Write your name here

Surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Friday 19 January 2018 – Morning
Time: 1 hour 40 minutes

Paper Reference
WCH05/01

Candidates must have: Scientific calculator
Data Booklet

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

P51947A

6/5/5/5/1/

P 5 1 9 4 7 A 0 1 3 2

Pearson

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which electrode and solution would be used to measure the standard electrode potential of the manganese(III)/manganese(II) half-cell?

$$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$$

	Electrode	Solution
☒ **A**	manganese	1 mol dm^{-3} $Mn^{3+}(aq)$
☒ **B**	manganese	1 mol dm^{-3} with respect to $Mn^{3+}(aq)$ and $Mn^{2+}(aq)$
☒ **C**	platinum	1 mol dm^{-3} $Mn^{3+}(aq)$
☒ **D**	platinum	1 mol dm^{-3} with respect to $Mn^{3+}(aq)$ and $Mn^{2+}(aq)$

(Total for Question 1 = 1 mark)

2 In which pair of species are the oxidation numbers of the d-block elements the same?

☒ **A** $[Cr(NH_3)_4Cl_2]^+$ and $[Mn(H_2O)_6]^{2+}$

☒ **B** CrO_4^{2-} and $TiCl_3$

☒ **C** Cr_2O_3 and $[Fe(CN)_6]^{3-}$

☒ **D** $Cr_2O_7^{2-}$ and MnO_4^-

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

3 One mole of metal ions reacted in solution with one mole of sulfur dioxide.
The half-equation for the sulfur dioxide reaction is

$$SO_2(aq) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$$

The original oxidation number of the metal was +3. What was the oxidation number of the metal after the reaction?

☒ **A** +1

☒ **B** +2

☒ **C** +4

☒ **D** +5

(Total for Question 3 = 1 mark)

4 This question concerns four complexes.

(a) Which complex has a tetrahedral structure?

(1)

☒ **A** $[CrCl_4]^-$

☒ **B** $[CuCl_2]^-$

☒ **C** $[Pt(NH_3)_2Cl_2]$

☒ **D** $[TiCl_6]^{2-}$

(b) Which complex contains a metal in the +1 oxidation state?

(1)

☒ **A** $[CrCl_4]^-$

☒ **B** $[CuCl_2]^-$

☒ **C** $[Pt(NH_3)_2Cl_2]$

☒ **D** $[TiCl_6]^{2-}$

(Total for Question 4 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

5 An ion of metal M has a charge of +n. It forms a complex ion with a charged bidentate ligand, L.

(a) The formula of the complex ion formed between the metal ion and the bidentate ligand is $[ML_2]^{(+n-4)}$. What is the charge on ligand L?

(1)

☒ **A** +2

☒ **B** 0

☒ **C** –2

☒ **D** –4

(b) Another complex ion can be formed in which both of the bidentate ligands L, in $[ML_2]^{(+n-4)}$, are replaced by the neutral monodentate ligand Z.
What is the formula of the complex ion?

(1)

☒ **A** $[MZ_2]^{n+}$

☒ **B** $[MZ_2]^{2n+}$

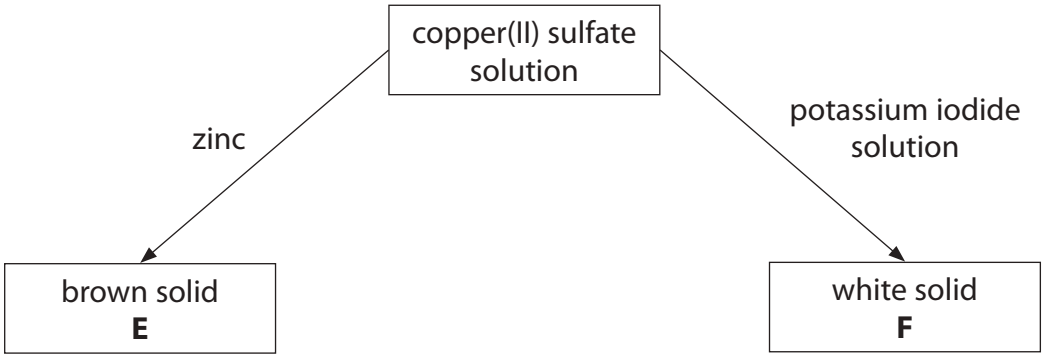
☒ **C** $[MZ_4]^{n+}$

☒ **D** $[MZ_4]^{2n+}$

(Total for Question 5 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

6 Two reactions of copper(II) sulfate solution are shown.



(a) What is the insoluble brown solid **E**?

