Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Monday 02 June 2025

Morning (Time: 1 hour 45 minutes)

Paper reference **WCH15/01**

Chemistry

International Advanced Level
UNIT 5: Transition Metals and Organic Nitrogen Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions:

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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.*
- In the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice:

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

Turn over

P 7 8 7 4 6 A 0 1 3 2

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 reaction is thermodynamically feasible under standard conditions?

Use your Data Booklet.

☐ **A** $Ag + V^{3+} \rightarrow Ag^{+} + V^{2+}$

☐ **B** $Cu^{+} + V^{3+} \rightarrow Cu^{2+} + V^{2+}$

☐ **C** $Fe^{2+} + V^{3+} \rightarrow Fe^{3+} + V^{2+}$

☐ **D** $Zn + 2V^{3+} \rightarrow Zn^{2+} + 2V^{2+}$

(Total for Question 1 = 1 mark)

2: In a redox titration, 0.0500 mol dm^{-3} potassium manganate(VII) is titrated against 25.0 cm^{3} of a solution containing iron(II) ions.

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

The mean titre of potassium manganate(VII) is 18.95 cm^{3}.

(a) What colour change is seen at the end-point?

(1)

☐ **A** pale pink to pale green

☐ **B** purple to pale pink

☐ **C** pale green to pale pink

☐ **D** pale pink to purple

(b) What is the concentration, in mol dm^{-3}, of the Fe^{2+} ions in the solution?

(1)

- ☒ **A** 1.90×10^{-1}
- ☒ **B** 7.58×10^{-3}
- ☒ **C** 4.74×10^{-3}
- ☒ **D** 1.90×10^{-4}

(c) What is the percentage error in a single titre of 18.95 cm^3?

(1)

[The uncertainty in a single burette reading is ±0.05 cm^3]

- ☒ **A** ±0.20%
- ☒ **B** ±0.26%
- ☒ **C** ±0.40%
- ☒ **D** ±0.53%

(d) Which row shows the correct changes in oxidation states?

(1)

	manganese	iron
☒ **A**	II → VII	III → II
☒ **B**	II → VII	II → III
☒ **C**	VII → II	III → II
☒ **D**	VII → II	II → III

(Total for Question 2 = 4 marks)

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

3: Which reaction occurs at an electrode in a hydrogen-oxygen fuel cell?

☒ **A** $O_2(g) + 2H_2(g) \rightarrow 2H_2O(l)$

☒ **B** $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

☒ **C** $4H^+(aq) + 4OH^-(aq) \rightarrow 4H_2O(l)$

☒ **D** $H_2O(l) + 2OH^-(aq) \rightarrow 2H_2(g) + 1\frac{1}{2}O_2(g) + 2e^-$

(Total for Question 3 = 1 mark)

4: What is the electronic configuration of a Zn^{2+} ion?

☒ **A** [Ar] $3d^{10}$

☒ **B** [Ar] $3d^{10}\,4s^2$

☒ **C** [Ar] $3d^9\,4s^1$

☒ **D** [Ar] $3d^8\,4s^2$

(Total for Question 4 = 1 mark)

5: What is the colour of an aqueous solution of V^{2+} ions?

☒ **A** blue

☒ **B** green

☒ **C** purple

☒ **D** yellow

(Total for Question 5 = 1 mark)

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

6: Which is **incorrect** for H_2O, OH^- and NH_3?

- ☒ **A** all can act as bidentate ligands
- ☒ **B** all can act as electron pair donors
- ☒ **C** all can form dative covalent bonds
- ☒ **D** all can take part in complex ion formation

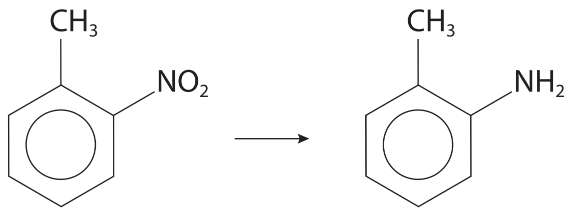
(Total for Question 6 = 1 mark)

7: Which product forms when butylamine reacts with ethanoyl chloride?

