Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number	Candidate Number

Tuesday 22 January 2019

Morning (Time: 1 hour 40 minutes) | Paper Reference **WCH05/01**

Chemistry

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

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.
- Show your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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 Chromium is classified as a transition element because

☒ **A** it is in the d block of the Periodic Table.

☒ **B** it forms stable ions in which it has different oxidation numbers.

☒ **C** it has incompletely filled d orbitals.

☒ **D** it forms stable ions which have incompletely filled d orbitals.

(Total for Question 1 = 1 mark)

2 The series below show the first four ionisation energies (in kJ mol^{-1}) of different elements. Which could be those of a transition element?

☒	**A**	496	4563	6913	9544
☒	**B**	578	1817	2745	11 578
☒	**C**	658	1310	2653	4175
☒	**D**	738	1451	7733	10 541

(Total for Question 2 = 1 mark)

3 Which of the following are the oxidation states of chromium in the ions shown?

		$Cr(OH)_6^{3-}$	CrO_4^{2-}
☒	**A**	−3	+4
☒	**B**	+3	+6
☒	**C**	+3	+4
☒	**D**	−3	+6

(Total for Question 3 = 1 mark)

4 A metal **M** reacts with nitrate ions, NO_3^-, in acid conditions.
The products are $\mathbf{M}^{n+}$ ions, water and nitrogen(II) oxide, NO.
The reacting ratio of **M** atoms to nitrate ions is 3:2.

What is the value of n in the $\mathbf{M}^{n+}$ ion?

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(Total for Question 4 = 1 mark)

5 Use these electrode potentials to answer the following questions.

Electrode reaction	$E^\ominus$ / V
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	−0.26
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

(a) Which of these species is the strongest oxidising agent?

(1)

☒ **A** $V^{3+}(aq)$

☒ **B** $V^{2+}(aq)$

☒ **C** $Cl_2(aq)$

☒ **D** $Cl^-(aq)$

(b) Which species would convert vanadium(IV) to vanadium(III) under standard conditions?

(1)

☒ **A** $V^{2+}(aq)$

☒ **B** $I^-(aq)$

☒ **C** $Cl_2(aq)$

☒ **D** $Cl^-(aq)$

(Total for Question 5 = 2 marks)

6 Which statement about $E^{\ominus}$ for a cell reaction is true?

☒ **A** $E^{\ominus}$ is proportional to $\ln K$.

☒ **B** $\ln E^{\ominus}$ is proportional to K.

☒ **C** $E^{\ominus}$ is proportional to $\ln \Delta S_{total}$.

☒ **D** $\ln E^{\ominus}$ is proportional to ΔS_{total}.

(Total for Question 6 = 1 mark)

7 Which of the following **cannot** disproportionate?

☒ **A** Cl_2

☒ **B** BrO^-

☒ **C** SO_3^{2-}

☒ **D** NO_3^-

(Total for Question 7 = 1 mark)

8 Which of these complex ions could exist as stereoisomers?

☒ **A** $[Co(NH_3)_6]^{3+}$

☒ **B** $[Co(NH_3)_5(H_2O)]^{3+}$

☒ **C** $[Co(NH_3)_5(Cl)]^{2+}$

☒ **D** $[Co(NH_3)_4(Cl)_2]^+$

(Total for Question 8 = 1 mark)

9 Iron is a suitable catalyst for the reaction of nitrogen with hydrogen to form ammonia because iron

☒ **A** can be oxidised easily.

☒ **B** adsorbs reactant molecules.

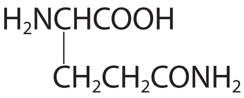
☒ **C** does not desorb product molecules easily.

☒ **D** forms hydrogen bonds with the ammonia.