(1)

- ☒ **A** Copper
- ☒ **B** Copper(I) oxide
- ☒ **C** Copper(II) oxide
- ☒ **D** Zinc sulfate

(b) What is the insoluble white solid **F**?

(1)

- ☒ **A** Copper
- ☒ **B** Copper(I) iodide
- ☒ **C** Copper(II) iodide
- ☒ **D** Potassium sulfate

(Total for Question 6 = 2 marks)

7 When benzene reacts with a mixture of concentrated nitric and sulfuric acids, the reaction is

- ☒ **A** electrophilic addition.
- ☒ **B** electrophilic substitution.
- ☒ **C** nucleophilic addition.
- ☒ **D** nucleophilic substitution.

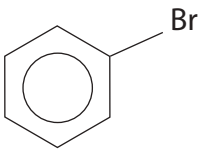
(Total for Question 7 = 1 mark)

8 Benzene and phenol react with bromine.

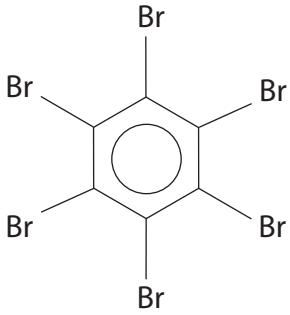
(a) What is the organic product when benzene reacts with excess bromine in the presence of ultraviolet light?

(1)

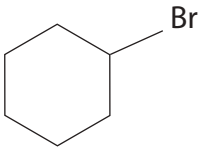
☒ **A**



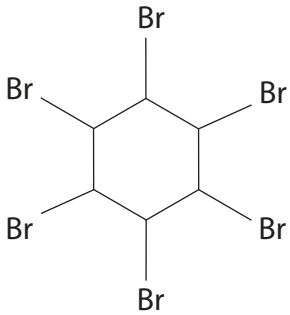
☒ **B**



☒ **C**



☒ **D**



(b) Bromine reacts more readily with phenol than with benzene. This is because the

(1)

☒ **A** benzene ring in phenol is more susceptible to nucleophilic attack.

☒ **B** benzene ring in phenol is deactivated because the oxygen of the OH group is very electronegative.

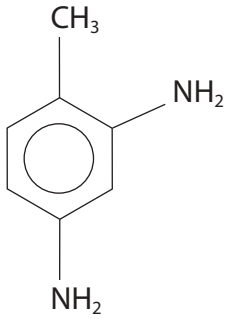
☒ **C** lone pair of electrons on the oxygen atom in phenol overlap with the delocalised electrons in the benzene ring.

☒ **D** lone pair of electrons on the oxygen atom enable phenol to act as an electrophile.

(Total for Question 8 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

9 The structure of compound **G** is



(a) What is the systematic name of compound **G**?

(1)

☒ **A** 4-methylbenzene-1,3-diamine

☒ **B** 4-methylbenzene-1,5-diamine

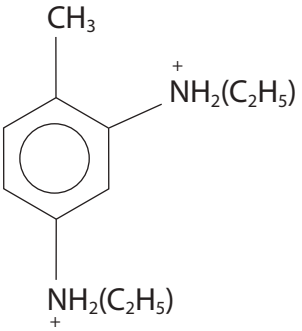
☒ **C** 2-methylphenyldiamine

☒ **D** 4-methylphenyldiamine

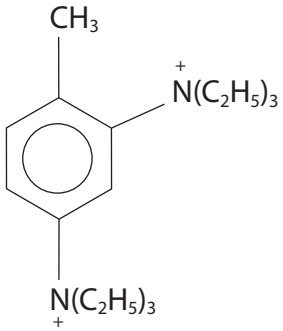
(b) What is the organic species formed in the reaction between compound **G** and **excess** ethanoyl chloride?

