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9701/41

October/November 2011

2 hours

Additional Materials: Data Booklet

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO NOT WRITE ON ANY BARCODES.

Answer **all** questions.

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	
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6	
7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.

Section A

Answer **all** questions in the spaces provided.

For
Examiner's
Use

- 1 (a) The halogens chlorine and bromine react readily with hydrogen.



- (i) Describe how you could carry out this reaction using chlorine.

.....

- (ii) Describe **two** observations you would make if this reaction was carried out with bromine.

.....

.....

- (iii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^\ominus$ for this reaction when

X = Cl,

$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

X = Br.

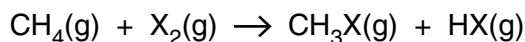
$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

- (iv) What is the major reason for the difference in these two $\Delta H^\ominus$ values?

.....

[8]

- (b) Some halogens also react readily with methane.



- (i) What conditions are needed to carry out this reaction when X is bromine, Br?

.....

- (ii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^\ominus$ of this reaction for the situation where X is iodine, I.

$$\Delta H^\ominus = \text{..... kJ mol}^{-1}$$

- (iii) Hence suggest why it is not possible to make iodomethane, CH_3I , by this reaction.

.....

[4]

- (c) Halogenoalkanes can undergo *homolytic fission* in the upper atmosphere.

- (i) Explain the term *homolytic fission*.

.....

.....

- (ii) Suggest the most likely organic radical that would be formed by the homolytic fission of bromochloromethane, CH_2BrCl . Explain your answer.

.....

.....

.....

[3]

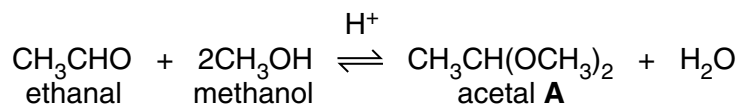
- (d) The reaction between propane and chlorine produces a mixture of many compounds, four of which are structural isomers with the molecular formula $\text{C}_3\text{H}_6\text{Cl}_2$. Draw the structural or skeletal formulae of these isomers, and indicate any chiral atoms with an asterisk (*).

[3]

[Total: 18]

- 2 Acetals are compounds formed when aldehydes are reacted with an alcohol and an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

For
Examiner's
Use



- (a) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	[CH ₃ CHO] / mol dm ⁻³	[CH ₃ OH] / mol dm ⁻³	[H ⁺] / mol dm ⁻³	relative rate
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

- (i) Use the data in the table to determine the order with respect to each reactant.

order with respect to [CH₃CHO]

order with respect to [CH₃OH]

order with respect to [H⁺]

- (ii) Use your results from part (i) to write the rate equation for the reaction.

.....

- (iii) State the units of the rate constant in the rate equation

- (iv) Calculate the relative rate of reaction for a mixture in which the starting concentrations of all three reactants are 0.20 mol dm⁻³.

relative rate = ...

[6]

- (b) The concentration of the acetal product was measured when experiment number 1 was allowed to reach equilibrium. The result is included in the following table.

For
Examiner's
Use

	$[\text{CH}_3\text{CHO}]$ /mol dm ⁻³	$[\text{CH}_3\text{OH}]$ /mol dm ⁻³	$[\text{H}^+]$ /mol dm ⁻³	[acetal A] /mol dm ⁻³	$[\text{H}_2\text{O}]$ /mol dm ⁻³
at start	0.20	0.10	0.05	0.00	0.00
at equilibrium	(0.20- x)			x	
at equilibrium				0.025	

- (i) Complete the second row of the table in terms of x , the concentration of acetal **A** at equilibrium. You may wish to consult the chemical equation opposite.
- (ii) Using the [acetal **A**] as given, 0.025 mol dm⁻³, calculate the equilibrium concentrations of the other reactants and products and write them in the third row of the table.
- (iii) Write the expression for the equilibrium constant for this reaction, K_c , stating its units.

$K_c = \dots\dots\dots$ units = $\dots\dots\dots$

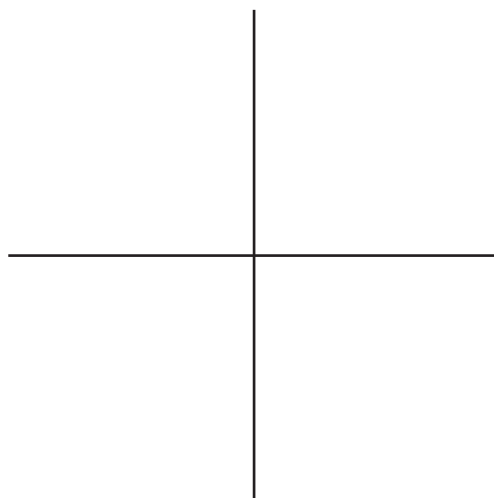
- (iv) Use your values in the third row of the table to calculate the value of K_c .

$K_c = \dots\dots\dots$
[9]

[Total: 15]

- 3 (a) On the following diagram draw a clear **labelled** sketch to describe the shape and symmetry of a typical d-orbital.

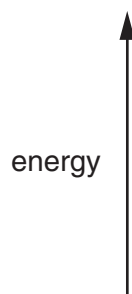
For
Examiner's
Use



[2]

- (b) Although the five d-orbitals are at the same energy in an isolated atom, when a transition element ion is in an octahedral complex the orbitals are split into two groups.

- (i) Draw an orbital energy diagram to show this, indicating the number of orbitals in each group.



- (ii) Use your diagram as an aid in explaining the following.

- Transition element complexes are often coloured.

.....

.....

.....

.....

- The colour of a complex of a given transition element often changes when the ligands around it are changed.

.....

.....

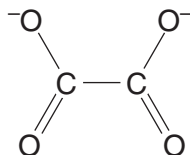
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[7]

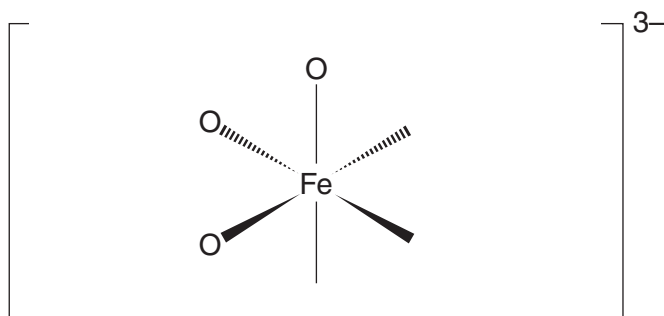
- (c) Heating a solution containing potassium ethanedioate, iron(II) ethanedioate and hydrogen peroxide produces the light green complex $\text{K}_3\text{Fe}(\text{C}_2\text{O}_4)_3$, which contains the ion $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$.

For
Examiner's
Use

The structure of the ethanedioate ion is as follows.