- ☒ **A** ethanamide
- ☒ **B** butanamide
- ☒ **C** *N*-butylethanamide
- ☒ **D** *N*-ethylbutanamide

(Total for Question 7 = 1 mark)

8: Which are the reagents and conditions for the reaction shown?

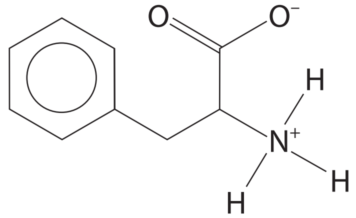


- ☒ **A** $K_2Cr_2O_7$, H^+ and reflux
- ☒ **B** $LiAlH_4$ in dry ether
- ☒ **C** H_2 gas at high temperature
- ☒ **D** Sn, concentrated HCl and reflux

(Total for Question 8 = 1 mark)

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

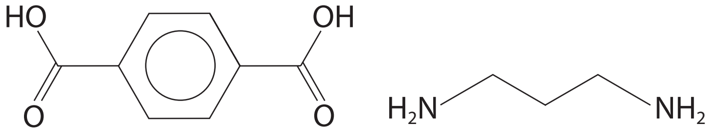
9: At what pH would the amino acid phenylalanine have the structure shown?



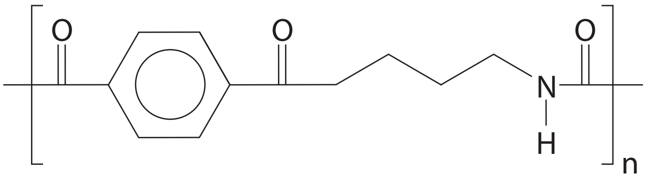
- ☒ **A** pH 2
- ☒ **B** pH 6
- ☒ **C** pH 10
- ☒ **D** pH 14

(Total for Question 9 = 1 mark)

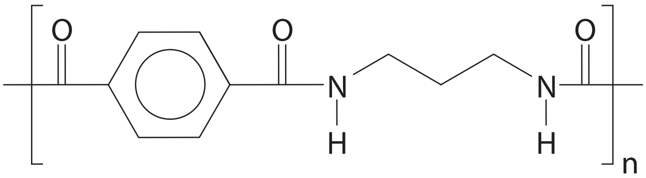
10: Which is the repeat unit of the polymer formed from the monomers shown?



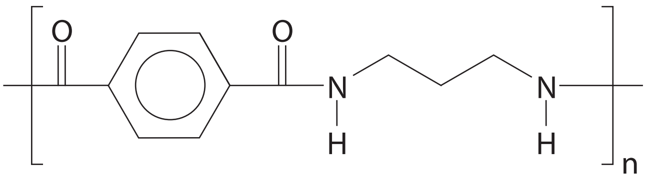
☒ **A**



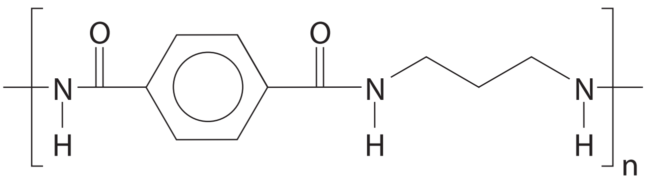
☒ **B**



☒ **C**



☒ **D**



(Total for Question 10 = 1 mark)

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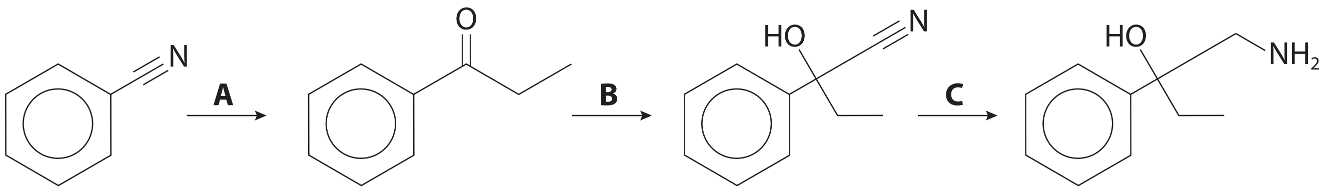
11: A reaction scheme is shown.