(1)

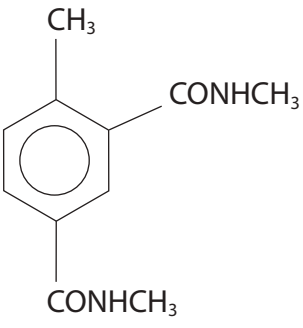
☒ **A**



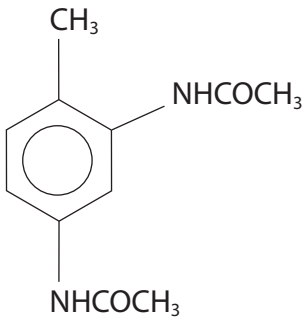
☒ **B**



☒ **C**

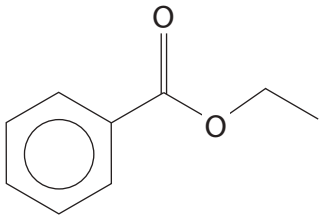


☒ **D**

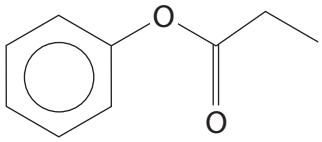


(Total for Question 9 = 2 marks)

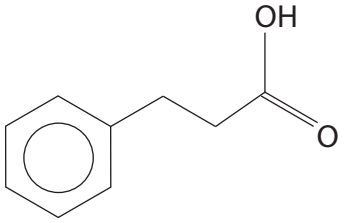
10 Four different compounds, **P**, **Q**, **R** and **S**, are structural isomers with molecular formula $C_9H_{10}O_2$.



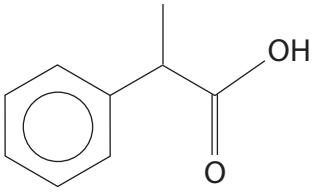
compound **P**



compound **Q**



compound **R**



compound **S**

(a) Which compound does **not** exhibit optical isomerism but does react with sodium hydrogencarbonate to give a colourless gas?

(1)

☒ **A** Compound **P**

☒ **B** Compound **Q**

☒ **C** Compound **R**

☒ **D** Compound **S**

(b) Which compound reacts with sodium hydroxide solution to give sodium benzoate as one of the products?

(1)

☒ **A** Compound **P**

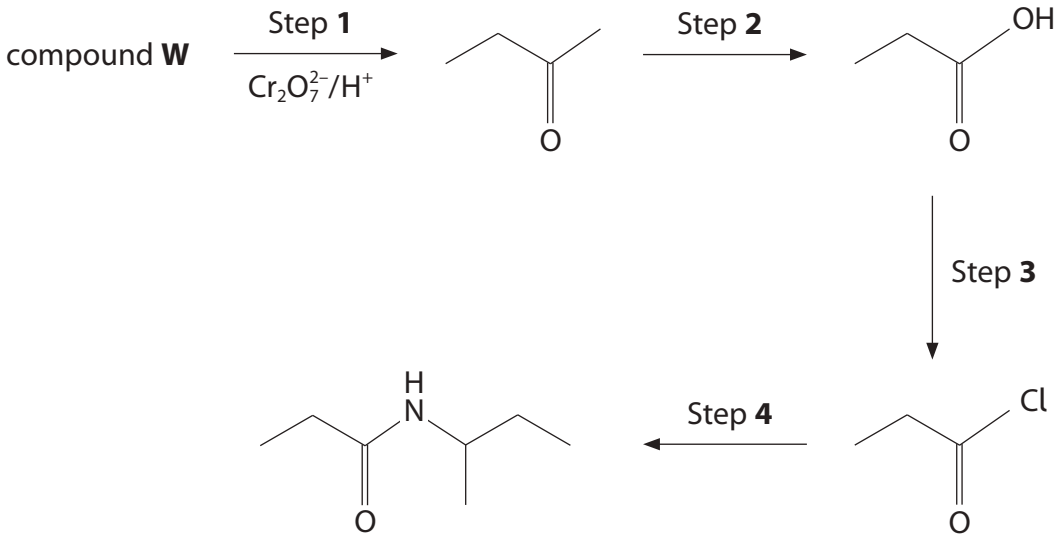
☒ **B** Compound **Q**

☒ **C** Compound **R**

☒ **D** Compound **S**

(Total for Question 10 = 2 marks)

11 A reaction sequence is shown.



(a) What is compound **W**?

