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

[AC222]

AC222

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 fifteen** 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 five** 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 120.
Quality of written communication will be assessed in Question **12(f)(i)**.
In Section A all questions carry equal marks, i.e. **two** marks for each question.
In Section B the figures printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of the Elements, containing some data, is included in this question paper.

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 In a fuel cell the following reaction takes place:

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

The relevant standard electrode potentials are:

$$2H_2(g) + 4OH^-(aq) \rightleftharpoons 4H_2O(l) + 4e^- \qquad -0.83\,V$$

$$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq) \qquad +0.40\,V$$

The emf of the fuel cell is

A $-0.43\,V$.

B $+0.43\,V$.

C $-1.23\,V$.

D $+1.23\,V$.

2 Which one of the following ligands is regarded as a large ligand?

A Cl^-

B H_2O

C NH_3

D OH^-

3 Ethanedioic acid reacts with manganate(VII) ions according to the following equation:

$$5C_2H_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

25 cm^3 of 0.015 M manganate(VII) ions were added to 25 cm^3 of 0.0208 M ethanedioic acid. Which one of the following is the number of moles of carbon dioxide produced?

A 3.75×10^{-4}

B 5.2×10^{-4}

C 1.04×10^{-3}

D 1.88×10^{-3}

4 Which one of the following does **not** take place during heterogeneous catalysis by transition metals?

A Absorption

B Bonds breaking

C Desorption

D d-orbital interaction

5 A standard hydrogen electrode operates

A at 20 °C.

B at a pressure of 1 atmosphere of hydrogen gas.

C using molar sulfuric acid.

D with platinum-palladium electrodes.

[Turn over

6 When methylbenzoate is nitrated the product is

A methyl 1-nitrobenzoate.

B methyl-1-nitrobenzoate.

C methyl 3-nitrobenzoate.

D methyl-3-nitrobenzoate.

7 In a plane, the emergency oxygen system is based on sodium chlorate(V) which decomposes to give oxygen and sodium chloride when heated. A human under stress uses 38.0 dm^3 of oxygen every 15 minutes. Assuming the oxygen is measured at 20 °C and 1 atmosphere pressure, what is the minimum mass of sodium chlorate(V) needed in the emergency oxygen system to supply 15 minutes of oxygen for one person?

A 56 g

B 112 g

C 224 g

D 336 g

8 Which one of the following vanadium ions is green?

A $V^{2+}(aq)$

B $V^{3+}(aq)$

C $VO^{2+}(aq)$

D $VO_2^{+}(aq)$

9 In which one of the following compounds does manganese show the lowest oxidation state?

A $KMnO_4$

B K_2MnO_4

C Mn_2O_7

D $Mn(CH_3CO_2)_2.4H_2O$

10 Which one of the following molecules is **not** optically active?

A $BrCH_2CH(OH)CH_2Br$

B $CH_3CHBrCH_2Br$

C $CH_3CH(CH_3)CHBrCH_3$

D $BrCH_2CH(CH_3)CH_2OH$

[Turn over

Section B

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

11 (a) Explain the following terms which are used in nmr spectroscopy.

(i) Low resolution nmr spectrum.

_____

_____ [1]

(ii) Chemically equivalent hydrogen atoms.

_____

_____ [1]

(iii) Chemical shift.

_____

_____ [1]

(iv) Integration curve.

_____

_____ [2]

(v) The n + 1 rule.

_____

_____ [2]

(b) Suggest how you would prepare a solution of a compound for nmr analysis. Name a solvent that would not interfere with the spectrum and name a substance that could be used as a standard.

_____

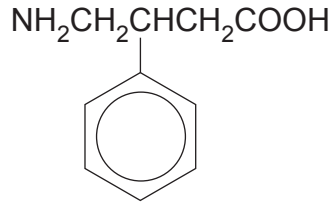
_____

_____

_____ [3]

[Turn over

12 Phenibut was first synthesised in Russia and was used by cosmonauts because it relieved anxiety and depression without causing drowsiness.



Phenibut

(a) Assuming that the benzene ring is regarded as a phenyl group, suggest a systematic name for phenibut.

_____ [2]

(b) The structure of phenibut reveals that it is an amino acid. Suggest why it is not found in proteins.

