Rewarding Learning

Centre Number

Candidate Number

ADVANCED
General Certificate of Education
2019

Chemistry

Assessment Unit A2 1
assessing
Further Physical and
Organic Chemistry

ACH12

[ACH12]
TUESDAY 4 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 twenty-one** 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 eleven** 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(a)(ii)** and **20(a)(ii)**.
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.

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 How many sigma bonds are there in benzene?

A 3

B 6

C 12

D 24

2 Which compound has the highest boiling point?

A Methanal

B Methanol

C Methanoic acid

D Methyl methanoate

3 Which reagent will distinguish between the molecules C_6H_5CHO and $C_6H_5COCH_3$?

A Aqueous bromine

B Aqueous diammine silver(I) ions

C Lithium tetrahydridoaluminate(III)

D Sodium

4 The following reaction is an intermediate stage in the manufacture of the polymer perspex.

$$CH_3COCH_3 + HCN \rightarrow CH_3C(OH)(CN)CH_3$$

What type of reaction is this?

A Electrophilic addition

B Nucleophilic addition

C Nucleophilic substitution

D Radical substitution

5 For which compound is it possible to construct a Born–Haber cycle?

A Boron trichloride

B Hydrogen chloride

C Lead(II) chloride

D Phosphorus(III) chloride

6 What is the name of the NO_2^+ ion?

A Nitrate cation

B Nitrite cation

C Nitronium ion

D Nitrosonium ion

[Turn over

7 What is the percentage of carbon in dimethylbenzene?

A 88.9 %

B 89.7 %

C 90.3 %

D 90.6 %

8 Vegetable oils are hardened to

A convert to unsaturated fats.

B increase the melting temperature.

C prevent oxidation.

D reduce viscosity.

9 What is the conjugate base of the acid HCO_3^-?

A CO_3^-

B CO_3^{2-}

C H_2CO_3

D OH^-

10 Which pair of reactants would produce the ester $C_3H_7CO_2C_2H_5$?

A C_2H_5Cl and $C_3H_7CO_2H$

B C_3H_7OH and C_2H_5COCl

C C_2H_5OH and C_3H_7COCl

D C_3H_7Cl and $C_2H_5CO_2H$

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(Questions continue overleaf)

[Turn over

Section B

Answer **all eleven** questions in this section

11 The splitting of water into hydrogen and oxygen becomes feasible at 5440 K.

$$H_2O(g) \longrightarrow H_2(g) + \tfrac{1}{2}O_2(g)$$

molecule	$H_2O(g)$	$H_2(g)$	$O_2(g)$
S /J K^{-1} mol^{-1}	189	131	205

(a) Define the term **entropy**.

_____

_____ [1]

(b) Using the data in the table, calculate the molar entropy change for this reaction.

_____

_____

_____ [1]

(c) Suggest, and explain, the effect upon the entropy change if liquid water was split instead of gaseous water.

_____

_____

_____ [2]

(d) Define the term **feasible**.

_____

_____ [1]

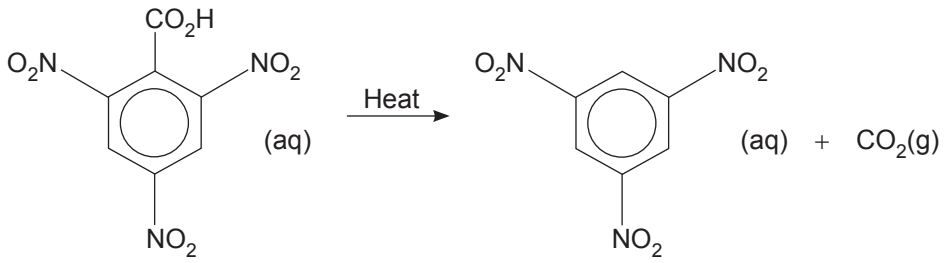
(e) Calculate the value for the molar enthalpy change for the splitting of gaseous water at 5440 K.

_____

_____ [2]

[Turn over

12 In 1931 Moelwyn-Hughes and Hinshelwood monitored the decarboxylation of the strong acid **A**:



A

(a) (i) Suggest an IUPAC name for the organic product.