(Total for Question 9 = 1 mark)

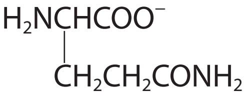
10 In aqueous solution at pH 12, the amino acid glutamine exists in the form

☒ **A**



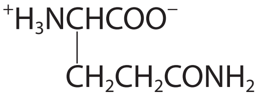
$\mathrm{H_2N\underset{\underset{CH_2CH_2CONH_2}{|}}{C}HCOOH}$

☒ **B**



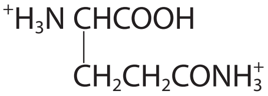
$\mathrm{H_2N\underset{\underset{CH_2CH_2CONH_2}{|}}{C}HCOO^-}$

☒ **C**



$\mathrm{^+H_3N\underset{\underset{CH_2CH_2CONH_2}{|}}{C}HCOO^-}$

☒ **D**



$\mathrm{^+H_3N\ \underset{\underset{CH_2CH_2CONH_3^+}{|}}{C}HCOOH}$

(Total for Question 10 = 1 mark)

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11 The best method for separating a mixture of amino acids in solution, for the purpose of identification, is

☒ **A** recrystallisation.

☒ **B** distillation.

☒ **C** chromatography.

☒ **D** solvent extraction.

(Total for Question 11 = 1 mark)

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12 Which molecule does **not** contain a chiral carbon atom?

☒ **A** 2-bromobutane

☒ **B** 2-bromo-2-methylbutane

☒ **C** 3-methylhexane

☒ **D** 2-hydroxypropanoic acid

(Total for Question 12 = 1 mark)

13 How many peaks would you expect to see in a **low resolution** proton nmr spectrum of pentan-3-one, $CH_3CH_2COCH_2CH_3$?

☒ **A** 2

☒ **B** 4

☒ **C** 5

☒ **D** 10

(Total for Question 13 = 1 mark)

14 The **high resolution** proton nmr spectrum of ethyl ethanoate, $CH_3COOCH_2CH_3$, contains

☒ **A** two triplets and one doublet.

☒ **B** one triplet, one doublet and one singlet.

☒ **C** one quartet, one triplet, and one singlet.

☒ **D** one quartet and two triplets.

(Total for Question 14 = 1 mark)

15 In a methanol fuel cell, in **alkaline** conditions, the following reaction occurs at one electrode.

$$CH_3OH + 6OH^- \rightarrow CO_2 + 5H_2O + 6e^-$$

The reaction occurring at the other electrode is

☒ **A** $2H_2 + 2O_2 + 4e^- \rightarrow 4OH^-$

☒ **B** $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

☒ **C** $4H^+ + O_2 + 4e^- \rightarrow 2H_2O$

☒ **D** $4OH^- \rightarrow 2H_2 + 2O_2 + 4e^-$

(Total for Question 15 = 1 mark)

16 The infrared spectrum of a compound with molecular formula $C_{10}H_{12}O_2$ includes strong peaks in the ranges 1750–1735 cm^{-1} and 1150–1100 cm^{-1}.

The compound could be

☒ **A** $C_6H_5CH_2CH_2CH_2COOH$

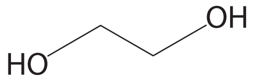
☒ **B** $C_6H_5CH_2CH_2COOCH_3$

☒ **C** $C_6H_5CH_2COOCH_2CH_3$

☒ **D** $C_6H_5COOCH_2CH_2CH_3$

(Total for Question 16 = 1 mark)

17 Which pair of monomers could react to form a condensation polymer?

☒ **A** 

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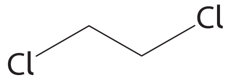
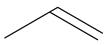


☒ **B** 
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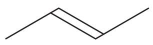
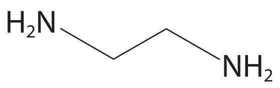


☒ **C** 

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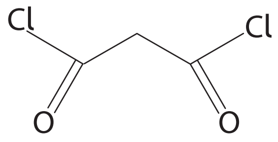
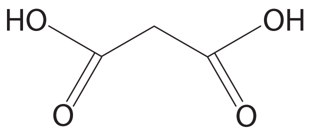


☒ **D** 

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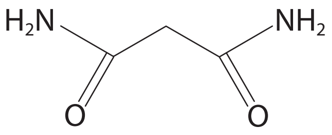


(Total for Question 17 = 1 mark)

18 Cinnamaldehyde, $C_6H_5CH{=}CHCHO$, is a liquid that is slightly soluble in water but is much more soluble in ether. It decomposes below its boiling temperature.