_____

_____ [1]

(c) Phenibut has a melting point of 253 °C. Explain why phenibut has such a high melting point.

_____

_____ [2]

(d) Phenibut reacts with nitrous acid, methanol, sodium hydrogencarbonate and ethanoyl chloride. Write equations for the reactions.

(i) nitrous acid

_____ [2]

(ii) methanol

_____ [2]

(iii) sodium hydrogencarbonate

_____ [2]

(iv) ethanoyl chloride

_____ [2]

[Turn over

(e) Phenibut is an optically active molecule. When used as a mixture of the optical isomers, only one of the isomers is biologically active.

(i) Explain the meaning of the term **optically active**.

[2]

(ii) Explain, using the structure of phenibut, why it is optically active.

[2]

(iii) Suggest why only one of the optically active molecules is biologically active.

[2]

(f) Phenibut is very soluble in both ethanol and water. If sodium hydroxide solution is added to an aqueous solution of impure phenibut the sodium salt is formed.

(i) Explain, giving practical details, how you could obtain a pure sample of phenibut crystals from the aqueous sodium salt.

[5]

Quality of written communication [2]

(ii) Explain, giving full experimental directions, how you would use TLC to compare the purity of the phenibut before and after purification.

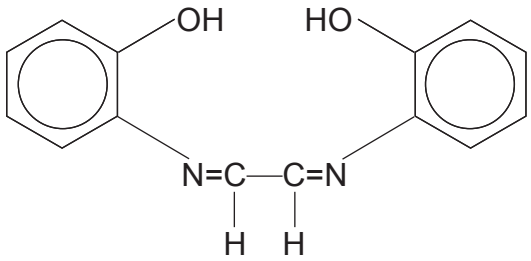
[4]

(iii) Explain whether TLC would enable you to show that phenibut consisted of two optical isomers.

[2]

[Turn over

13 The cations of the Group II elements form only a limited number of complexes in aqueous solution. Edta has been widely used in the complexometric titration of these ions but the end point is difficult to observe. However, calcium can also be determined in microgram quantities using the glyoxalin complex.



glyoxalin complex

The intensity of the pink colour of its complex is a measure of how much Ca^{2+} is present and is determined by a colorimeter.

(a) (i) Explain how you would carry out an edta titration for Ca^{2+} stating the indicator used, what the pH is adjusted to and the colour change at the end point. Routine aspects of practical titration are not needed.

[4]

(ii) 0.4505 g of calcium carbonate was dissolved in hydrochloric acid and the solution made up to 250 cm^3 in a volumetric flask. A 25 cm^3 sample of the solution required 24.25 cm^3 of an edta solution for titration. Calculate the molar concentration of the edta solution in mol dm^{-3}.

[3]

(iii) Edta is a hexadentate ligand. What type of ligand is the glyoxalin complex?

_____ [1]

(b) The compound formed by Ca^{2+} with the glyoxalin complex is pink and is insoluble in water but dissolves in butan-1-ol. The mass of calcium in a sample is determined by adding a buffer solution, the glyoxalin complex and butan-1-ol to the solution of calcium ions.

(i) The mixture is shaken and becomes homogeneous. Explain why the mixture becomes homogeneous.

_____

_____ [1]

(ii) Explain why a green filter is used in the colorimeter.

_____

_____ [2]

(iii) Deionised water is used as a **reference** solution. Explain what this term means.

_____

_____ [1]

(iv) A calibration curve is needed to determine the amount of calcium ions in solution. Explain how you would experimentally determine a calibration curve.

_____

_____

_____ [3]

[Turn over

14 The benzene ring is stable to the addition of halogens. Halogens normally react with double bonds by adding to them; however with a benzene ring they react by substitution. The substitution reaction is speeded up using a catalyst.

(a) Explain why halogens are more reactive with alkenes than with benzene.