(1)

☒ **A** Butan-1-ol

☒ **B** Butan-2-ol

☒ **C** 2-methylpropan-1-ol

☒ **D** 2-methylpropan-2-ol

(b) Which substances are required for Step **2**?

(1)

☒ **A** Acidified potassium dichromate(VI)

☒ **B** Iodine in alkali, followed by hydrochloric acid

☒ **C** Sodium hydroxide solution followed by hydrochloric acid

☒ **D** Ammoniacal silver nitrate (Tollens' reagent)

(c) Which is the reagent for Step **3**?

(1)

☒ **A** Aqueous chlorine

☒ **B** Chlorine gas

☒ **C** Hydrochloric acid

☒ **D** Phosphorus(V) chloride

(d) Which is the reagent for Step **4**?

(1)

☒ **A** $CH_3CH_2CH_2CH_2NH_2$

☒ **B** $CH_3CH(NH_2)CH_2CH_3$

☒ **C** $CH_3CH_2CH_2CONH_2$

☒ **D** $CH_3CH(CONH_2)CH_3$

(Total for Question 11 = 4 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

12 Aluminium and iron are both metallic elements. There are similarities and differences in the properties of their compounds.

(a) Both elements form compounds in which their oxidation number is +3.

(i) Complete the electronic configuration of the Al^{3+} and Fe^{3+} ions, using the s, p, d notation.

(2)

Al^{3+} $1s^2$ .....

Fe^{3+} $1s^2$ .....

(ii) Aluminium only forms compounds in which its oxidation number is +3, whereas iron has compounds with a variety of oxidation numbers. Suggest a reason why iron forms stable compounds with more than one oxidation number.

(1)

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*(b) Most aluminium compounds are colourless but iron(III) compounds are coloured.

Explain why $[Fe(H_2O)_6]^{3+}$ ions are coloured.

(4)

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(c) Aluminium ions and iron(III) ions form complexes in solution.
These solutions are acidic.

(i) Draw the structure of the $[Fe(H_2O)_6]^{3+}$ complex ion, showing clearly the shape around the Fe^{3+} ion, and which atoms in the ligands are attached to the Fe^{3+} ion.

(2)

*(ii) The following equilibrium occurs in aqueous solution

$$[Fe(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Fe(OH)(H_2O)_5]^{2+} + H_3O^+$$

Suggest why one of the water ligands loses a proton.

(2)

.....

.....

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.....

(d) Aluminium chloride, $AlCl_3$, and iron(III) chloride, $FeCl_3$, can both be used as catalysts in Friedel-Crafts reactions.

The reaction between benzene and chloromethane, using an aluminium chloride catalyst, can be summarised as

$$C_6H_6 + CH_3Cl + AlCl_3 \rightarrow C_6H_6CH_3^+ + AlCl_4^-$$

$$C_6H_6CH_3^+ + AlCl_4^- \rightarrow C_6H_5CH_3 + HCl + AlCl_3$$

Suggest, by reference to the electronic structure of $AlCl_3$, how the $AlCl_4^-$ ion forms.

(2)

.....

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.....

.....

(e) Thiocyanate ions, SCN^-, are used to test for the presence of Fe^{3+} ions in aqueous solution. A blood red colour, caused by the complex ion $[Fe(SCN)(H_2O)_5]^{2+}$, is seen.

(i) State the type of reaction taking place.

(1)

.....

(ii) Draw a dot-and-cross diagram of the thiocyanate ion, $[SCN]^-$.
Hence suggest a structure of the ion, showing all the bonds and which atom has the negative charge.

(2)

(iii) Suggest **two** ways in which the thiocyanate ion could bond to the Fe^{3+} in the complex.

(1)

.....

.....