_____ [1]

(ii) Moelwyn-Hughes and Hinshelwood followed the kinetics of the reaction by titration. Explain how they could have determined the rate of reaction. Include in your answer the names of an alkali and an indicator which could be used. Indicate what steps and graphs would be needed to determine the order of reaction with respect to **A**.

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

[6]

(b) Moelwyn-Hughes and Hinshelwood obtained the following data from their experiments.

experiment	[A] × 10^{-4}/ mol dm^{-3}	initial rate × 10^{-6}/ mol $dm^{-3}min^{-1}$
1	2.50	2.40
2	1.67	1.64
3	1.04	1.02

(i) State the order of the reaction.

[1]

(ii) Using the results from experiment 1 calculate the rate constant, stating its units.

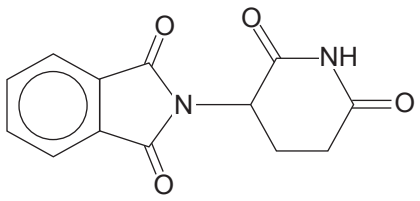
[2]

(iii) Explain why the rate constant would increase if the experiment was repeated at a higher temperature.

[1]

[Turn over

13 Thalidomide was first marketed in 1957 as a sedative to reduce morning sickness during pregnancy. It contains a chiral centre and exists as two optical isomers.



thalidomide

(a) Circle the chiral centre in the structure above. [1]

(b) Define the term **optical isomers**.

_____

_____ [1]

(c) The original use of thalidomide led to babies being born with deformed limbs. It was found that one optical isomer of thalidomide caused these birth defects. Suggest how the drug action may be determined by the stereochemistry of the drug.

_____

_____ [1]

(d) Thalidomide, in the sedative, was used as a racemic mixture. Define the term **racemic mixture** and explain why a racemic mixture would be optically inactive.

_____

_____

_____ [2]

14 The titration curve for a strong acid with a strong alkali can be determined by measuring pH using specialised pH paper or a pH meter.

(a) Suggest an advantage and a disadvantage of using the pH meter compared to pH paper.

_____

_____

_____

_____ [2]

(b) Explain, using your knowledge of titration curves, why both methyl orange and phenolphthalein are suitable indicators for this titration.

_____

_____ [1]

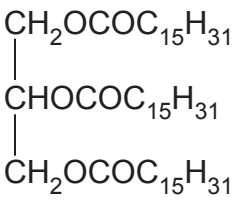
(c) Explain whether the salt solution formed from the reaction between sulfuric acid and sodium hydroxide is neutral or not.

_____

_____ [1]

[Turn over

15 The ester tripalmitin can be used to make biodiesel using transesterification. Tripalmitin is formed when glycerol reacts with palmitic acid.



tripalmitin

(a) Write an equation for the formation of tripalmitin from glycerol and palmitic acid.

[2]

(b) Use the structure of tripalmitin to explain whether tripalmitin is a saturated or unsaturated fat.

[2]

(c) Explain the term **transesterification**.

[2]

(d) Write the equation for the reaction between tripalmitin and methanol forming molecules, some of which are used in biodiesel.

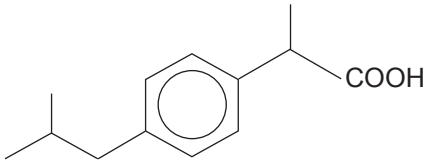
[1]

(e) From the equation written in **(d)**, write the formula of the product that could be used as biodiesel.

_____ [1]

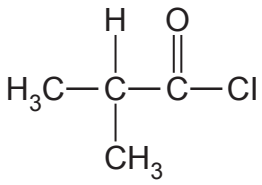
[Turn over

16 Benzene is used to synthesise the analgesic, ibuprofen. This occurs using a multi-step reaction involving both Friedel–Crafts acylation and alkylation.



ibuprofen

(a) The first step in this reaction is the acylation of benzene with 2-methylpropanoyl chloride. The structure of 2-methylpropanoyl chloride is shown below.