It can be extracted from cinnamon. Sticks of cinnamon are ground up and mixed with water.

(a) Select the correct order of practical techniques to obtain cinnamaldehyde from this mixture.

(1)

☒ **A** steam distilling, extracting with ether, distilling off the ether

☒ **B** refluxing, extracting with ether, distilling off the ether

☒ **C** filtering, refluxing, extracting with ether

☒ **D** steam distilling, filtering, extracting with ether

(b) Which test result for cinnamaldehyde is **not** correct?

(1)

	Test	Result
☒ **A**	warm with acidified potassium dichromate(VI)	no change
☒ **B**	warm with acidified potassium manganate(VII)	solution decolorises
☒ **C**	add phosphorus(V) chloride	no change
☒ **D**	warm with Tollens' solution	silver mirror

(Total for Question 18 = 2 marks)

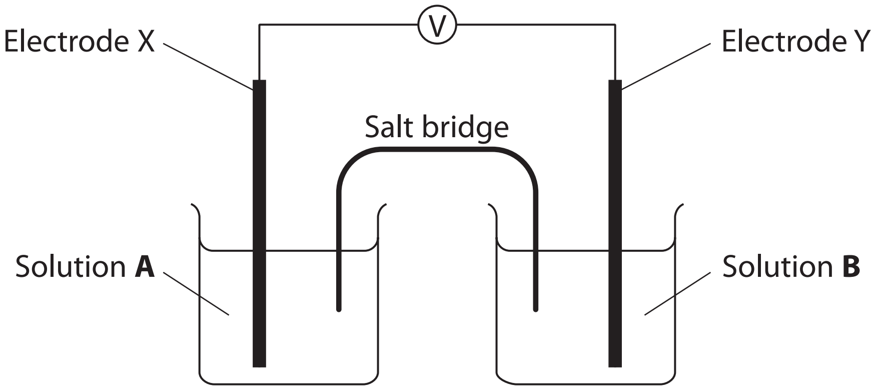
TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

19 (a) The reaction between iron(II) ions and manganate(VII) ions was investigated by setting up a cell.

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



Solution **A** contains both iron(II) and iron(III) ions.

(i) Identify the substance used for the electrodes.

(1)

X ....

Y ....

(ii) A student suggested that, for standard conditions, solution **A** should be made by mixing equal volumes of 1 mol dm^{-3} iron(II) sulfate solution and 1 mol dm^{-3} iron(III) sulfate solution.

This mixture is not suitable for measuring the standard electrode potential of this cell.

State how this mixture should be changed. Justify your answer.

(2)

....

....

....

....

(iii) Identify the **compounds** that may be used to make solution **B**.

(2)

(iv) A student suggested that the salt bridge could be made by soaking a strip of filter paper in barium nitrate solution.

A reaction occurs when this salt bridge comes into contact with iron(II) sulfate in solution **A**.

State what observation would be made and write the **ionic** equation for this reaction. Include state symbols.

(2)

Observation:

(v) Suggest a more suitable compound to use when making the salt bridge.

(1)

(vi) Calculate $E^\ominus$ for the cell. Use the data on page 17 of the Data Booklet.

(1)

(b) A 3.00 g sample of powdered haematite contains iron(III) oxide, Fe_2O_3, as the only iron compound. It was dissolved in dilute sulfuric acid forming a solution of iron(III) sulfate.