(f) Aluminium hydroxide, $Al(OH)_3$, is amphoteric.

Write **ionic** equations for the reactions of aluminium hydroxide with hydrochloric acid and with sodium hydroxide solution.
State symbols are not required.

(2)

Ionic equation with hydrochloric acid

Ionic equation with sodium hydroxide solution

(Total for Question 12 = 19 marks)

13 This question is about carboxylic acids.

(a) An organic compound, **T**, contains the elements carbon, hydrogen and oxygen only. **T** contains a carboxylic acid group and one other functional group.

*(i) A sample of compound **T** of mass 2.25 g was burned completely, producing 3.30 g of carbon dioxide and 1.35 g of water. In the mass spectrum of compound **T**, the molecular ion peak is at $m/e = 90$.

Use all the data to calculate the molecular formula of compound **T**.
You **must** show your working.

(6)

(ii) The mass spectrum of compound **T** has a peak at *m*/*e* = 45.

Give the **displayed formulae** of **two** species that could produce this peak.

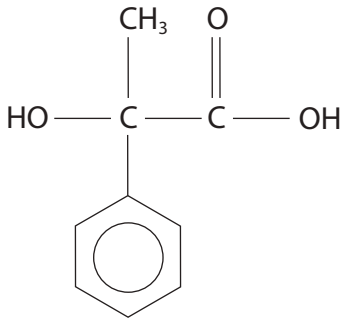
(2)

(iii) The low resolution proton nmr spectrum of compound **T** has four peaks with areas in the ratio 1 : 2 : 2 : 1.

Draw the structure of compound **T** and explain how your structure is consistent with the proton nmr data.

(3)

(b) The structure of 2-hydroxy-2-phenylpropanoic acid is shown.



*(i) Outline how 2-hydroxy-2-phenylpropanoic acid can be synthesised in **three** steps starting from benzene and an acyl chloride.

Include the reagents for each step in the synthesis and draw the structures of the two organic intermediates.

(5)

(ii) Poly(2-hydroxy-2-phenylpropanoic acid) is a possible biodegradable polymer.

Draw a section of this polymer, showing **two** repeat units.

(2)

(Total for Question 13 = 18 marks)

14 This question is about redox reactions.

(a) Vanadium exists in different oxidation states which can be interconverted using suitable oxidising and reducing agents.

Some relevant standard electrode potentials are shown in the table.

Half-equation	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons SO_2(aq) + 2H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00

(i) Write the overall half-equation for the oxidation of vanadium(II) ions to the vanadium(V) ions, VO_2^+. State symbols are not required.

(1)

(ii) Select, from the table, a reducing agent which should reduce vanadium(V) to vanadium(IV) but not to vanadium(III). Justify your answer.

(3)

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(iii) Write the balanced equation for the disproportionation of V^{3+} into V^{2+} and VO^{2+} and explain whether this reaction is feasible under standard conditions. State symbols are not required.

(3)

(b) Excess potassium iodide solution was added to 25.0 cm^3 of an aqueous solution of bromine.

$$Br_2 + 2I^- \rightarrow 2Br^- + I_2$$

The iodine produced was titrated with sodium thiosulfate solution. All of the iodine required 24.20 cm^3 of 0.100 mol dm^{-3} sodium thiosulfate solution for reaction.

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

(i) Calculate the concentration of the aqueous solution of bromine.

(2)

(ii) In another experiment, 100.0 cm^3 of the same aqueous solution of bromine was treated directly with 0.00100 moles of sodium thiosulfate.

Excess potassium iodide was then added to the unreacted bromine.

The iodine produced required 16.80 cm^3 of the 0.100 mol dm^{-3} sodium thiosulfate solution for reaction.

Deduce the mole ratio of $S_2O_3^{2-}$: Br_2 and hence write a balanced equation for the reaction between thiosulfate ions and bromine.
State symbols are not required.