(a) Which is the name of the functional group that is replaced in step **A**?

(1)

- ☒ **A** phenyl
- ☒ **B** nitrile
- ☒ **C** amine
- ☒ **D** amide

(b) What type of reaction mechanism is taking place in step **B**?

(1)

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

(c) What are the reagents used in step **B**?

(1)

- ☒ **A** KCN and NaOH
- ☒ **B** HCN and KCN
- ☒ **C** HCl and KNO_2
- ☒ **D** HNO_3 and H_2SO_4

(d) What is the percentage of carbon, by mass, in the final product?

(1)

[M_r of the final product = 165]

- ☒ **A** 58.2%
- ☒ **B** 65.5%
- ☒ **C** 72.7%
- ☒ **D** 80.0%

(Total for Question 11 = 4 marks)

12: A substituted benzene compound has the general formula C_nH_{2n-6}.

When completely combusted, 0.025 mol of the compound produced 11.0 g of CO_2.

Which could be the M_r of the compound?

☒ **A** 64

☒ **B** 78

☒ **C** 128

☒ **D** 134

(Total for Question 12 = 1 mark)

13: This question is about branched alkanes.

(a) How many peaks are there in the ^{13}C NMR spectrum of 2,2-dimethylpropane?

(1)

☒ **A** one

☒ **B** two

☒ **C** three

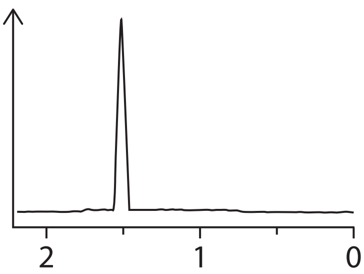
☒ **D** five

(b) Four students sketched the high-resolution proton NMR spectrum of 2,3-dimethylbutane.

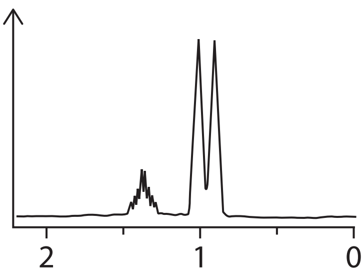
Which sketch is most likely to be correct?

(1)

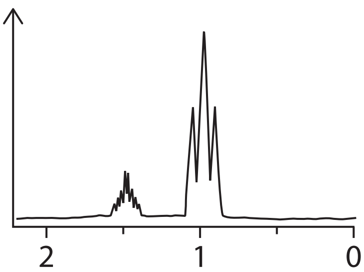
☒ **A**



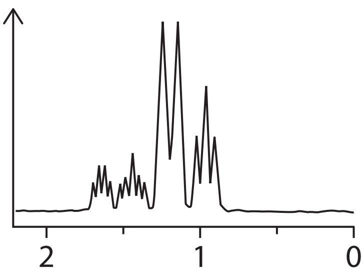
☒ **B**



☒ **C**



☒ **D**



(Total for Question 13 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

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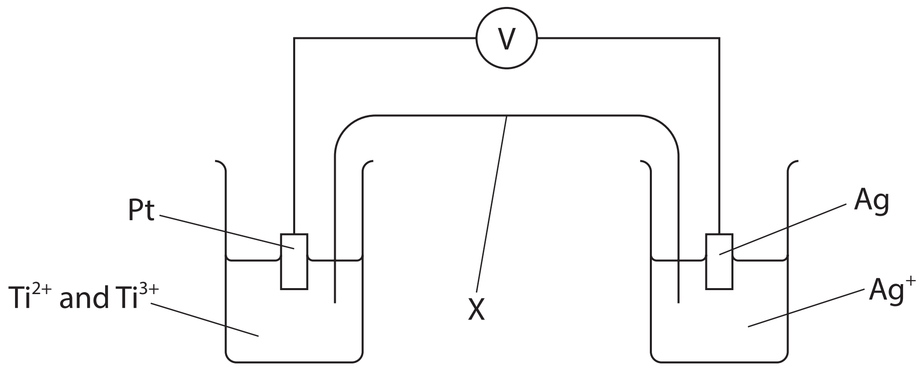
SECTION B

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

14: This question is about the electrochemical cell shown.