The Fe^{3+}(aq) was reduced to Fe^{2+}(aq) using a solution of sulfur dioxide (H_2SO_3(aq)). The resulting solution was made up to 250.0 cm^3 with dilute sulfuric acid in a volumetric flask.
25.00 cm^3 portions of this solution were titrated with 0.0250 mol dm^{-3} potassium manganate(VII) solution.
The mean titre was 24.50 cm^3.

(i) Explain why the solution of sulfur dioxide is suitable for reducing the iron(III) ions.

Use the electrode potentials on page 15 of the Data Booklet.

(2)

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....

(ii) Calculate the percentage, by mass, of iron(III) oxide in this sample of haematite.

(4)

(iii) Iron(II) sulfate can be oxidised by dichromate(VI) ions in acid conditions.
Use the half equations for the oxidation of iron(II) ions and the reduction of dichromate(VI) ions to write the overall ionic equation for the reaction.
State symbols are not required.

(2)

(iv) Suggest a practical reason why potassium manganate(VII) is preferred to potassium dichromate(VI) for use in titrations with iron(II) sulfate.

(1)

....

....

(Total for Question 19 = 18 marks)

20 This question is about compounds of copper.

(a) When copper(II) sulfate solution is mixed with potassium iodide solution, the copper(II) ions are reduced. The products are a mixture of iodine and potassium sulfate in solution, and a white precipitate of a copper compound.

(i) Write the **ionic** equation for the reaction of Cu^{2+}(aq) and I^-(aq) ions. State symbols are not required.

(1)

(ii) Complete the electronic configuration for the metal ion in the white precipitate.

(1)

$1s^2$ ....

(iii) Give the formula of a stable **ion** of an element in Period 4 of the Periodic Table, which is isoelectronic with the metal ion in the white precipitate.

(1)

....

(b) Aqueous copper(II) sulfate contains the complex ion $[Cu(H_2O)_6]^{2+}$.

(i) State how the electronic energy levels of the copper(II) ion change when water ligands form this complex.

(1)

....

....

....

*(ii) Explain how this change in energy levels causes complex ions to have **different** colours, depending on the ligand.

(3)

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....

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....

(iii) State the shape of the $[Cu(H_2O)_6]^{2+}$ ion.

(1)

....

(iv) $[Cu(H_2O)_6]^{2+}$ ions react with the ligand 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$, to produce a complex ion. All the water ligands are replaced and the coordination number of copper does not change.

Draw the structure of this complex ion, making clear how the ligands form bonds with the copper ions.

(2)

(v) When excess concentrated hydrochloric acid is added to $[Cu(H_2O)_6]^{2+}$, a chloro complex is formed. Write the equation for this reaction and state the shape of the complex ion formed.

(2)

Equation:

Shape of complex ion ....

(vi) The reaction of ammonia with a solution containing $[Cu(H_2O)_6]^{2+}$ ions takes place in two steps.

Step **1**: A few drops of ammonia are added.

$$[Cu(H_2O)_6]^{2+}(aq) + 2NH_3(aq) \rightarrow [Cu(H_2O)_4(OH)_2](s) + 2NH_4^+(aq)$$

Step **2**: An excess of ammonia is added to the products of Step **1**.

Name the types of reaction occurring in the two steps and give the **formula** of the copper complex ion in the final product.

(3)

Step **1** ....

Step **2** ....

Final product

(vii) Describe what you would see in each of the two steps.

(2)

....

....

....

....

Turn over ▶

*(viii) Explain, in terms of entropy, why the equilibrium constant for the overall reaction of aqueous copper(II) ions with ammonia is less than the equilibrium constant when aqueous copper(II) ions react with 1,2-diaminoethane.

(3)

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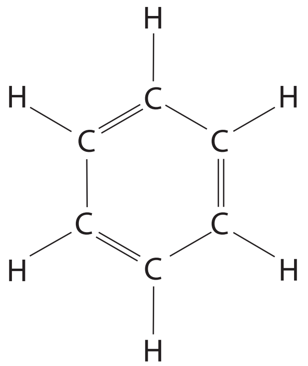
(Total for Question 20 = 20 marks)

21 The structure shown was suggested for benzene by a chemist called Kekulé.



Benzene is now thought to have a delocalised structure.

