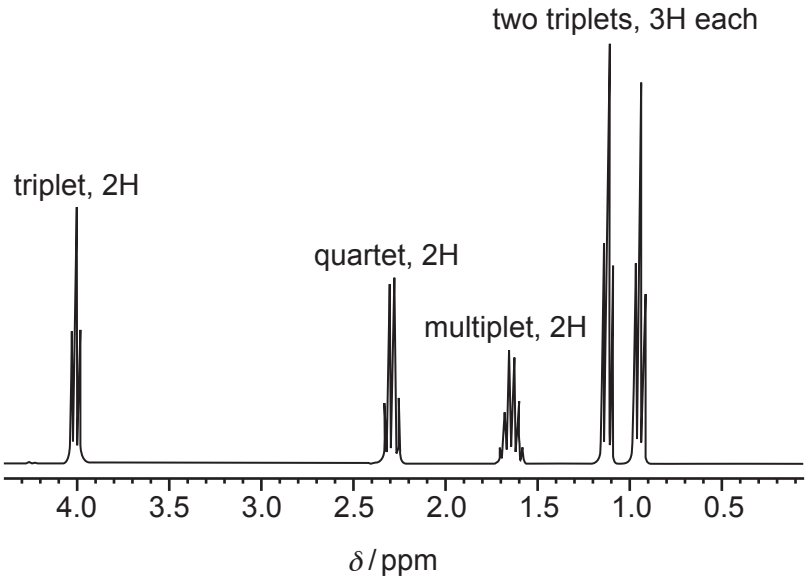
(g)* Compound **A** has six carbon atoms and can be made from propene using several steps.

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

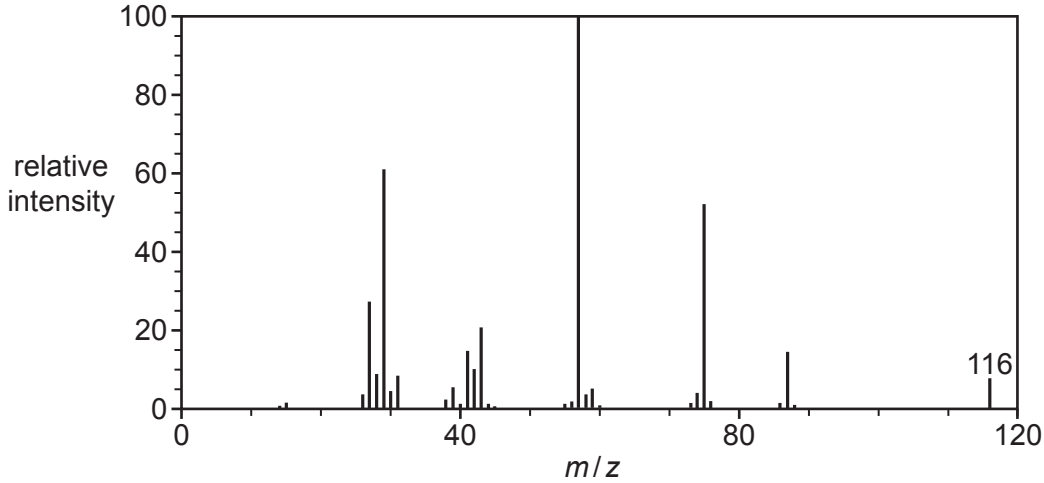
Infrared spectrum



Proton NMR spectrum



Mass spectrum



Working shown on this page will not be marked.