(5)

(Total for Question 14 = 14 marks)

TOTAL FOR SECTION B = 51 MARKS

SECTION C

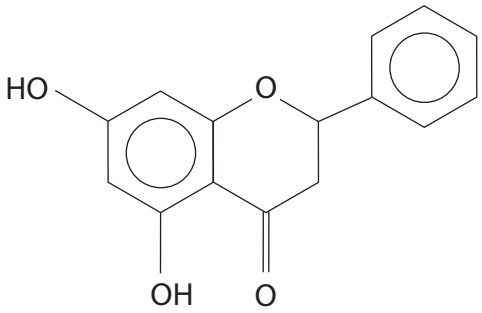
Answer ALL the questions. Write your answers in the spaces provided.

15

Sweeteners

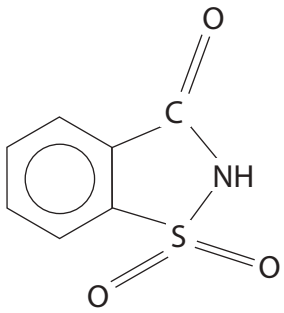
Table sugar (sucrose) contributes to tooth decay and obesity, so some manufacturers add other natural or artificial sweeteners to food.

Honey is a natural sweetener and has about the same relative sweetness as sucrose. The sweetness arises from the simple sugars glucose and fructose. Honey also contains pinocembrin which is an antioxidant.



pinocembrin

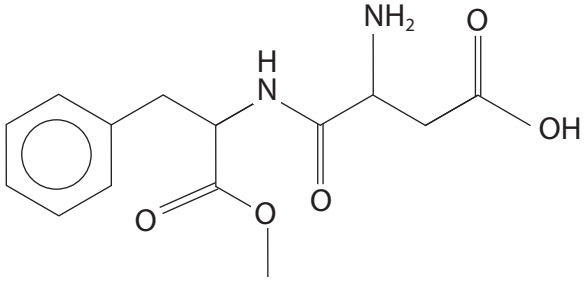
Saccharin is an artificial sweetener, which was first produced in 1879. It is over 300 times sweeter than sucrose.



saccharin

It is normally used as the sodium salt, which is very soluble in water.

Aspartame is an ester of the dipeptide formed from the amino acids phenylalanine and aspartic acid. It was first produced in 1965 and is about 200 times sweeter than sucrose.



aspartame

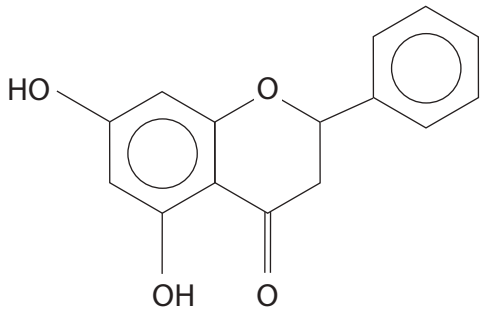
(a) (i) Give the molecular formula for pinocembrin.

(1)

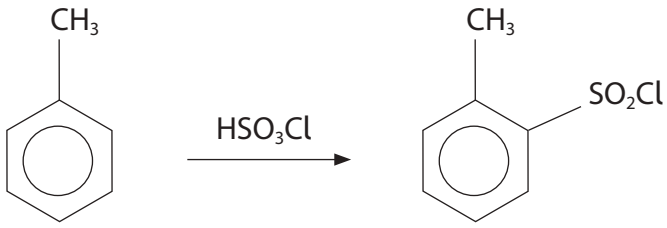
.....

(ii) Label the chiral carbon atom in pinocembrin with an asterisk (*).

(1)



(b) One route for the synthesis of saccharin starts with the reaction between methylbenzene and chlorosulfonic acid, HSO_3Cl.