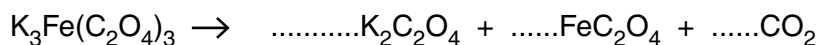


- (i) Calculate the oxidation number of carbon in this ion.
- (ii) Calculate the oxidation number of iron in $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$
- (iii) The iron atom in the $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ ion is surrounded octahedrally by six oxygen atoms. Complete the following **displayed** formula of this ion.



- (iv) In sunlight the complex decomposes into potassium ethanedioate, iron(II) ethanedioate and carbon dioxide.

Use oxidation numbers to help you balance the following equation for this decomposition.



[5]

[Total: 14]

- 4 (a) (i) Write the equation for a reaction in which ethylamine, $\text{C}_2\text{H}_5\text{NH}_2$, acts as a Brønsted-Lowry base.

.....

- (ii) Ammonia, ethylamine and phenylamine, $\text{C}_6\text{H}_5\text{NH}_2$, are three nitrogen-containing bases.

Place these three compounds in order of basicity, with the most basic first.

most basic		least basic

- (iii) Explain why you have placed the three compounds in this order.

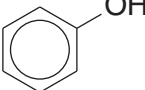
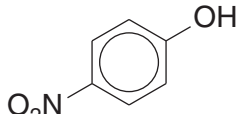
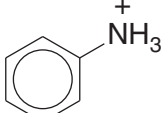
.....

[4]

- (b) (i) Write an equation for a reaction in which phenol, $\text{C}_6\text{H}_5\text{OH}$, acts as a Brønsted-Lowry acid.

.....

The $\text{p}K_{\text{a}}$ values for phenol, 4-nitrophenol and the phenylammonium ion are given in the table.

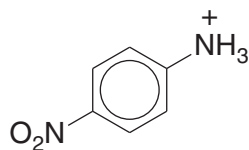
compound	$\text{p}K_{\text{a}}$
	10.0
	7.2
	4.6

- (ii) Suggest an explanation for the difference in the $\text{p}K_{\text{a}}$ values of phenol and nitrophenol.

.....

- (iii) Using the information in the table opposite, predict which of the following pK_a values is the most likely for the 4-nitrophenylammonium ion.

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Place a tick (✓) in the box beside the value you have chosen.

pK_a	
1.0	
4.5	
7.0	
10.0	

- (iv) Explain your answer to part (iii).

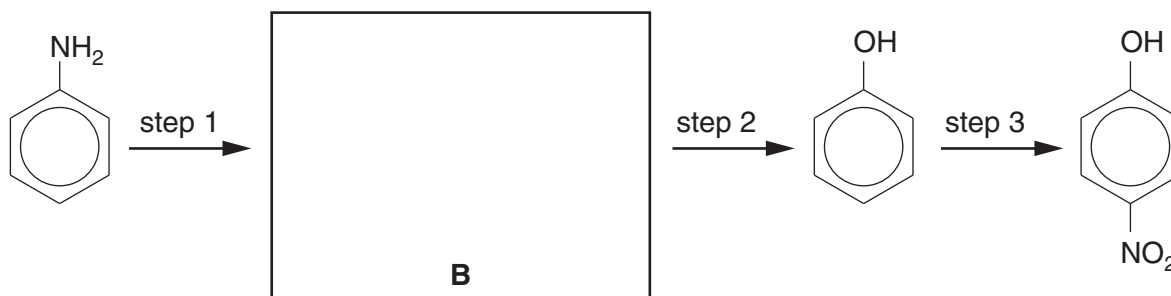
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[5]

- (c) Phenylamine can be converted to 4-nitrophenol by the following steps.



- (i) Suggest the identity of intermediate **B** by drawing its structure in the box above.
- (ii) Suggest reagents and conditions for the three steps in the above scheme.

	reagent(s)	conditions
step 1		
step 2		
step 3		

[5]

[Total: 14]

- 5 Compound **C** has the molecular formula $C_7H_{14}O$. Treating **C** with hot concentrated acidified $KMnO_4(aq)$ produces two compounds, **D**, C_4H_8O , and **E**, $C_3H_4O_3$. The results of four tests carried out on these three compounds are shown in the following table.

For
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Use

test reagent	result of test with		
	compound C	compound D	compound E
$Br_2(aq)$	decolourises	no reaction	no reaction
$Na(s)$	fizzes	no reaction	fizzes
$I_2(aq) + OH^-(aq)$	no reaction	yellow precipitate	yellow precipitate
2,4-dinitrophenylhydrazine	no reaction	orange precipitate	orange precipitate

- (a) State the functional groups which the above four reagents test for.

(i) $Br_2(aq)$

.....

(ii) $Na(s)$

.....

(iii) $I_2(aq) + OH^-(aq)$

.....

(iv) 2,4-dinitrophenylhydrazine

.....

[4]

- (b) Based upon the results of the above tests, suggest structures for compounds **D** and **E**.

D, C_4H_8O

E, $C_3H_4O_3$

[2]

(c) Compound **C** exists as two stereoisomers.

Draw the structural formula of **each** of the two isomers, and state the type of stereoisomerism involved.

For
Examiner's
Use

type of stereoisomerism
[3]

[Total: 9]

Section B

Answer **all** questions in the spaces provided.

For
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Use

- 6 Proteins exist in an enormous variety of sizes and structures in living organisms. They have a wide range of functions which are dependent upon their structures. The structure and properties of an individual protein are a result of the primary structure – the sequence of amino acids that form the protein.

(a) Proteins are described as condensation polymers.

- (i) Write a balanced equation for the condensation reaction between two glycine molecules, $\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$.

- (ii) Draw the skeletal formula for the organic product.

[2]

- (b) X-ray analysis has shown that in many proteins there are regions with a regular arrangement within the polypeptide chain. This is called the secondary structure and exists in two main forms.

- (i) State the two forms of secondary structure found in proteins.

.....

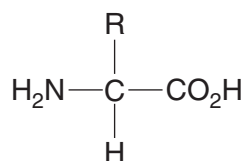
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- (ii) Draw a diagram to illustrate **one** form of secondary structure.

[4]

- (c) There are around 20 different common amino acids found in humans most of which have the same general structure.

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Examiner's
Use



The nature of the group R affects which bonds are formed as the secondary structure of the protein is further folded to give the tertiary structure.

Complete the table indicating the type of **tertiary** bonding that each pair of the amino acid residues is likely to produce.

residue 1	residue 2	type of tertiary bonding
$-\text{HNCH}(\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{CO}-$	$-\text{HNCH}(\text{CH}_2\text{CH}_2\text{CO}_2\text{H})\text{CO}-$	
$-\text{HNCH}(\text{CH}_3)\text{CO}-$	$-\text{HNCH}(\text{CH}_3)\text{CO}-$	
$-\text{HNCH}(\text{CH}_2\text{SH})\text{CO}-$	$-\text{HNCH}(\text{CH}_2\text{SH})\text{CO}-$	
$-\text{HNCH}(\text{CH}_2\text{OH})\text{CO}-$	$-\text{HNCH}(\text{CH}_2\text{CO}_2\text{H})\text{CO}-$	

[4]

[Total: 10]

- 7 One of the key areas of investigation in understanding the structures of polypeptides and proteins is the sequence of amino acids that make up the polypeptide chains.