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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]

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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]**

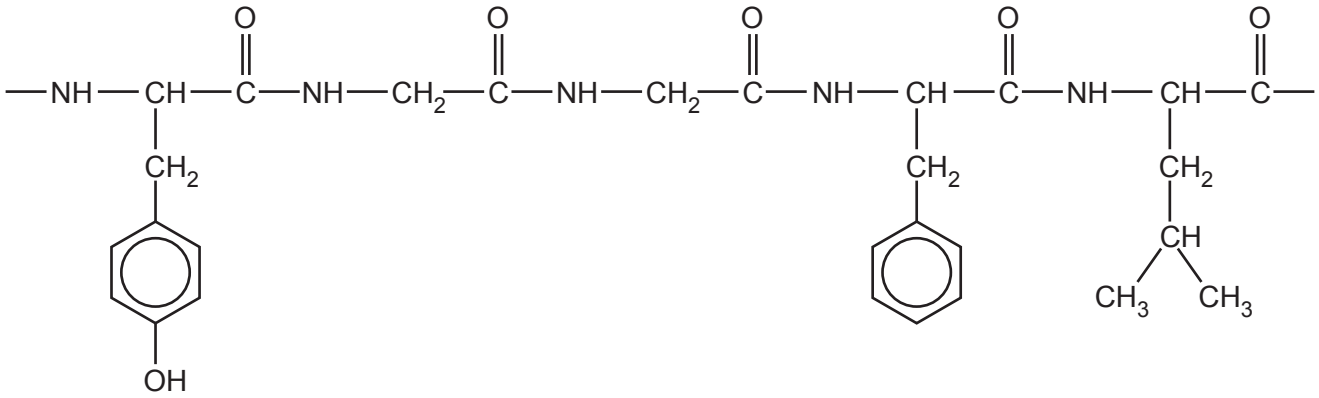
(b) Give **two** ways a substrate can bind to an enzyme.

1 .....

2 .....
[1]

(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]**



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

[4]

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(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]**

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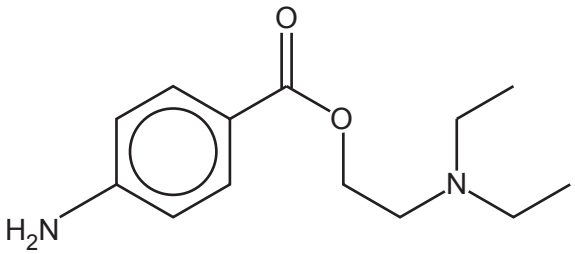
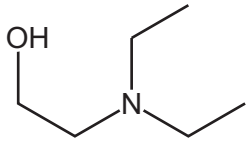
33 Procaine has been used as an anaesthetic in dentistry.



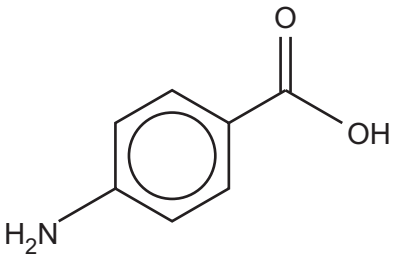
Procaine

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]**

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

.....

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

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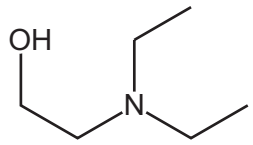
(iii) The students reacted procaine with ethanoyl chloride.

Give the formula of the organic product formed.

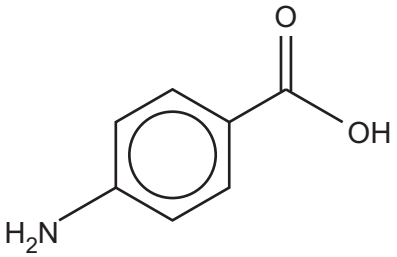
[1]

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

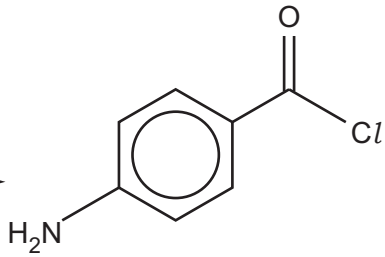


compound B

$CH_2CHN(C_2H_5)_2$ → **polymer D**

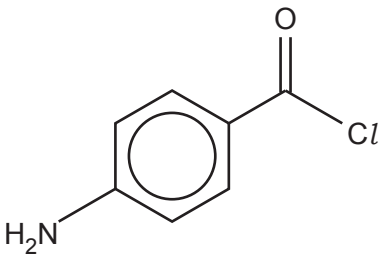


compound C



→ **polymer E**

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]

