New Specification

Rewarding Learning

Centre Number

Candidate Number

ADVANCED
General Certificate of Education
2018

Chemistry

Assessment Unit A2 2

assessing

Analytical, Transition Metals, Electrochemistry and Further Organic Chemistry

[ACH22]

ACH22

TUESDAY 12 JUNE, AFTERNOON

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all eighteen** questions.
Answer **all ten** questions in **Section A**. Record your answers by marking the appropriate letter on the answer sheet provided. Use only the spaces numbered 1 to 10. Keep in sequence when answering.
Answer **all eight** questions in **Section B**.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in black ink only. **Do not write with a gel pen.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 110.
Quality of written communication will be assessed in Questions **12(b)** and **13(a)(vi)**.
In Section A all questions carry equal marks, i.e. **one** mark for each question.
In Section B the figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of Elements, containing some data, is included with this question paper.

11589

Section A

For each of the following questions only **one** of the lettered responses (A–D) is correct.

Select the correct response in each case and mark its code letter by connecting the dots as illustrated on the answer sheet.

1 When hydrogen peroxide is added to acidified potassium dichromate(VI) the following reaction occurs:

$$Cr_2O_7^{2-} + 3H_2O_2 + 8H^+ \rightarrow 2Cr^{3+} + 3O_2 + 7H_2O$$

Which statement is **not** correct?

A Hydrogen peroxide is acting as an oxidising agent

B The solution changes colour from orange to green

C The oxidation state of oxygen changes in the reaction

D The oxidation state of chromium changes in the reaction

2 Which compound has only singlet peaks in its proton nmr spectrum?

A Ethyl ethanoate

B Methyl propanoate

C Methyl ethanoate

D Propyl ethanoate

3 A painkiller, ibuprofen, produced effervescence when added to a solution of sodium carbonate. Which functional group is present in ibuprofen?

A -CHO

B -COOH

C -COOR

D $-CONH_2$

4 Which compound is the weakest base?

A Ammonia

B Methanamide

C Methylamine

D Phenylamine

5 What is the oxidation number of cobalt in $[Co(H_2O)_4en]Cl_2$?

A –2

B 0

C +2

D +3

[Turn over

6 Which atom has an unpaired electron in an s-orbital in the ground state?

A Chromium

B Cobalt

C Iron

D Manganese

7 Which compound will react most rapidly with 1,6-diaminohexane to form nylon?

A Hexane-1,6-diol

B Hexanedioic acid

C Hexanedioyl dichloride

D Sodium hexanedioate

8 A sample of chlorine gas was placed in a mass spectrometer. How many molecular ion peaks would be observed?

A 2

B 3

C 4

D 5

9 What mass of butanamide is required to synthesise 6.90 g of butanenitrile if the yield is 80%?

A 6.97 g

B 8.70 g

C 10.9 g

D 12.2 g

10 Some glycine is dissolved in a buffer solution of pH 11. What is the structure formed at this pH?

A $HOOCCH_2NH_3^+$

B NH_2CH_2COOH

C $NH_2CH_2COO^-$

D $NH^-CH_2COO^-$

[Turn over

Section B

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

11 Transition metal complexes are often coloured.

(a) State the colour of the following aqueous complexes:

aqueous complex	colour
$[Mn(H_2O)_6]^{2+}$	
$[Ni(H_2O)_6]^{2+}$	
$[Co(H_2O)_6]^{2+}$	
$[V(H_2O)_6]^{3+}$	
$[Ni(NH_3)_6]^{2+}$	

[5]

(b) Aqueous hexaaquacopper(II) ions can undergo ligand replacement with concentrated hydrochloric acid to form tetrachlorocuprate(II) ions.

(i) Write the electronic configuration of the copper ion in hexaaquacopper(II) ions and use this to explain why copper can be described as a transition metal.

_____

_____

_____ [2]

(ii) Define the term **ligand**.

_____

_____

_____ [1]

(iii) Suggest why the co-ordination number changes when hexaaquacopper(II) ions react with concentrated hydrochloric acid.