(a) State the name and purpose of part **X**.

(2)

....

....

(b) Draw a cell diagram for this system.

(2)

(c) The electrode system for the titanium ions is shown.

$$Ti^{3+}(aq) + e^{-} \rightleftharpoons Ti^{2+}(aq) \qquad E^{\ominus} = -0.37\,V$$

Calculate the $E^{\ominus}_{cell}$ value. Use your Data Booklet.

(2)

(d) State the changes, if any, that would occur to the cell emf, the electrodes and the ion concentrations when current flows for several hours in this cell.

(3)

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(Total for Question 14 = 9 marks)

15: *Cis*-platin, $PtCl_2(NH_3)_2$, is used in cancer treatment as it inhibits DNA replication.

(a) State the shape of the *cis*-platin complex.

(1)

....

(b) Draw the isomer *trans*-platin.

(1)

(c) In human cells, the two chloride ions are replaced by water molecules in a ligand exchange reaction as shown.

$$PtCl_2(NH_3)_2 + 2H_2O \rightleftharpoons [Pt(NH_3)_2(H_2O)_2]^{2+} + 2Cl^-$$

Suggest why this occurs.

(2)

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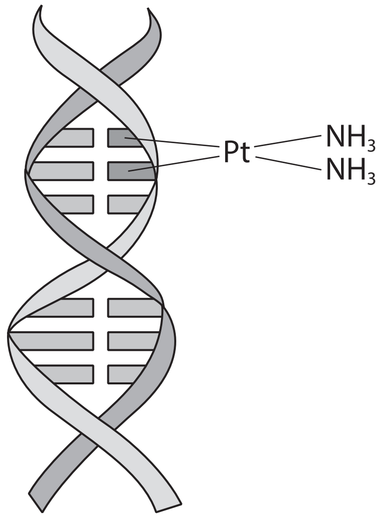
....

(d) DNA forms two dative covalent bonds with *cis*-platin as shown.



(i) DNA acts as a ligand in the formation of the complex shown in the diagram.

Name this type of ligand.

(1)

....

(ii) Explain, by considering the equation shown, why this process is thermodynamically feasible.

$$Pt(Cl)_2(NH_3)_2 \ + \ DNA \ \rightarrow \ [Pt(NH_3)_2(DNA)]^{2+} \ + \ 2Cl^-$$

(2)

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(Total for Question 15 = 7 marks)

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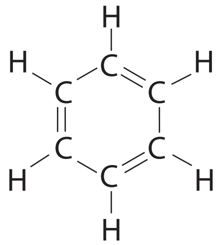
P 7 8 7 4 6 A 0 1 3 3 2