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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]**

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

$$OH + CO \rightarrow HOCO \qquad \textbf{Equation 34.1}$$

$$HOCO + O_2 \rightarrow HO_2 + CO_2 \qquad \textbf{Equation 34.2}$$

$$HO_2 + NO \rightarrow OH + NO_2 \qquad \textbf{Equation 34.3}$$

$$NO_2 + hv \rightarrow NO + O \qquad \textbf{Equation 34.4}$$

$$O + O_2 \rightarrow O_3 \qquad \textbf{Equation 34.5}$$

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

.....

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

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

[1]

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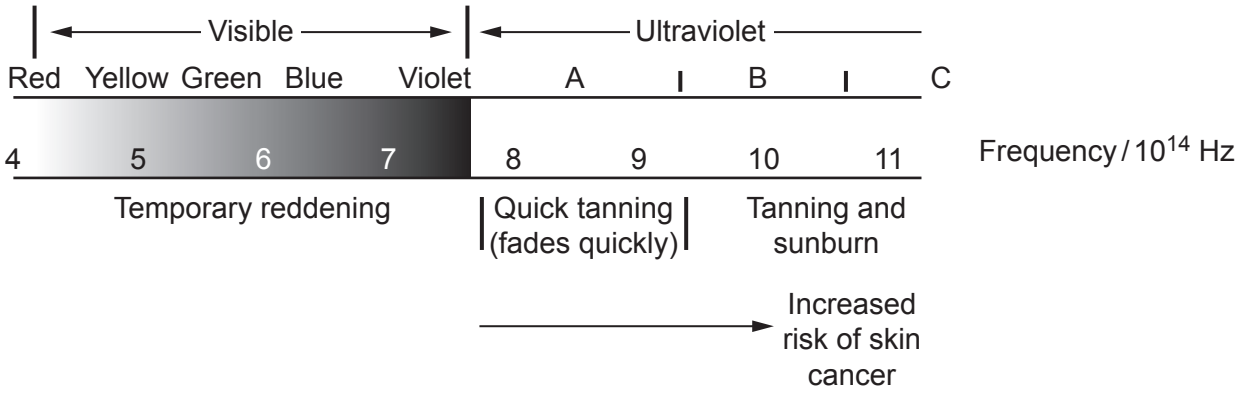
(c) Years ago, the air conditioning in cars used CFC-12, CCl_2F_2.

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–C*l*	+346
C–F	+467

.....

.....

.....

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

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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]**

(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.

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

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]**

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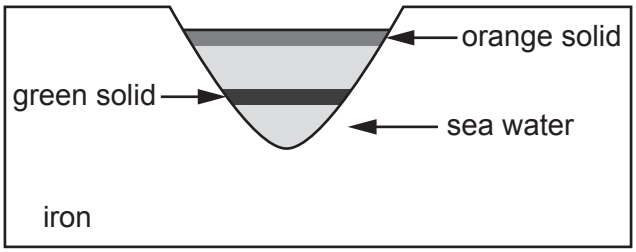
(c) The iron rusted in small dips in the surface. The chemists noticed a green solid that turned orange at the surface of the water.



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

[2]

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

Green solid .....

Orange solid .....

[1]

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

.....

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

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

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

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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]**

(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]**

(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]**

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36 Plants need nitrogen to synthesise proteins, but most plants cannot use atmospheric nitrogen. Ammonium nitrate is often used as a fertiliser as it contains nitrogen in a form that plants can absorb.

(a) The first step in the process of making ammonium nitrate is the synthesis of ammonia from atmospheric nitrogen.
This synthesis reaction has a very high activation enthalpy.
Explain this in terms of the bonding in nitrogen.

.....

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

(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]**

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

.....

.....

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

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(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]**

(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]**

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(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]**

(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]**

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(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]**

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

.....

.....

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

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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