_____

_____

_____ [1]

(iv) Write the equation for the ligand substitution reaction which occurs when hexaaquacopper(II) ions form tetrachlorocuprate(II) ions.

_____

_____ [2]

(v) Write the colour change observed when this reaction occurs.

_____ [1]

(vi) Explain why this ligand replacement is thermodynamically feasible.

_____

_____ [2]

(c) Copper can form complexes with ammonia or ethylamine. State and explain which of these would be the stronger ligand.

_____

_____

_____ [2]

[Turn over

12 Two standard electrode potentials are given below:

(a)

half-cell	$E^{\ominus}$/V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn$	–0.76
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu$	+0.34

(i) Define **standard electrode potential**.

_____

_____ [2]

(ii) When the two half-cells are connected zinc will reduce Cu^{2+} ions to Cu atoms. Write the equation for the reaction.

_____ [2]

(iii) Calculate the emf for this cell.

_____ [1]

(b) Describe how you would set up a standard hydrogen electrode and use it to measure the electrode potential for a half-cell.

In this question you will be assessed on using your written communication skills including the use of specialist scientific terms.

[6]

[Turn over

13 A method of synthesising aspirin is given below using the following steps:

1. Add 7.5 cm^3 (an excess) of ethanoic anhydride to 3.0 g of salicylic acid in a conical flask
2. Add eight drops of concentrated phosphoric acid
3. Heat, with stirring, for 20 minutes in a water bath
4. Add 3 cm^3 of deionised water to the flask
5. Add 30 cm^3 of deionised water and cool to room temperature, allowing the aspirin to crystallise
6. Filter the crystals by Buchner filtration; continue to suck air through the Buchner funnel for five minutes after completion of the filtration

(a) (i) Suggest **two** reasons why ethanoic anhydride is used in this reaction in preference to ethanoic acid.

_____

_____

_____

_____ [2]

(ii) Write the equation for the reaction in step 1.

[2]

(iii) Why is concentrated phosphoric acid added?

_____ [1]

(iv) Suggest why water is added in step 4.

_____

_____ [1]

(v) Explain why air is sucked through the apparatus for five minutes.

_____

_____ [1]

[Turn over

(vi) Describe, giving full experimental detail, the TLC method which can be used to determine whether the reaction is complete after step 3. The solvent is ethyl ethanoate.

In this question you will be assessed on using your written communication skills including the use of specialist scientific terms.

[6]

(b) Calculate the percentage yield if 2.3 g of aspirin is obtained (answer to one decimal place).

[3]

(c) Salicylic acid is a bifunctional molecule with a carboxylic acid group and a hydroxyl group attached to the benzene ring. The hydroxyl group displays acidic behaviour.

(i) Suggest why the hydroxyl group attached to a benzene ring is more acidic than the hydroxyl group in aliphatic alcohols.

_____

_____ [2]

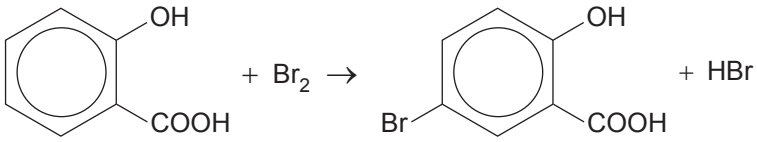
(ii) Write an equation for the reaction of salicylic acid with excess aqueous sodium hydroxide.

_____ [2]

(iii) State why it is preferable to use the sodium salt of aspirin.