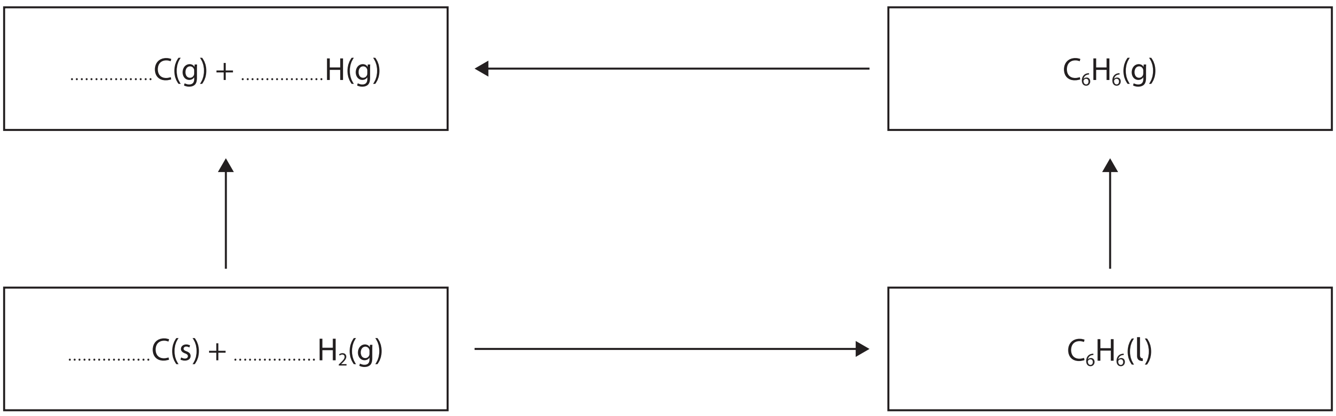
16: In 1865, Kekulé proposed a cyclic structure for benzene, C_6H_6.



(a) An incomplete Hess cycle is shown.

(i) Complete the cycle by adding balancing numbers.

(1)



(ii) Calculate the mean carbon-carbon bond enthalpy in benzene, using your completed cycle and the data shown.

(2)

C_6H_6(l) $\Delta_f H = +49.0\ \text{kJ mol}^{-1}$

C(s) $\rightarrow$ C(g) $\Delta_{at}H = +715\ \text{kJ mol}^{-1}$

H_2(g) $\rightarrow$ 2H(g) $\Delta_{at}H = +436\ \text{kJ mol}^{-1}$

C_6H_6(l) $\rightarrow$ C_6H_6(g) $\Delta_r H = +31\ \text{kJ mol}^{-1}$

Bond enthalpy C—H = $+413\ \text{kJ mol}^{-1}$

(iii) Explain why the bond enthalpy value calculated in (a)(ii) is not the exact mean of the carbon-carbon double bond and carbon-carbon single bond enthalpies that would be expected from the Kekulé structure.

Bond enthalpy C—C = +347 kJ mol^{-1}

Bond enthalpy C═C = +612 kJ mol^{-1}

(2)

(b) Describe how all the carbon-carbon bonds in benzene are formed.

(2)

(c) State one chemical property and one physical property of benzene which would **not** be shown by the compound with the Kekulé structure.

(2)

(Total for Question 16 = 9 marks)

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17: Trimethylamine, C_3H_9N, is the main reason rotting fish smells so bad. Trimethylamine is present in the blood and other fluids of many animals but it has higher concentrations in fish.

(a) (i) Draw the **skeletal** structure of trimethylamine.

(1)

(ii) Identify the class of amine to which trimethylamine belongs.

(1)

....

(iii) Trimethylamine is a gas at room temperature but readily dissolves in water.

Draw a diagram of the intermolecular force that leads to trimethylamine being soluble in water.

Include relevant dipoles and lone pairs.

(2)

(iv) An aqueous solution of trimethylamine is alkaline.

Write an **ionic** equation to show how trimethylamine acts as a base.

State symbols are not required.

(1)

(b) When trimethylamine oxidises, it forms trimethylamine *N*-oxide, C_3H_9NO.

Healthy humans have a concentration of 3.90×10^{-6} mol dm^{-3} trimethylamine *N*-oxide in their blood.