For
Examiner's
Use

- (a) One of the methods used to determine the amino acids present in a polypeptide chain is electrophoresis.

Sketch and label the apparatus used to carry out electrophoresis.

[4]

- (b) In electrophoresis, different amino acids move in different directions and at different speeds.

- (i) What factors determine the *direction of travel* of an amino acid?

.....
.....
.....

- (ii) What factors determine the *speed of movement* of an amino acid?

.....
.....

[3]

(c) Another important technique used to examine the structure of proteins is X-ray crystallography. In this technique the position of individual atoms can be determined, and the distances between them measured.

(i) Hydrogen atoms never produce images using X-ray crystallography. Explain why this is the case.

.....
.....

(ii) Suggest and explain which one of the atoms in a molecule of cysteine, $\text{H}_2\text{NCH}(\text{CH}_2\text{SH})\text{CO}_2\text{H}$, would show up most clearly using X-ray crystallography.

.....
.....

[3]

[Total: 10]

- 8 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.

For
Examiner's
Use

- (a) Complete the table identifying one traditional material that has been replaced by each polymer.

traditional material	modern polymer and its use
	PVC in packaging
	<i>Terylene</i> in fabrics
	polycarbonate bottle

[2]

- (b) Throwing away articles made from polymers after use is a major environmental concern for **two** main reasons. Identify **each** of these reasons and suggest a strategy that has been adopted to try to overcome each of these.

reasons :

.....

.....

strategy 1 :

.....

strategy 2 :

.....

[3]

- (c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.

polymer

reason

.....

.....

[2]

- (d) Polymers can be either thermoplastic or thermosetting.

Name a thermoplastic polymer.

State which type of polymerisation produces thermoplastic polymers, explaining your answer in terms of the structure of the polymer.

.....

.....

.....

.....

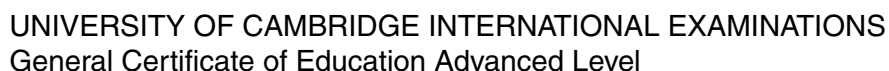
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[Total: 10]

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9701/42

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Section A

Answer **all** questions in the spaces provided.

For
Examiner's
Use

- 1 (a) The halogens chlorine and bromine react readily with hydrogen.



- (i) Describe how you could carry out this reaction using chlorine.

.....

- (ii) Describe **two** observations you would make if this reaction was carried out with bromine.

.....

.....

- (iii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^\ominus$ for this reaction when

X = Cl,

$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

X = Br.

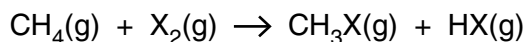
$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

- (iv) What is the major reason for the difference in these two $\Delta H^\ominus$ values?

.....

[8]

- (b) Some halogens also react readily with methane.



- (i) What conditions are needed to carry out this reaction when X is bromine, Br?

.....

- (ii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^\ominus$ of this reaction for the situation where X is iodine, I.

$$\Delta H^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$$

- (iii) Hence suggest why it is not possible to make iodomethane, CH_3I , by this reaction.

.....

[4]

- (c) Halogenoalkanes can undergo *homolytic fission* in the upper atmosphere.

- (i) Explain the term *homolytic fission*.

.....

.....

- (ii) Suggest the most likely organic radical that would be formed by the homolytic fission of bromochloromethane, CH_2BrCl . Explain your answer.

.....

.....

.....

[3]

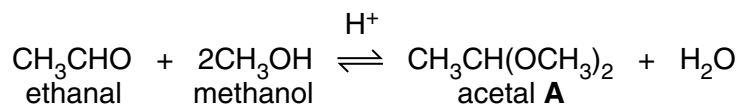
- (d) The reaction between propane and chlorine produces a mixture of many compounds, four of which are structural isomers with the molecular formula $\text{C}_3\text{H}_6\text{Cl}_2$. Draw the structural or skeletal formulae of these isomers, and indicate any chiral atoms with an asterisk (*).

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[Total: 18]

- 2 Acetals are compounds formed when aldehydes are reacted with an alcohol and an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

For
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Use



- (a) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	[CH ₃ CHO] / mol dm ⁻³	[CH ₃ OH] / mol dm ⁻³	[H ⁺] / mol dm ⁻³	relative rate
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3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

- (i) Use the data in the table to determine the order with respect to each reactant.

order with respect to [CH₃CHO]

order with respect to [CH₃OH]

order with respect to [H⁺]

- (ii) Use your results from part (i) to write the rate equation for the reaction.

.....

- (iii) State the units of the rate constant in the rate equation

- (iv) Calculate the relative rate of reaction for a mixture in which the starting concentrations of all three reactants are 0.20 mol dm⁻³.

relative rate = ...

[6]

- (b) The concentration of the acetal product was measured when experiment number 1 was allowed to reach equilibrium. The result is included in the following table.

For
Examiner's
Use

	$[\text{CH}_3\text{CHO}]$ /mol dm ⁻³	$[\text{CH}_3\text{OH}]$ /mol dm ⁻³	$[\text{H}^+]$ /mol dm ⁻³	[acetal A] /mol dm ⁻³	$[\text{H}_2\text{O}]$ /mol dm ⁻³
at start	0.20	0.10	0.05	0.00	0.00
at equilibrium	(0.20- <i>x</i>)			<i>x</i>	
at equilibrium				0.025	

- (i) Complete the second row of the table in terms of *x*, the concentration of acetal **A** at equilibrium. You may wish to consult the chemical equation opposite.
- (ii) Using the [acetal **A**] as given, 0.025 mol dm⁻³, calculate the equilibrium concentrations of the other reactants and products and write them in the third row of the table.
- (iii) Write the expression for the equilibrium constant for this reaction, K_c , stating its units.

$K_c = \dots\dots\dots$ units = $\dots\dots\dots$

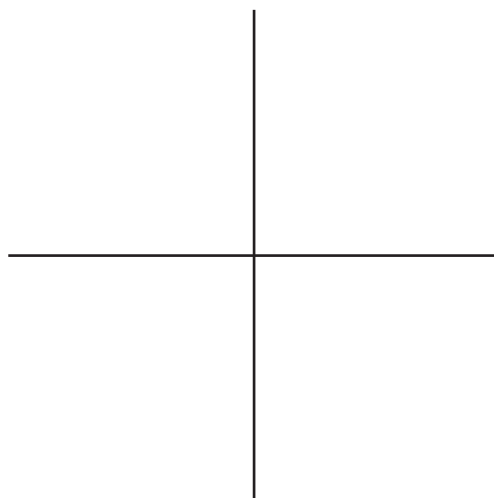
- (iv) Use your values in the third row of the table to calculate the value of K_c .