2-methylpropanoyl chloride

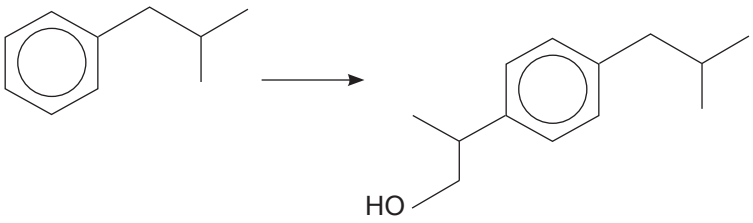
Show the mechanism for the catalysed reaction between 2-methylpropanoyl chloride and benzene, using aluminium chloride as a catalyst.

[5]

(b) Draw a dot and cross diagram for the aluminium-containing intermediate species formed by the catalyst during this reaction.

[1]

(c) A later step in the synthesis is shown below.



Suggest the structure of the organic reagent used for the step shown.

[1]

(d) The acylation and alkylation reactions of benzene are substitution reactions. Explain why benzene undergoes substitution reactions rather than addition reactions.

_____

_____ [1]

[Turn over

17 The dissociation of water is an endothermic process. At 60 °C the ionic product of water, K_w, has a value of 9.3×10^{-14} mol^2 dm^{-6}.

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

(a) (i) Write the expression for K_w.

_____ [1]

(ii) Explain why the expression for K_w does not include the concentration of water.

_____

_____ [1]

(b) (i) Calculate the pH of water at 60 °C. Give your answer to two decimal places.

_____

_____

_____ [2]

(ii) Explain whether water at 60 °C is neutral, acidic or alkaline.

_____

_____ [2]

(iii) Calculate the pH of a solution containing 256.5 g of barium hydroxide dissolved in 500 cm^3 of water at 60 °C. Give your answer to two decimal places.

[4]

(c) (i) An acidic buffer is formed when 10.0 cm^3 of 0.12 mol dm^{-3} aqueous sodium hydroxide is added to 25.0 cm^3 of 0.18 mol dm^{-3} ethanoic acid. Calculate the pH of this buffer. The pK_a of ethanoic acid is 4.76. Give your answer to two decimal places.

[4]

(ii) Explain, using an equation, the effect of adding small amounts of acid to the buffer.

[2]

[Turn over

18 Sulfur dioxide is reacted with oxygen to form sulfur trioxide in the manufacture of sulfuric acid in the Contact Process.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad -197\,kJ$$

(a) State the pressure and catalyst used in this reaction.

_____

_____ [2]

(b) Explain why the temperature chosen for this reaction, 450 °C, can be described as a compromise temperature.

_____

_____

_____

_____ [2]

(c) Write an expression for K_c for the above reaction.

[1]

(d) Sulfur dioxide, oxygen and sulfur trioxide were mixed and allowed to reach equilibrium in a 20 dm^3 container. At equilibrium, 8.0 moles of sulfur dioxide and 10.0 moles of sulfur trioxide were present. Calculate the number of moles of oxygen present if the numerical value of K_c is 27.9 mol^{-1} dm^3.

[4]

[Turn over

19 The lattice enthalpy of magnesium chloride is 2493 kJ mol^{-1} and that of calcium chloride is 2237 kJ mol^{-1}.

(a) (i) Write an equation, including state symbols, for the lattice enthalpy of calcium chloride.

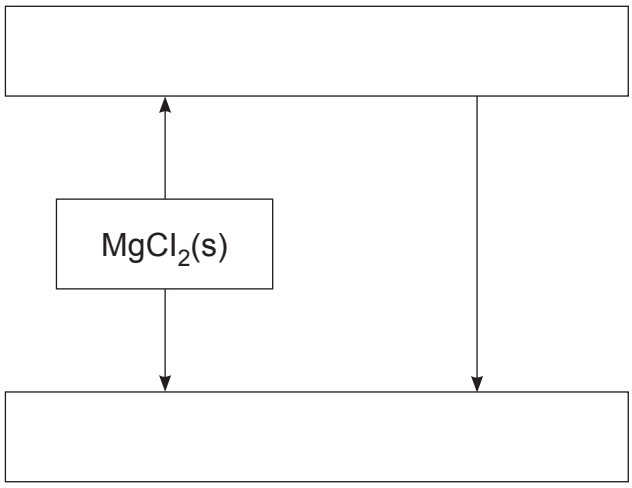
_____ [2]

(ii) Explain why the lattice enthalpy of magnesium chloride is greater than that of calcium chloride.