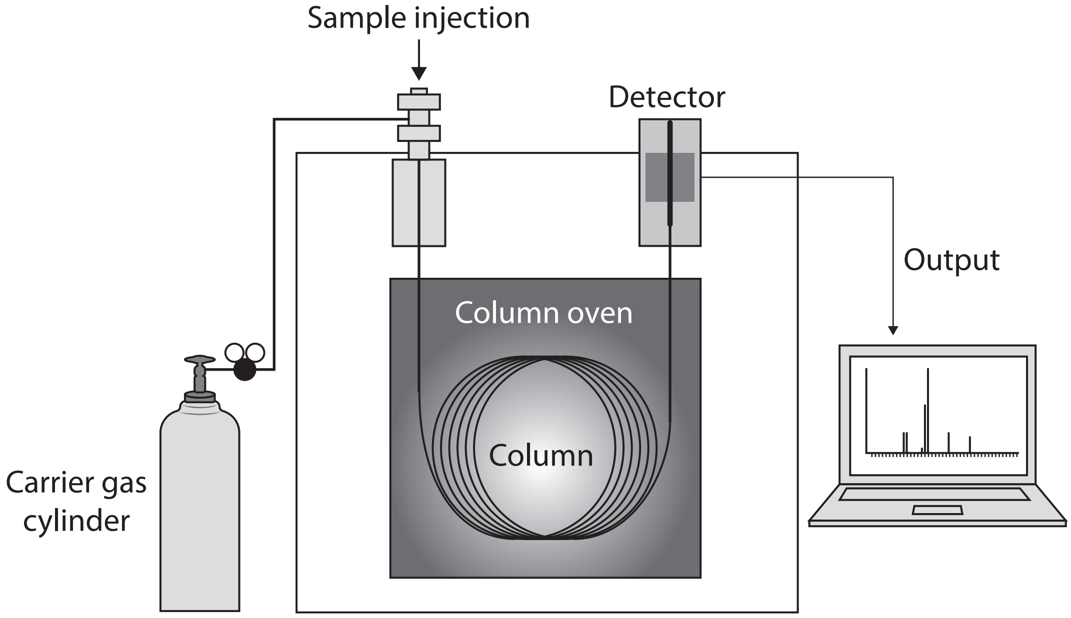
An average adult human has 5.00 dm^3 of blood.

Calculate the mass, in grams, of trimethylamine *N*-oxide in an average human's blood, giving your answer to a suitable number of significant figures.

(2)

(c) Trimethylamine is a major air pollutant originating from food waste, farm animals and vehicle exhausts. Trimethylamine levels need to be monitored as it can easily be absorbed through human skin.

Gas chromatography (GC) can be used to measure the level of trimethylamine in air, using the apparatus shown in the diagram.



(i) Briefly describe how trimethylamine will be **separated** from other chemicals present in the sample of air.

(2)

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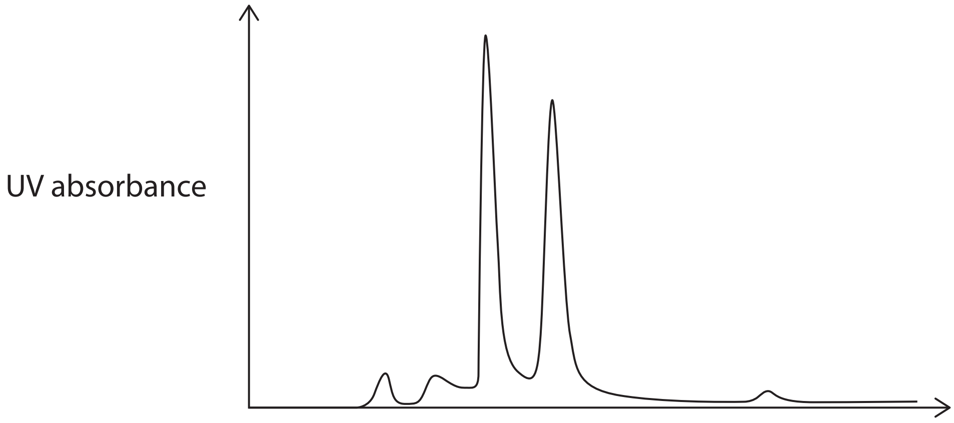
(ii) High-performance liquid chromatography (HPLC) is used to measure levels of trimethylamine and trimethylamine *N*-oxide in blood and urine.

Label the x-axis on the chromatogram.

(1)



....

(iii) Name the analytical technique that can be used with either GC or HPLC to identify the compound responsible for each peak.