$K_c = \dots\dots\dots$
[9]

[Total: 15]

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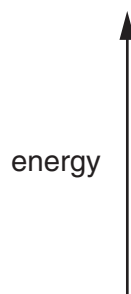
For
Examiner's
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[2]

- (b) Although the five d-orbitals are at the same energy in an isolated atom, when a transition element ion is in an octahedral complex the orbitals are split into two groups.

- (i) Draw an orbital energy diagram to show this, indicating the number of orbitals in each group.



- (ii) Use your diagram as an aid in explaining the following.

- Transition element complexes are often coloured.

.....

.....

.....

.....

- The colour of a complex of a given transition element often changes when the ligands around it are changed.

.....

.....

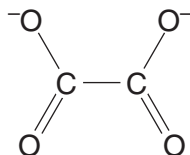
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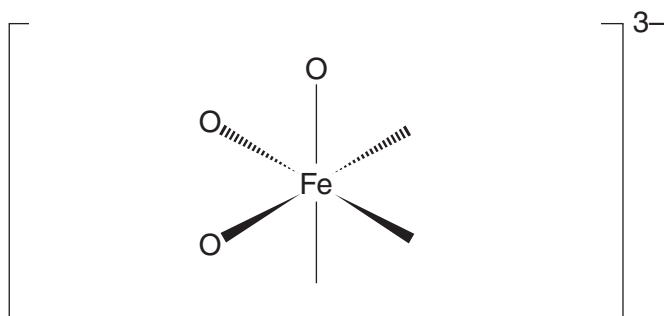
- (c) Heating a solution containing potassium ethanedioate, iron(II) ethanedioate and hydrogen peroxide produces the light green complex $\text{K}_3\text{Fe}(\text{C}_2\text{O}_4)_3$, which contains the ion $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$.

For
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Use

The structure of the ethanedioate ion is as follows.

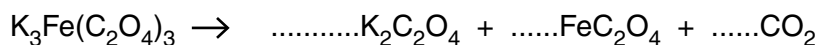


- (i) Calculate the oxidation number of carbon in this ion.
- (ii) Calculate the oxidation number of iron in $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$
- (iii) The iron atom in the $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ ion is surrounded octahedrally by six oxygen atoms. Complete the following **displayed** formula of this ion.



- (iv) In sunlight the complex decomposes into potassium ethanedioate, iron(II) ethanedioate and carbon dioxide.

Use oxidation numbers to help you balance the following equation for this decomposition.



[5]

[Total: 14]

- 4 (a) (i) Write the equation for a reaction in which ethylamine, $\text{C}_2\text{H}_5\text{NH}_2$, acts as a Brønsted-Lowry base.

.....

- (ii) Ammonia, ethylamine and phenylamine, $\text{C}_6\text{H}_5\text{NH}_2$, are three nitrogen-containing bases.

Place these three compounds in order of basicity, with the most basic first.

most basic		least basic

- (iii) Explain why you have placed the three compounds in this order.

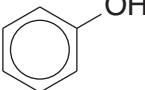
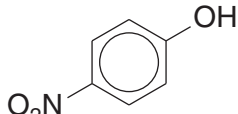
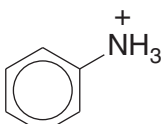
.....

[4]

- (b) (i) Write an equation for a reaction in which phenol, $\text{C}_6\text{H}_5\text{OH}$, acts as a Brønsted-Lowry acid.

.....

The $\text{p}K_{\text{a}}$ values for phenol, 4-nitrophenol and the phenylammonium ion are given in the table.

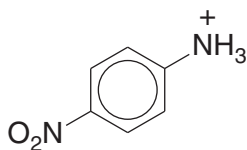
compound	$\text{p}K_{\text{a}}$
	10.0
	7.2
	4.6

- (ii) Suggest an explanation for the difference in the $\text{p}K_{\text{a}}$ values of phenol and nitrophenol.

.....

- (iii) Using the information in the table opposite, predict which of the following pK_a values is the most likely for the 4-nitrophenylammonium ion.

For
Examiner's
Use



Place a tick (✓) in the box beside the value you have chosen.

pK_a	
1.0	
4.5	
7.0	
10.0	

- (iv) Explain your answer to part (iii).

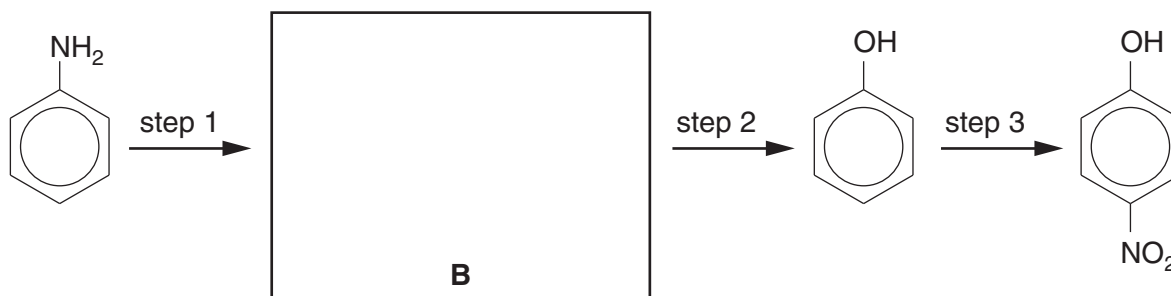
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.....

[5]

- (c) Phenylamine can be converted to 4-nitrophenol by the following steps.



- (i) Suggest the identity of intermediate **B** by drawing its structure in the box above.
- (ii) Suggest reagents and conditions for the three steps in the above scheme.

	reagent(s)	conditions
step 1		
step 2		
step 3		

[5]

[Total: 14]

- 5 Compound **C** has the molecular formula $C_7H_{14}O$. Treating **C** with hot concentrated acidified $KMnO_4(aq)$ produces two compounds, **D**, C_4H_8O , and **E**, $C_3H_4O_3$. The results of four tests carried out on these three compounds are shown in the following table.

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test reagent	result of test with		
	compound C	compound D	compound E
$Br_2(aq)$	decolourises	no reaction	no reaction
$Na(s)$	fizzes	no reaction	fizzes
$I_2(aq) + OH^-(aq)$	no reaction	yellow precipitate	yellow precipitate
2,4-dinitrophenylhydrazine	no reaction	orange precipitate	orange precipitate

- (a) State the functional groups which the above four reagents test for.

(i) $Br_2(aq)$

.....

(ii) $Na(s)$

.....