*(a) Evidence for the delocalised structure of benzene includes

- only one structure for 1,2-dichlorobenzene
- analysis of X-ray diffraction images of benzene.

Explain why each of these makes the delocalised structure more likely to be correct than the Kekulé structure.

(2)

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....

(b) Phenol also has a delocalised structure.

Compare the conditions and the products of the reaction for the bromination of phenol and of benzene.

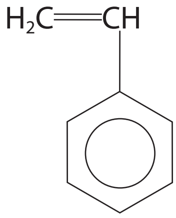
(4)

(c) Benzene can be converted to ethylbenzene, $C_6H_5C_2H_5$, in an electrophilic substitution reaction.

Write the mechanism for this reaction, including the step involving a catalyst in which the electrophile is formed.

(4)

(d) When ethylbenzene is dehydrogenated, it forms phenylethene.



(i) Predict one wavenumber range where the infrared spectrum of phenylethene would differ from the infrared spectrum of ethylbenzene.

(1)

....

....

(ii) Write the equation for the polymerisation of phenylethene.

(1)

(Total for Question 21 = 12 marks)

TOTAL FOR SECTION B = 50 MARKS

SECTION C

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

22

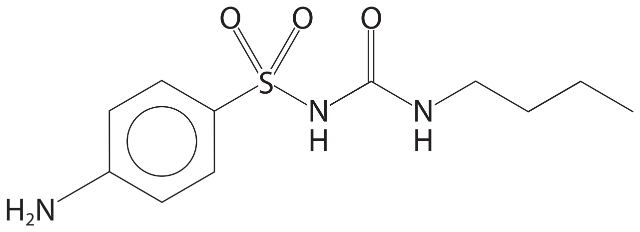
The importance of phenylamine

Phenylamine, $C_6H_5NH_2$, does not occur naturally, but can be prepared from benzene. However, it cannot be prepared in the same way as aliphatic amines. These can be prepared by simply reacting a bromoalkane with ammonia or an amine.

Many different aromatic compounds are synthesised using phenylamine as a starting material. In 1850 the chemist Hofmann made N,N-dimethylphenylamine, $C_6H_5N(CH_3)_2$. Using this compound and another compound derived from 4-aminobenzenesulfonic acid, the indicator methyl orange can be made.

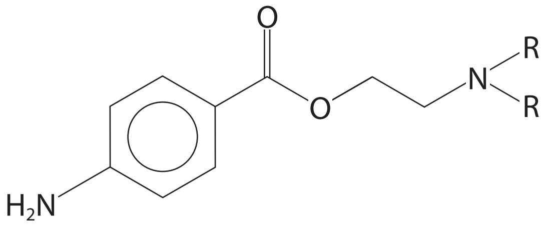
Other indicators such as methyl yellow and methyl red are also prepared using phenylamine.

Sulfonamide drugs are also synthesised from phenylamine. They were the first anti-bacterial agents, but some of this class of drugs, such as carbutamide, act as anti-diabetes drugs.

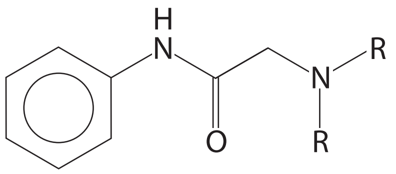


carbutamide

Phenylamine is also the starting point for the production of many anaesthetics. Most local anaesthetics contain an ester or amide link, and a tertiary amine group, in which a nitrogen atom is joined to three other groups. Examples of these are shown on the structures below. The symbol R represents an alkyl group.