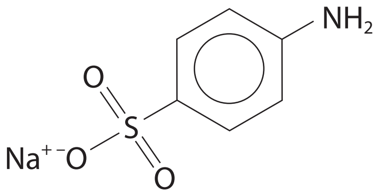
(1)

....

(Total for Question 17 = 11 marks)

18: Sunset yellow is a common food colouring.

Sunset yellow can be produced in a coupling reaction starting with compound **A**.



compound **A**

(a) State the reagents and conditions required for the formation of a diazonium ion from compound **A**.

(2)

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....

....

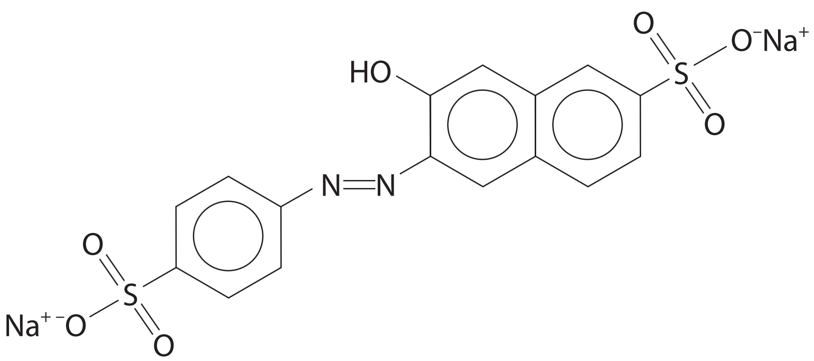
(b) Draw the structure of the diazonium ion formed.

(1)

(c) The structure of sunset yellow is shown.

Use a circle to identify the functional group, other than the diazonium group, that is essential for the coupling reaction to occur.

(1)



(d) (i) After sunset yellow is formed, it needs to be purified.

Name the process that is used.

(1)

....

(ii) The yield, by mass, for the formation of sunset yellow is 67.9%.

Calculate the mass of sunset yellow produced from 5.00 g of compound **A**.

[M_r of sunset yellow = 452.2]

(3)

(Total Question 18 = 8 marks)

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P 7 8 7 4 6 A 0 2 2 3 2

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***19:** A solution containing tetrachlorocuprate(II) ions, $[CuCl_4]^{2-}$, is treated with dilute aqueous ammonia.

The ammonia solution is added gradually.

The following observations are made:

yellow solution → pale blue solution → pale blue precipitate → deep blue solution

Explain the changes occurring in this sequence.

Your explanation should refer to the formulae, shapes and colours of the species present at each stage.

Detailed explanations of how the colours of transition metal complexes occur are not required.

(6)

(Total for Question 19 = 6 marks)

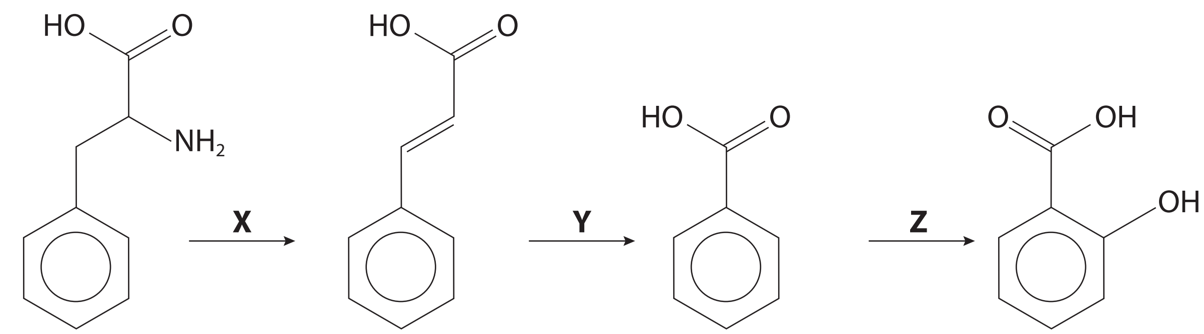
TOTAL FOR SECTION B = 50 MARKS

SECTION C

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

20: Salicylic acid has been characterised as a plant hormone and is often used by students to prepare aspirin.