_____ [1]

(d) Bromine will give an electrophilic substitution reaction with salicylic acid as shown below:



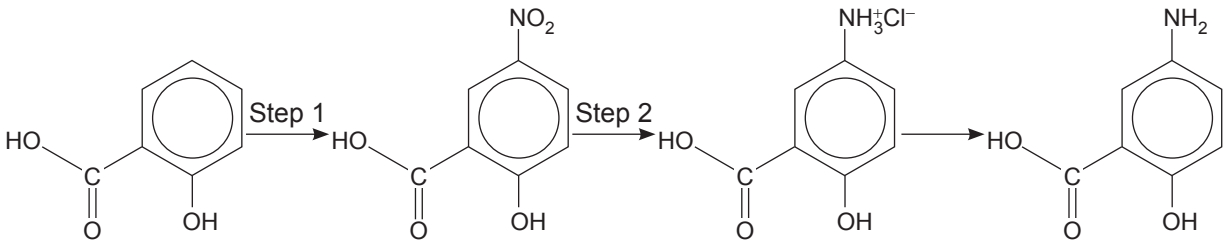
Salicylic acid will react with bromine without a catalyst being present. This differs from benzene, which requires a metal halide catalyst.

Name a catalyst which is used in the bromination of benzene.

_____ [1]

[Turn over

14 Mesalazine, an anti-inflammatory drug which is used to treat bowel disease, can be synthesised from 2-hydroxybenzoic acid using the flow scheme below.



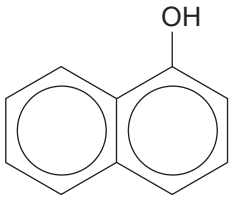
2-hydroxybenzoic acid mesalazine

(a) (i) State the reagents that could be used for Step 1 and Step 2.

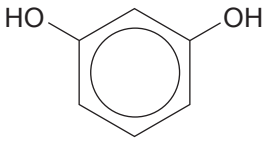
Step 1: _____

Step 2: _____ [2]

(ii) Mesalazine can be converted into azo dyes through reaction with naphth-1-ol or resorcinol:



naphth-1-ol



resorcinol

Draw the structure of the ion mesalazine must be converted into before the azo dye can be formed.

[2]

(iii) Draw the structure of the azo dye produced by the reaction with resorcinol.

[2]

(iv) Explain why azo dyes are coloured and suggest why the azo dyes produced by resorcinol and naphth-1-ol have slightly different colours.

[4]

(b) 2-hydroxybenzoic acid can be converted into an ester by reacting with an equimolar amount of ethane-1,2-diol. Write an equation for this reaction.

[2]

(c) Polyethylene terephthalate can be produced from ethane-1,2-diol.

(i) State a use for polyethylene terephthalate.

[1]

(ii) Explain why polyethylene terephthalate is biodegradable.

[1]

[Turn over

15 An ester, with the molecular formula $C_7H_{14}O_2$, produced three signals when analysed by proton nmr. The data is provided in the table below:

signal	**a**	**b**	**c**
chemical shift	4.1	1.2	1.1
integration ratio	2	3	9
splitting pattern	quartet	triplet	singlet

(a) **(i)** Explain why solvents which contain hydrogen atoms should not be used in nmr spectroscopy. Suggest a suitable solvent which could be used.

_____

_____ [2]

(ii) Give the name and formula of the molecule used in nmr spectroscopy as a standard.

_____ [2]

(iii) State **two** reasons why the molecule identified in part **(ii)** is used.

_____

_____ [2]

(b) (i) Explain which alkyl group in the ester produces signals **a** and **b** making reference to the spin-spin splitting pattern and the integration ratios.

[3]

(ii) Draw the alkyl group that would give rise to signal **c**.

[1]

(c) Draw the possible structure of the ester based upon the nmr data given.

[2]

[Turn over

16 The bromate(V) ion, BrO_3^-, is an oxidising agent produced by the reaction of bromine with a hot concentrated solution of sodium hydroxide.

(a) (i) Write the ionic equation for the reaction of bromine with sodium hydroxide.

_____ [2]

(ii) State the colour change observed for the above reaction.

_____ [1]

(b) Acidified bromate(V) ions will oxidise iodide ions to iodine.

(i) Write a half-equation for the reduction of bromate(V) ions to bromide.

_____ [1]

(ii) Write a half-equation for the oxidation of iodide ions to iodine.

_____ [1]

(iii) Write the overall equation for this reaction.