_____

_____ [1]

(b) (i) The enthalpy of solution of magnesium chloride is −155 kJ mol^{-1}. Complete the following enthalpy diagram for dissolving magnesium chloride.



[2]

(ii) Calculate the enthalpy of hydration of magnesium ions. The enthalpy of hydration of chloride ions is $-364\,kJ\,mol^{-1}$.

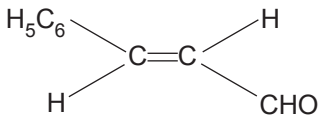
_____

_____

_____ [2]

[Turn over

20 Cinnamaldehyde is a pale yellow liquid that can be obtained from the bark of cinnamon trees.



cinnamaldehyde

(a) (i) Cinnamaldehyde is a geometric isomer. State and explain which geometric isomer cinnamaldehyde is.

[2]

(ii) Explain how a pale yellow oil suspected as being cinnamaldehyde, could be identified using 2,4-dinitrophenylhydrazine. Include in your answer experimental details of the preparation of cinnamaldehyde-2,4-dinitrophenylhydrazone.

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

[6]

(b) Write an equation for the reduction of cinnamaldehyde with lithal using [H] to represent the reducing agent.

[1]

(c) Oxidation of cinnamaldehyde produces cinnamic acid which is a solid at room temperature with a melting point of 132–133 °C. Explain why cinnamic acid has a higher melting point than cinnamaldehyde.

[3]

[Turn over

21 Ethanoyl chloride can be used in the preparation of esters. It reacts readily with moisture in the air.

(a) Write an equation for the reaction of ethanoyl chloride with water.

_____ [1]

(b) Describe a chemical test for the inorganic product of the reaction, indicating a positive result for this test.

_____

_____ [2]

(c) **(i)** Write an equation for the reaction of excess ethanoyl chloride with ethane-1,2-diol to produce an ester.

[2]

(ii) Calculate the percentage yield if 31 g of ethane-1,2-diol produces 49 g of the ester.

_____

_____

_____ [3]

(d) State **three** advantages of using ethanoyl chloride instead of ethanoic acid in esterification reactions.

_____

_____

_____ [3]

(e) Give the formula and the IUPAC name of a reagent that could convert ethanoic acid into ethanoyl chloride.

_____ [2]

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General Information

1 tonne = 10^6 g
1 metre = 10^9 nm
One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm^3
Avogadro Constant = 6.02×10^{23} mol^{-1}
Planck Constant = 6.63×10^{-34} J s
Specific Heat Capacity of water = 4.2 J g^{-1} K^{-1}
Speed of Light = 3×10^8 m s^{-1}

Characteristic absorptions in IR spectroscopy

Wavenumber/cm^{-1}	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–C**H**	Saturated alkanes
0.5–5.5	–O**H**	Alcohols
1.0–3.0	–N**H**	Amines
2.0–3.0	–CO–C**H**	Ketones
	–N–C**H**	Amines
	C_6H_5–C**H**	Arene (aliphatic on ring)
2.0–4.0	X–C**H**	X = Cl or Br (3.0–4.0)
		X = I (2.0–3.0)
4.5–6.0	–C=C**H**	Alkenes
5.5–8.5	RCON**H**	Amides
6.0–8.0	–C_6**H**$_5$	Arenes (on ring)
9.0–10.0	–C**H**O	Aldehydes
10.0–12.0	–COO**H**	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

COUNCIL FOR THE **CURRICULUM, EXAMINATIONS** AND **ASSESSMENT**
29 Clarendon Road, Clarendon Dock, Belfast BT1 3BG
Tel: +44 (0)28 9026 1200 Fax: +44 (0)28 9026 1234
Email: info@ccea.org.uk Web: www.ccea.org.uk

Rewarding Learning

New Specification

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level 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

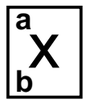
For first teaching from September 2016
For first award of AS Level in Summer 2017
For first award of A Level in Summer 2018
Subject Code: 1110

THE PERIODIC TABLE OF ELEMENTS

I	II											III	IV	V	VI	VII	0
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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	98 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	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	285 Cn Copernicium 112						

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 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 = relative atomic mass (approx)
x = atomic symbol
b = atomic number