Y



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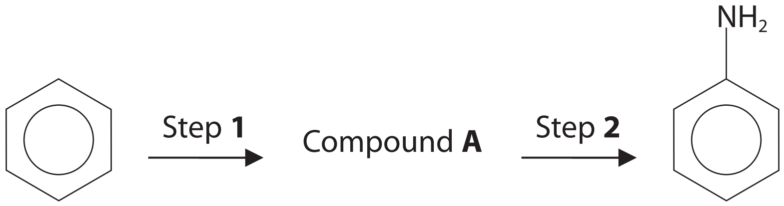
(a) Phenylamine can be prepared from benzene.



(i) Identify Compound **A** and state the reagents and conditions needed to carry out Step **1**.

(2)

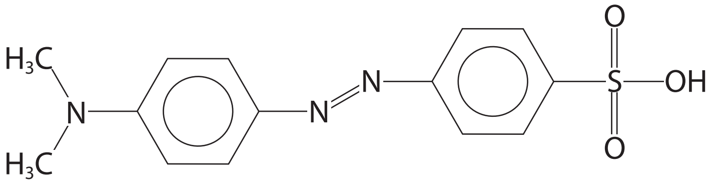
(ii) State the reagents needed for Step **2**.

(1)

(b) Suggest an equation for the reaction of phenylamine with iodomethane, forming N,N-dimethylphenylamine.

(1)

(c) Methyl orange is the sodium salt of compound **X**.



compound **X**

Compound **X** cannot be formed by a direct reaction of 4-aminobenzenesulfonic acid with N,N-dimethylphenylamine.

4-aminobenzenesulfonic acid must first be converted into a diazonium salt. Give the reagents and conditions for this reaction.

(2)

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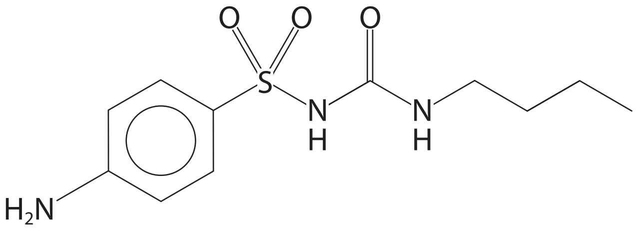
....

(d) (i) Draw a circle round an amide group in the formula of carbutamide.

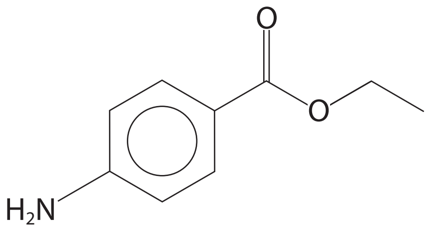
(1)



(ii) Write an equation showing the reaction of phenylamine with ethanoyl chloride. Show the displayed structure of the amide group in the product of this reaction.

(2)

(e) Benzocaine is an anaesthetic with the structure shown.



(i) Deduce the molecular formula of benzocaine.

(1)

....

(ii) The mass spectrum of benzocaine has significant peaks at

$m/e = 92$ and $m/e = 120$

Suggest the formula of the species responsible for each of these peaks.

(2)

92 ....

120 ....

(iii) Suggest the formulae of the organic products which would form when benzocaine is hydrolysed with dilute hydrochloric acid.

(2)

(f) Procaine, also called novocaine, is a local anaesthetic.
It contains thirteen carbon atoms per molecule.

On combustion, 100.0 g of procaine produced 242.4 g of carbon dioxide and 76.30 g of water. The mass of nitrogen atoms in 100.0 g was 11.86 g.

(i) Use these data to calculate the mass of oxygen atoms in 100.0 g of procaine and hence its empirical formula, which is the same as its molecular formula.

(4)

(ii) Suggest the structure of procaine using the formula you calculated in (f)(i) and the structural formula of the local anaesthetic **Y** given in the introduction to the question.

(2)

(Total for Question 22 = 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	2											3	4	5	6	7	0 (8)
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(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							

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

* 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