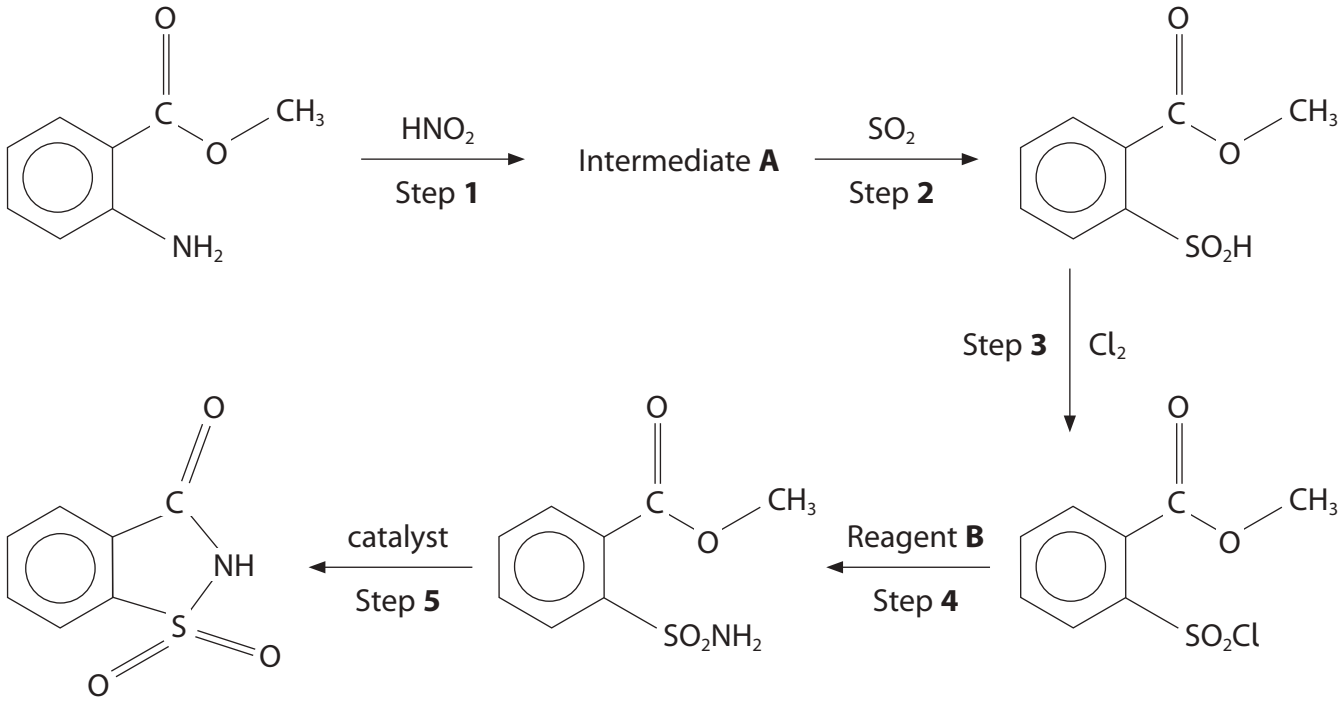


Draw the mechanism for this reaction.

The electrophile is $^{+}SO_2Cl$.

(3)

(c) Another route for the synthesis of saccharin starts with the reaction between methyl 2-aminobenzoate and nitrous acid (prepared from sodium nitrite and hydrochloric acid).



saccharin

(i) Give the structure of the Intermediate **A**.

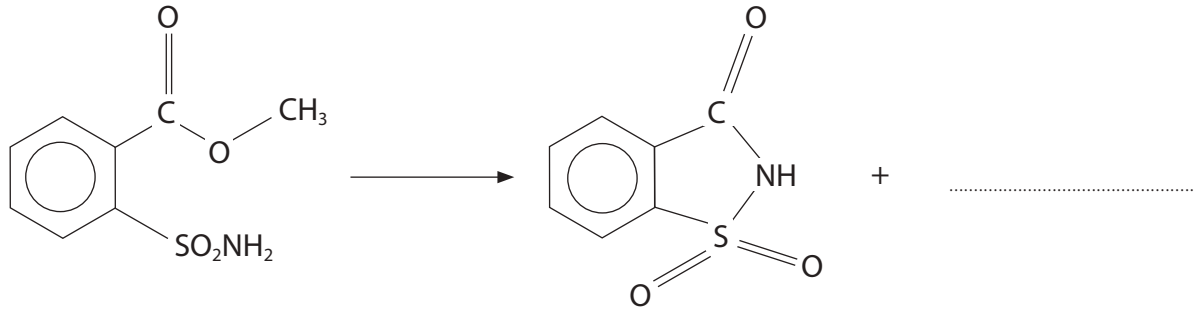
(1)

(ii) Suggest a substance for Reagent **B** in Step **4**.