_____ [1]

(c) The iodine produced can then be reduced by thiosulfate ions. Titrations of the liberated iodine with sodium thiosulfate solution can be used to determine the concentration of bromate(V) ions. A 20.0 cm^3 solution containing acidified bromate(V) ions was added to a solution containing excess iodide ions and the resulting mixture made up to 1.0 dm^3. A 25.0 cm^3 aliquot was titrated against 0.10 M sodium thiosulfate, adding starch indicator just before the end point. The titre was found to be 23.8 cm^3.

(i) Explain why it is necessary to add the starch indicator just before the end point.

_____

_____ [1]

(ii) Calculate, to two significant figures, the concentration of the original bromate(V) solution.

_____

_____

_____

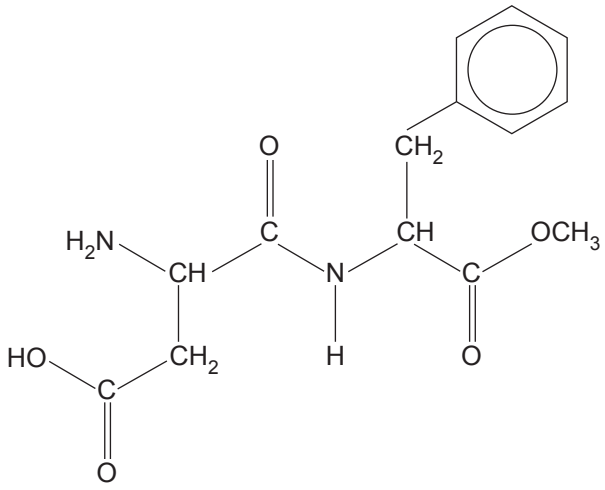
_____

_____

_____ [4]

[Turn over

17 Aspartame is used as a sweetener in many food products. It is a methyl ester of the dipeptide produced in the condensation reaction between aspartic acid and phenylalanine.



Aspartame

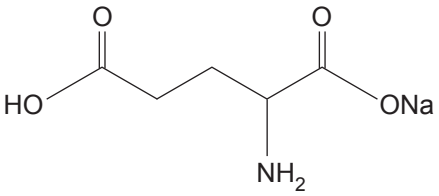
(a) Use the structure of aspartame to suggest structures for aspartic acid and phenylalanine.

aspartic acid

phenylalanine

[2]

(b) Another amino acid derivative that is used as a food additive is monosodium glutamate which can be synthesised from glutamic acid.



monosodium glutamate

(i) Circle on the structure above any chiral centre present in monosodium glutamate. [1]

(ii) Draw the structure of the zwitterion formed by glutamic acid.

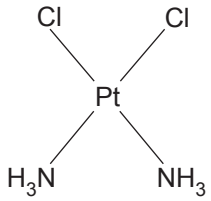
[1]

(iii) Write an equation for the reaction of glutamic acid with sodium carbonate to form monosodium glutamate.

[2]

[Turn over

18 Cisplatin was first described by Peyrone in 1845 and was approved for use in the treatment of testicular and ovarian cancers in the USA in 1978.



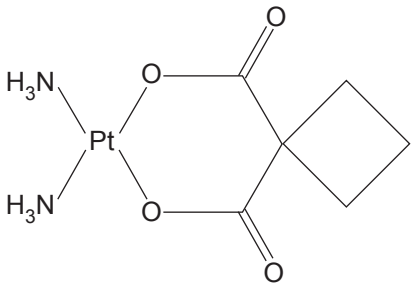
cisplatin

(a) Explain why cisplatin is effective in acting as an anticancer drug.

_____

_____ [1]

(b) Cisplatin has a number of undesired side-effects which are believed to be caused by the drug activating before it reaches the targeted tumour. Attempts to reduce these side-effects have included modifying the structure to give derivatives such as carboplatin.