Salicylic acid is produced in plants, from phenylalanine via cinnamic acid, using enzymes.



phenylalanine   cinnamic acid   salicylic acid

(a) (i) Draw an asterisk (*****) on the chiral carbon in phenylalanine.

(1)

(ii) State the type of reaction taking place in Step **X**.

(1)

(iii) Only one isomer of cinnamic acid is produced in Step **X**.

Draw the other geometric isomer of cinnamic acid.

(1)

(iv) In Step **Y** a diol is formed as an intermediate before further oxidation. The mixture is heated so the reaction can proceed.

Suggest the reagents required to form the diol in the laboratory.

(2)

....

....

(v) Suggest a reason why it is unlikely the reaction scheme proceeds by this route in plants.

(1)

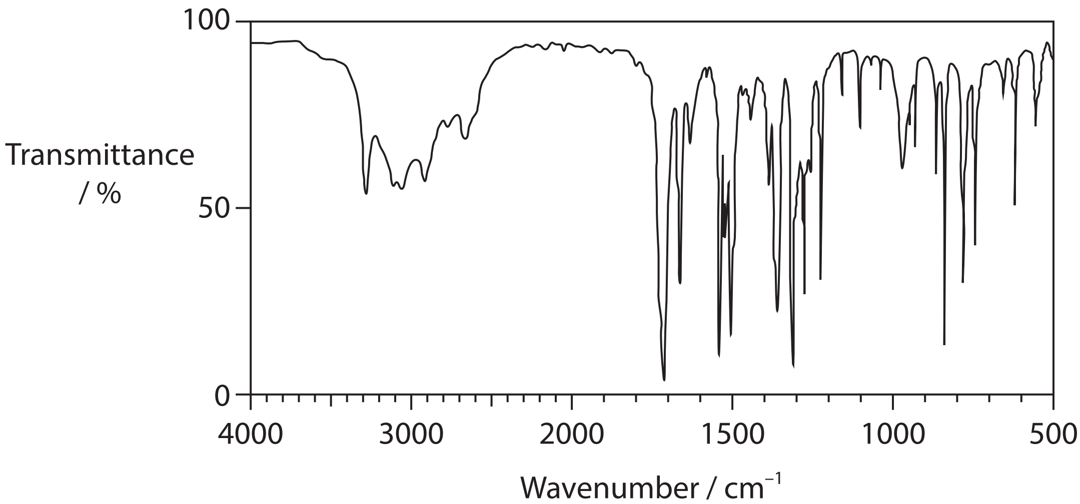
....

(b) State the IUPAC name for salicylic acid.

(1)

....

(c) The infrared spectrum for salicylic acid is shown.



Identify **two** wavenumbers on the spectrum and the bond responsible for each which show that an aromatic group is present in salicylic acid.

Use your Data Booklet.

(2)

....

....

....

....

(d) 5-Nitrosalicylic acid, produced from salicylic acid, is an important raw material and intermediate used in organic synthesis.

(i) Concentrated nitric and sulfuric acid are used to produce NO_2^+ to initiate the reaction.

Write the equation for the production of NO_2^+.

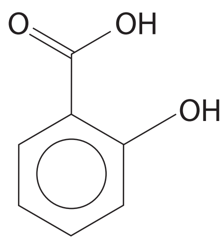
(1)

(ii) Complete the reaction mechanism to form 5-nitrosalicylic acid, naming the reaction mechanism.

(5)

Reaction mechanism ....

NO_2^+



(iii) Explain why benzenecarboxylic acid requires concentrated nitric and sulfuric acids for nitration while salicylic acid may be nitrated using dilute nitric acid.

(3)

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....

(e) 5-Nitrosalicylic acid has a solubility of 1 g in 1475 cm^3 of water.

Calculate the concentration of a saturated solution in mol dm^{-3}.

(2)

[5-nitrosalicylic acid M_r = 183]

(Total for Question 20 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											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											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							

* Lanthanide series	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
* Actinide series	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