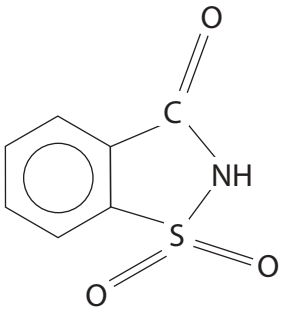
(1)

(iii) Complete the equation for the formation of saccharin in Step **5**.

(1)



(iv) The sodium salt of saccharin is much more soluble in water than saccharin.

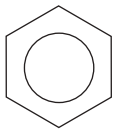


saccharin

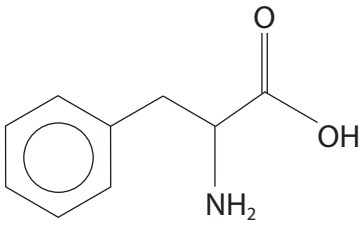
The acidic hydrogen is the one that is attached to the nitrogen atom.

Complete the structure of the sodium salt of saccharin, showing the charges on both ions.

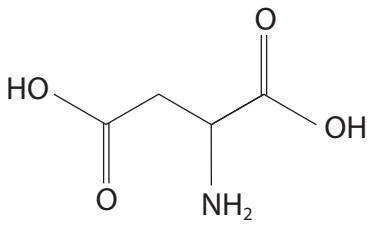
(1)



(d) Phenylalanine and aspartic acid are amino acids.



phenylalanine



aspartic acid

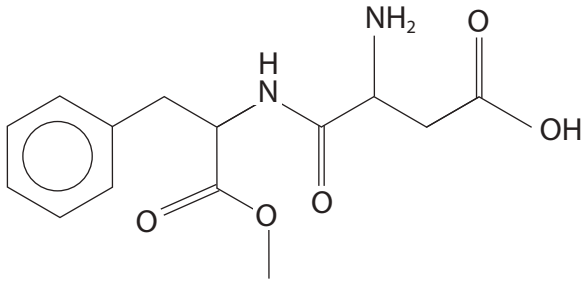
(i) Draw the structure of the organic compound formed when hydrochloric acid is added to phenylalanine.

(1)

(ii) Draw the structure of the organic product formed when **excess** sodium hydroxide solution is added to aspartic acid.

(1)

(iii) The structure of aspartame is



aspartame

Draw the structure of the dipeptide formed between phenylalanine and aspartic acid that is required to form aspartame.

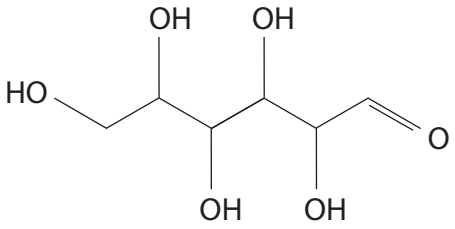
(2)

(iv) Identify, by name or formula, the alcohol needed to form aspartame from the dipeptide in (d)(iii).

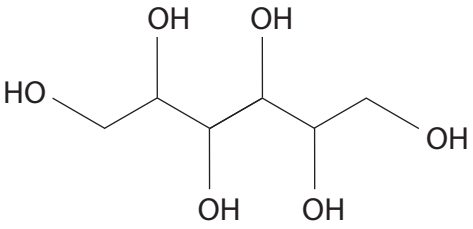
(1)

.....

(e) Sugar alcohols, such as sorbitol, are also used as artificial sweeteners.
Sorbitol is made from glucose.



glucose



sorbitol

(i) State the reagent needed to convert glucose into sorbitol.

(1)

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(ii) Describe a chemical test which will distinguish between glucose and sorbitol.
Give the result for each substance.

(3)

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.....

(iii) Sorbitol is dehydrated to form sorbitan. Sorbitan contains a ring with four carbon atoms and one oxygen atom. Complete the formula of sorbitan.

(1)

(Total for Question 15 = 19 marks)

TOTAL FOR SECTION C = 19 MARKS
TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

* Lanthanide series

* Actinide series