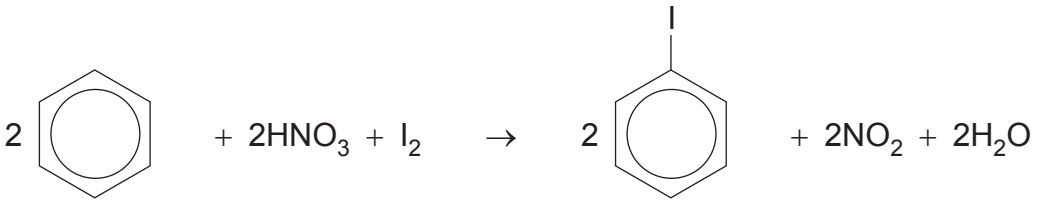
_____

_____ [2]

(b) Draw a flow scheme for the mechanism of the bromination of benzene using a catalyst such as iron(III) bromide.

[4]

(c) The iodination of benzene does not take place with iodine at room temperature. However, it is formed by refluxing benzene with iodine and concentrated nitric acid.



(i) Explain, using oxidation numbers, the redox reaction taking place.

_____

_____

_____ [3]

(ii) The electrophile in this reaction is the iodonium ion. Write the formula of the iodonium ion and give the definition of an **electrophile**.

_____

_____

_____ [3]

(iii) Explain why nitric acid is not regarded as a catalyst in this reaction.

_____

_____ [1]

[Turn over

(d) The preparation of iodobenzene using concentrated nitric acid is time consuming, dangerous and expensive. It is better prepared using the Sandmeyer reaction which involves the diazotisation of phenylamine.

(i) Explain why the preparation of iodobenzene is dangerous.

_____

_____ [1]

(ii) Explain, giving experimental details, how you would diazotise phenylamine.

_____

_____

_____

_____ [3]

(iii) Explain why the benzenediazonium ion is relatively stable at low temperature and why it decomposes at higher temperatures.

_____

_____ [2]

(iv) Name the reagent used to convert benzenediazonium chloride to iodobenzene.

_____

_____ [1]

(v) Write the overall equation for the conversion of benzenediazonium chloride to iodobenzene.

_____ [2]

(e) The boiling points of the halogenobenzenes are shown below.

Bromobenzene	156 °C
Chlorobenzene	131 °C
Iodobenzene	188 °C

(i) Explain which of the halogenobenzenes you would expect to have the highest polarity.

_____

_____ [2]

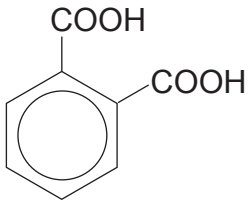
(ii) Explain why iodobenzene has the highest boiling point.

_____

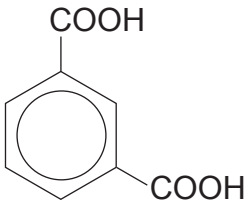
_____ [2]

[Turn over

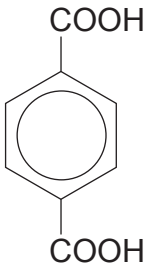
15 There are three benzene dicarboxylic acids.



A



B



C

(a) Suggest why acid B has the highest boiling point.

_____

_____ [1]

(b) The French chemist Caillot obtained terephthalic acid, C, by the oxidation of turpentine (turpentine = terebenthine in French). Today it is obtained by the oxidation of 1,4-dimethylbenzene.

(i) Write the equation for the oxidation of 1,4-dimethylbenzene to form terephthalic acid using [O] as the oxidising agent.

_____ [2]

(ii) Terephthalic acid is purified using its dimethyl ester. Write the equation for the formation of the dimethyl ester from the acid.

_____ [2]

(iii) The dimethyl ester is formed during the recycling of polyethylene terephthalate from plastic bottles. Explain why it is useful to form the ester to help the recycling process.

_____

_____ [2]

(c) The major use of terephthalic acid is in the production of the polymer polyethylene terephthalate (PET).

(i) Draw the repeating structure of PET.

[2]

(ii) PET can be hydrolysed both in nature and in industry. Compare the two methods, stating the conditions used in each case.

[4]

(iii) PET is an exceptional polymer because it has high **crystallinity** and no **branching**. Explain the meaning of these terms with regard to PET.

[3]

(d) Suggest why polythene bags are often burnt rather than recycled.

[1]

DO NOT WRITE ON THIS PAGE

For Examiner's use only	
Question Number	**Marks**
Section A	
1–10	
Section B	
11	
12	
13	
14	
15	
Total Marks	

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