(iii) $I_2(aq) + OH^-(aq)$

.....

(iv) 2,4-dinitrophenylhydrazine

.....

[4]

- (b) Based upon the results of the above tests, suggest structures for compounds **D** and **E**.

D, C_4H_8O

E, $C_3H_4O_3$

[2]

(c) Compound **C** exists as two stereoisomers.

Draw the structural formula of **each** of the two isomers, and state the type of stereoisomerism involved.

For
Examiner's
Use

type of stereoisomerism

[3]

[Total: 9]

Section B

Answer **all** questions in the spaces provided.

For
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Use

- 6 Proteins exist in an enormous variety of sizes and structures in living organisms. They have a wide range of functions which are dependent upon their structures. The structure and properties of an individual protein are a result of the primary structure – the sequence of amino acids that form the protein.

(a) Proteins are described as condensation polymers.

- (i) Write a balanced equation for the condensation reaction between two glycine molecules, $\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$.

- (ii) Draw the skeletal formula for the organic product.

[2]

- (b) X-ray analysis has shown that in many proteins there are regions with a regular arrangement within the polypeptide chain. This is called the secondary structure and exists in two main forms.

- (i) State the two forms of secondary structure found in proteins.

.....

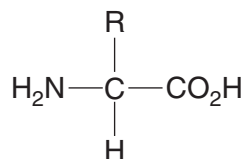
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- (ii) Draw a diagram to illustrate **one** form of secondary structure.

[4]

- (c) There are around 20 different common amino acids found in humans most of which have the same general structure.

For
Examiner's
Use



The nature of the group R affects which bonds are formed as the secondary structure of the protein is further folded to give the tertiary structure.

Complete the table indicating the type of **tertiary** bonding that each pair of the amino acid residues is likely to produce.

residue 1	residue 2	type of tertiary bonding
$-\text{HNCH}(\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{CO}-$	$-\text{HNCH}(\text{CH}_2\text{CH}_2\text{CO}_2\text{H})\text{CO}-$	
$-\text{HNCH}(\text{CH}_3)\text{CO}-$	$-\text{HNCH}(\text{CH}_3)\text{CO}-$	
$-\text{HNCH}(\text{CH}_2\text{SH})\text{CO}-$	$-\text{HNCH}(\text{CH}_2\text{SH})\text{CO}-$	
$-\text{HNCH}(\text{CH}_2\text{OH})\text{CO}-$	$-\text{HNCH}(\text{CH}_2\text{CO}_2\text{H})\text{CO}-$	

[4]

[Total: 10]

- 7 One of the key areas of investigation in understanding the structures of polypeptides and proteins is the sequence of amino acids that make up the polypeptide chains.

For
Examiner's
Use

- (a) One of the methods used to determine the amino acids present in a polypeptide chain is electrophoresis.

Sketch and label the apparatus used to carry out electrophoresis.

[4]

- (b) In electrophoresis, different amino acids move in different directions and at different speeds.

- (i) What factors determine the *direction of travel* of an amino acid?

.....
.....
.....

- (ii) What factors determine the *speed of movement* of an amino acid?

.....
.....

[3]

(c) Another important technique used to examine the structure of proteins is X-ray crystallography. In this technique the position of individual atoms can be determined, and the distances between them measured.

(i) Hydrogen atoms never produce images using X-ray crystallography. Explain why this is the case.

.....
.....

(ii) Suggest and explain which one of the atoms in a molecule of cysteine, $\text{H}_2\text{NCH}(\text{CH}_2\text{SH})\text{CO}_2\text{H}$, would show up most clearly using X-ray crystallography.

.....
.....

[3]

[Total: 10]

- 8 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.

For
Examiner's
Use

- (a) Complete the table identifying one traditional material that has been replaced by each polymer.

traditional material	modern polymer and its use
	PVC in packaging
	<i>Terylene</i> in fabrics
	polycarbonate bottle

[2]

- (b) Throwing away articles made from polymers after use is a major environmental concern for **two** main reasons. Identify **each** of these reasons and suggest a strategy that has been adopted to try to overcome each of these.

reasons :

.....

.....

strategy 1 :

.....

strategy 2 :

.....

[3]

- (c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.

polymer

reason

.....

.....

[2]

- (d) Polymers can be either thermoplastic or thermosetting.

Name a thermoplastic polymer.

State which type of polymerisation produces thermoplastic polymers, explaining your answer in terms of the structure of the polymer.

.....

.....

.....

.....

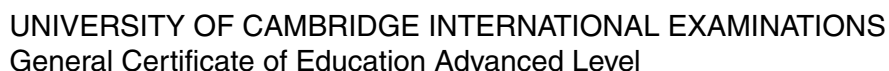
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[Total: 10]

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9701/43

October/November 2011

2 hours

Additional Materials: Data Booklet

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO NOT WRITE ON ANY BARCODES.

Answer **all** questions.

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [] at the end of each question or part question.

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2	
3	
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6	
7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.

Section A

Answer **all** questions in the spaces provided.

For
Examiner's
Use

- 1 (a) Complete the electronic configurations of the following ions.

Cr³⁺: 1s²2s²2p⁶.....

Mn²⁺: 1s²2s²2p⁶.....

[2]

- (b) Both KMnO₄ and K₂Cr₂O₇ are used as oxidising agents, usually in acidic solution.

- (i) Use information from the *Data Booklet* to explain why their oxidising power increases as the [H⁺(aq)] in the solution increases.

.....
.....
.....

- (ii) What colour changes would you observe when each of these oxidising agents is completely reduced?

- KMnO₄ from to
- K₂Cr₂O₇ from..... to

[4]

- (c) Manganese(IV) oxide, MnO₂, is a dark brown solid, insoluble in water and dilute acids. Passing a stream of SO₂(g) through a suspension of MnO₂ in water does, however, cause it to dissolve, to give a colourless solution.

- (i) Use the *Data Booklet* to suggest an equation for this reaction, and explain what happens to the oxidation states of manganese and of sulfur during the reaction.

.....
.....
.....

- (ii) The pH of the suspension of MnO₂ is reduced. Explain what effect, if any, this would have on the extent of this reaction.

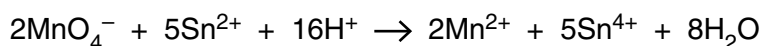
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[4]

- (d) The main ore of manganese, pyrolusite, is mainly MnO_2 . A solution of SnCl_2 can be used to estimate the percentage of MnO_2 in a sample of pyrolusite, using the following method.
- A known mass of pyrolusite is warmed with an acidified solution containing a known amount of SnCl_2 .
 - The excess $\text{Sn}^{2+}(\text{aq})$ ions are titrated with a standard solution of KMnO_4 .