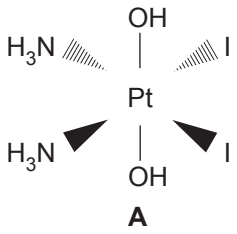


carboplatin

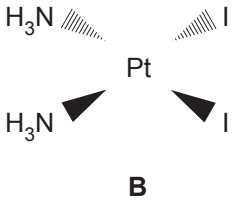
Give the molecular formula of carboplatin.

_____ [1]

(c) Another method of developing more targetable platinum-based anticancer drugs has been through the development of photoactivable drugs which are activated through photoreduction by light. Early examples of these were diiodo complexes.



A



B

(i) Explain, using oxidation states, why converting **A** into **B** is regarded as a reduction.

_____

_____ [2]

(ii) Describe the change in both shape and co-ordination number in converting **A** into **B**.

_____

_____

_____

_____ [4]

THIS IS THE END OF THE QUESTION PAPER

DO NOT WRITE ON THIS PAGE

237486

Rewarding Learning

Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and Advanced Level
Chemistry Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations.

gce A/AS examinations

chemistry (advanced)

THE PERIODIC TABLE OF ELEMENTS

I	II										III	IV	V	VI	VII	0

Group

1 **H** Hydrogen 1

4 **He** Helium 2

7 **Li** Lithium 3

9 **Be** Beryllium 4

11 **B** Boron 5

12 **C** Carbon 6

14 **N** Nitrogen 7

16 **O** Oxygen 8

19 **F** Fluorine 9

20 **Ne** Neon 10

23 **Na** Sodium 11

24 **Mg** Magnesium 12

27 **Al** Aluminium 13

28 **Si** Silicon 14

31 **P** Phosphorus 15

32 **S** Sulfur 16

35.5 **Cl** Chlorine 17

40 **Ar** Argon 18

39 **K** Potassium 19

40 **Ca** Calcium 20

45 **Sc** Scandium 21

48 **Ti** Titanium 22

51 **V** Vanadium 23

52 **Cr** Chromium 24

55 **Mn** Manganese 25

56 **Fe** Iron 26

59 **Co** Cobalt 27

59 **Ni** Nickel 28

64 **Cu** Copper 29

65 **Zn** Zinc 30

70 **Ga** Gallium 31

73 **Ge** Germanium 32

75 **As** Arsenic 33

79 **Se** Selenium 34

80 **Br** Bromine 35

84 **Kr** Krypton 36

85 **Rb** Rubidium 37

88 **Sr** Strontium 38

89 **Y** Yttrium 39

91 **Zr** Zirconium 40

93 **Nb** Niobium 41

96 **Mo** Molybdenum 42

99 **Tc** Technetium 43

101 **Ru** Ruthenium 44

103 **Rh** Rhodium 45

106 **Pd** Palladium 46

108 **Ag** Silver 47

112 **Cd** Cadmium 48

115 **In** Indium 49

119 **Sn** Tin 50

122 **Sb** Antimony 51

128 **Te** Tellurium 52

127 **I** Iodine 53

131 **Xe** Xenon 54

133 **Cs** Caesium 55

137 **Ba** Barium 56

139 **La*** Lanthanum 57

178 **Hf** Hafnium 72

181 **Ta** Tantalum 73

184 **W** Tungsten 74

186 **Re** Rhenium 75

190 **Os** Osmium 76

192 **Ir** Iridium 77

195 **Pt** Platinum 78

197 **Au** Gold 79

201 **Hg** Mercury 80

204 **Tl** Thallium 81

207 **Pb** Lead 82

209 **Bi** Bismuth 83

210 **Po** Polonium 84

210 **At** Astatine 85

222 **Rn** Radon 86

223 **Fr** Francium 87

226 **Ra** Radium 88

227 **Ac†** Actinium 89

One mole of any gas at 20 °C and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm^3.

Planck Constant = 6.63×10^{-34} Js

Gas Constant = 8.31 J mol^{-1} K^{-1}

Avogadro Constant = 6.02×10^{23} mol^{-1}

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	162 **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

* 58–71 Lanthanum series

† 90–103 Actinium series

a
b x

a = relative atomic mass (approx.)

x = atomic symbol

b = atomic number