In one such experiment, 0.100 g of pyrolusite was warmed with an acidified solution containing $2.00 \times 10^{-3} \text{ mol Sn}^{2+}$. After the reaction was complete, the mixture was titrated with $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4$, and required 18.1 cm^3 of this solution to reach the end point.

The equation for the reaction between $\text{Sn}^{2+}(\text{aq})$ and $\text{MnO}_4^{-}(\text{aq})$ is as follows.



- (i) Use the *Data Booklet* to construct an equation for the reaction between MnO_2 and Sn^{2+} ions in acidic solution.
-

- (ii) Calculate the percentage of MnO_2 in this sample of pyrolusite by the following steps.

- number of moles of MnO_4^{-} used in the titration
- number of moles of Sn^{2+} this MnO_4^{-} reacted with
- number of moles of Sn^{2+} that reacted with the 0.100 g sample of pyrolusite
- number of moles of MnO_2 in 0.100 g pyrolusite. Use your equation in (i).
- mass of MnO_2 in 0.100 g pyrolusite
- percentage of MnO_2 in pyrolusite

percentage = ...%

[6]

[Total: 16]

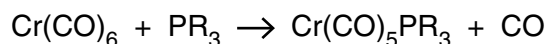
- 2 (a) (i) What is meant by the term *ligand* as applied to the chemistry of the transition elements?

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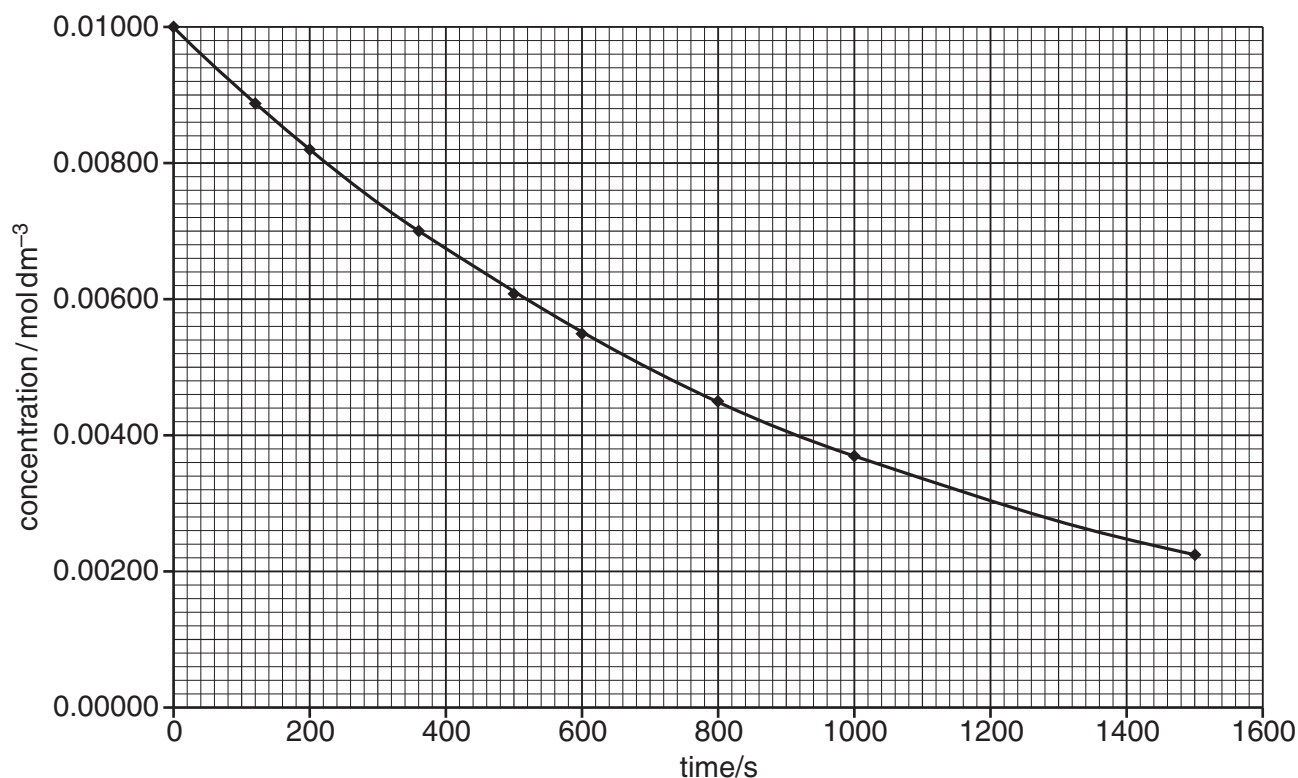
- (ii) Describe the type of bonding that occurs between a ligand and a transition element.

[2]

- (b) Chromium hexacarbonyl undergoes the following ligand replacement reaction.



Two separate experiments were carried out to study the rate of this reaction. In the first experiment, the ligand PR_3 was in a large excess and $[\text{Cr(CO)}_6]$ was measured with time. The results are shown on the graph below.



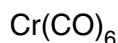
In the second experiment, Cr(CO)_6 was in a large excess, and $[\text{PR}_3]$ was measured with time. The following results were obtained.

time/s	$[\text{PR}_3]/\text{mol dm}^{-3}$
0	0.0100
120	0.0076
200	0.0060
360	0.0028

- (i) Plot the data in the table on the graph above, using the same axis scales, and draw the best-fit line through your points.

- (ii) Use the graphs to determine the order of reaction with respect to Cr(CO)_6 and PR_3 . In each case explain how you arrived at your answer.

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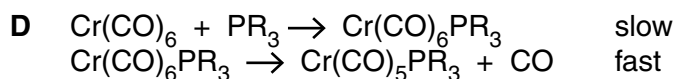
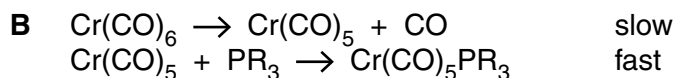
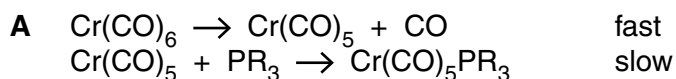
- (iii) Write the rate equation for the reaction, and calculate a value for the rate constant, using the method of initial rates, or any other method you prefer.

.....
.....
.....
.....

- (iv) State the units of the rate constant.

.....

- (v) Four possible mechanisms for this reaction are given below. Draw a **circle** around the letter next to the **one** mechanism which is consistent with the rate equation you have written in (iii).



Explain your answer.

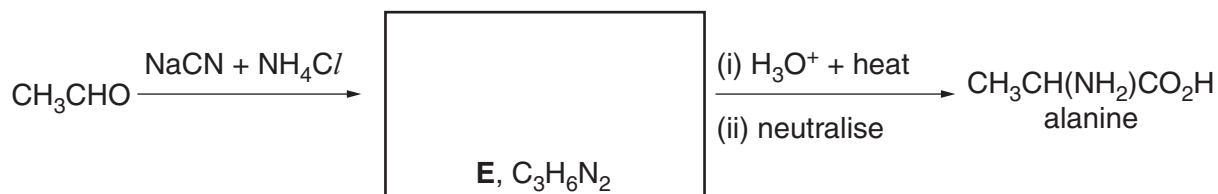
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[9]

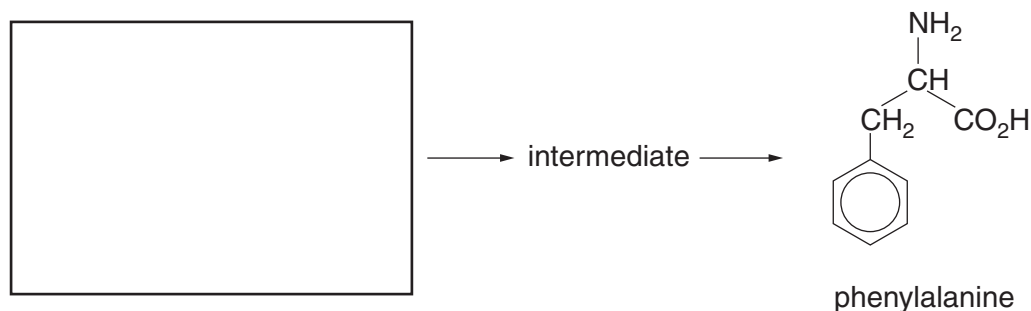
[Total: 11]

- 3 (a) Amino acids such as alanine are essential building blocks for making proteins. They can be synthesised by a general reaction of which the following is an example.

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Use



- (i) Suggest the structure of the intermediate compound **E** by drawing its structural formula in the box above.
- (ii) Suggest, in the box below, the structural formula of the starting material needed to synthesise phenylalanine by the above general reaction.



[2]

- (b) (i) What is a *protein*?

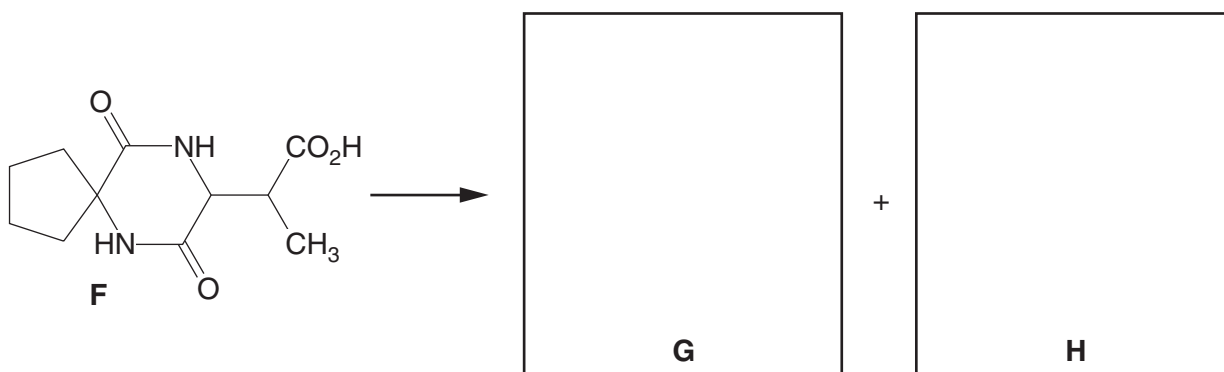
.....

- (ii) Using alanine as an example, draw a diagram to show how proteins are formed from amino acids. Show two repeat units in your answer.

[3]

(c) The hydrolysis of compound **F** produces two compounds **G** and **H**.

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(i) State the reagents and conditions needed for this hydrolysis.

.....

(ii) Draw the structures of the two products **G** and **H** in the boxes above.

[3]

(d) (i) Draw the zwitterionic structure of alanine.

(ii) Suggest the structural formulae of the zwitterions that could be formed from the following compounds.

compound	zwitterion

[4]

(e) Solutions of amino acids are good buffers.

(i) What is meant by the term *buffer*?

.....

(ii) Write an equation to show how a solution of alanine, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$, behaves as a buffer in the presence of an acid such as $\text{HCl}(\text{aq})$.

.....

(iii) Briefly describe how the pH of blood is controlled.

.....

.....

.....

(iv) Calculate the pH of the buffer formed when 10.0cm^3 of 0.100mol dm^{-3} NaOH is added to 10.0cm^3 of 0.250mol dm^{-3} $\text{CH}_3\text{CO}_2\text{H}$, whose $\text{p}K_{\text{a}} = 4.76$.

pH = ...
[7]

[Total: 19]

- 4 (a) Write an equation representing the action of heat on calcium nitrate, $\text{Ca}(\text{NO}_3)_2$.

.....
[1]

- (b) Describe and explain the trend in the thermal stabilities of the nitrates of the Group II elements.

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

- (c) Sodium carbonate is stable to heat, but heating lithium carbonate readily produces $\text{CO}_2(\text{g})$.

- (i) Suggest an equation for the action of heat on lithium carbonate.

.....

- (ii) Suggest a reason for the difference in reactivity of these two carbonates.

.....
.....

- (iii) Predict what you would see if a sample of lithium nitrate was heated. Explain your answer.

.....
.....
.....

[4]

[Total: 8]

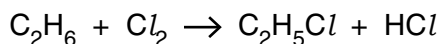
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- 5 Alkanes are generally considered to be unreactive compounds, showing an inertness to common reagents such as NaOH, H₂SO₄, and K₂Cr₂O₇.

(a) Suggest a reason why these reagents **do not** attack an alkane such as CH₄.

.....
[1]

- (b) When a mixture of chlorine and ethane gas is exposed to strong sunlight, an explosion can occur due to the fast exothermic reaction.
Under more controlled conditions, however, the following reaction occurs.



(i) What is the name of this type of reaction?

.....

(ii) Use equations to describe the mechanism of this reaction, naming the steps involved.

.....
.....
.....
.....
.....
.....

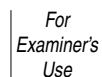
(iii) This reaction can produce organic by-products, in addition to C₂H₅Cl.
Draw the structural formulae of three possible organic by-products. Two of your by-products should contain 4 carbon atoms per molecule.
Briefly describe how each by-product could be formed.

structural formula of by-product	formed by

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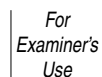
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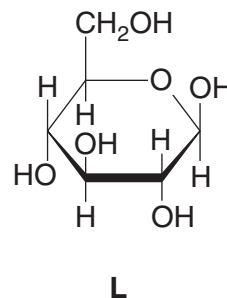
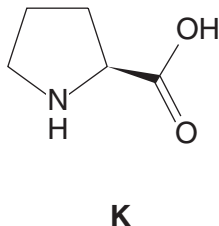
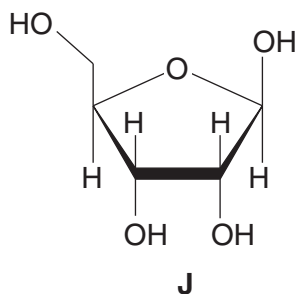
Section B

Answer **all** questions in the spaces provided.

For
Examiner's
Use

- 6 The formation of proteins is a key process in the growth and repair of tissues in living organisms.

- (a) (i) Study the structures of the three molecules below. One of the molecules could be a building block for a protein while the other two could be building blocks for other biological polymers.



Which of the three could be a building block for a protein? Explain your answer.

.....

- (ii) For which biological polymer could **one** of the other molecules form a building block?

molecule **polymer**

[2]

- (b) Protein molecules have four levels of structure as the long molecules fold and take shape.

- (i) The primary structure is the sequence of amino acids in the protein chain. What type of bonding exists between the amino acids in this chain?

.....

- (ii) What type of bonding can exist in **all** of the other types of structure?

.....

- (iii) Name one type of bonding that does **not** occur in the primary or secondary structure of the protein.

.....

[3]

- (c) Many proteins play an important role in catalysing chemical reactions in living organisms.

*For
Examiner's
Use*

- (i) What name is given to these catalysts?

.....

- (ii) Give **two** changes in conditions under which these catalysts may be inactivated, explaining the chemical reason for this in each case.

.....

.....

.....

.....

.....

.....

[4]

[Total: 9]

- 7** Different analytical techniques are used to build up a picture of complex molecules. Each technique on its own provides different information about complex molecules but together the techniques can give valuable structural information.

For
Examiner's
Use

- (a)** Complete the table, identifying the technique which can provide the appropriate structural information.

structural information	analytical technique
three-dimensional arrangement of atoms and bonds in a molecule	
chemical environment of protons in a molecule	
identity of amino acids present in a polypeptide	

[3]

- (b)** One general method of separating organic molecules is chromatography. Briefly explain the chemical principles involved in each of the following techniques.

- (i)** paper chromatography

.....

.....

.....

- (ii)** thin-layer chromatography

.....

.....

.....

[2]

- (c) A combination of mass spectrometry and NMR spectroscopy is often enough to determine the structure of a simple organic compound.

The organic compound **N** produced a mass spectrum in which the ratio of the $M:M+1$ peaks was 5.9:0.20, and which had an $M+2$ peak of similar height to the M peak.

- (i) Calculate how many carbon atoms are present in one molecule of **N**.

- (ii) Deduce which element, other than carbon and hydrogen, is present in **N**.

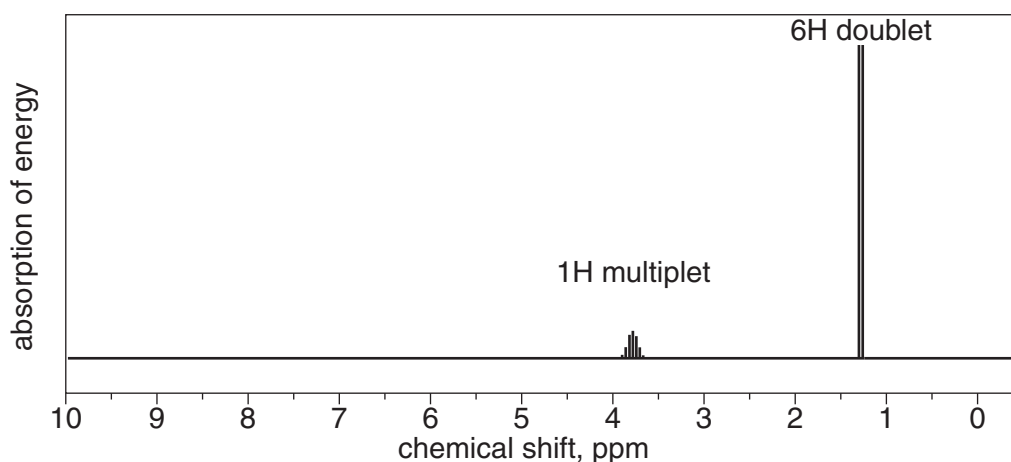
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- (iii) Explain how many atoms of this element are present in one molecule of **N**.

.....

.....

The NMR spectrum of **N** is shown.



- (iv) State the empirical formula of **N** and, using the NMR data, suggest the structural formula of **N**, explaining your reasons.

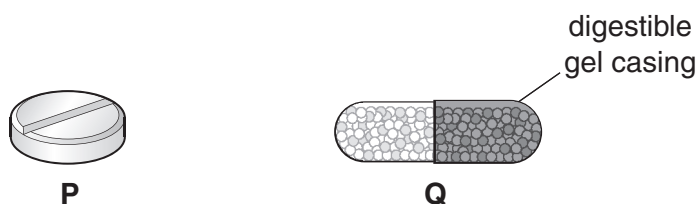
[6]

[Total: 11]

- 8 Drugs can be delivered in a number of ways. The method chosen depends both on the nature of the drug, and the problem it is being used to treat.

For
Examiner's
Use

- (a) Many common drugs are taken by mouth in forms similar to those shown.



- (i) Some drugs are available in solution. How would the speed of action of this form compare with **P** and **Q**? Explain your answer.

.....
.....

- (ii) Explain which of the two forms, **P** or **Q**, would act the most rapidly when taken by mouth.

.....
.....

- (iii) Some drugs are broken down before they can be absorbed by the intestine. Suggest how the design of **Q** prevents this.

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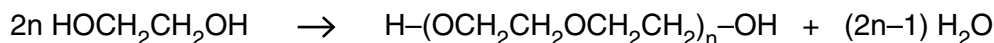
[3]

- (b) After an abdominal operation drugs are often delivered by means of a 'drip' inserted into a blood vessel in the patient's arm. Explain why this is more effective than taking painkillers by mouth.

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[2]

- (c) One of the molecules that has found a variety of uses in drug delivery is poly(ethylene glycol) or PEG. It is formed from dihydroxyethane, $\text{HOCH}_2\text{CH}_2\text{OH}$.



- (i) What type of reaction is this?

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Attaching a PEG molecule to a drug increases the time that it takes for the drug to be broken down and flushed from the body. There are thought to be two major reasons for this: firstly the PEG can form bonds to slow the passage of the drug around the body; secondly it may reduce the efficiency of breakdown of the drug by enzymes.

- (ii) What type of bonds would the PEG part of the molecule form with molecules in the body?

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- (iii) Suggest why attaching a PEG molecule to a drug molecule would reduce the rate of the drug's decomposition by enzymes.

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- (iv) Drugs are often protein or polypeptide molecules. What type of reaction might occur in the breakdown of such a drug?

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[5]

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