New Specification

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ADVANCED
General Certificate of Education
2018

Centre Number

Candidate Number

Chemistry

Assessment Unit A2 1

assessing

Further Physical and Organic Chemistry

ACH12

[ACH12]

TUESDAY 5 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 sixteen** 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 six** 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 **13(a)** and **14(b)(iii)**.
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.

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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 K_w has the units

A $mol^{-2}\ dm^{-6}$.

B $mol^{-2}\ dm^{6}$.

C $mol^{2}\ dm^{-6}$.

D $mol^{2}\ dm^{6}$.

2 Which solution has the lowest pH?

A 3.65 g of hydrogen chloride dissolved in 500 cm^3 of water

B 0.1 mol dm^{-3} hydrochloric acid

C 4.9 g of sulfuric acid dissolved in 250 cm^3 of water

D 0.1 mol dm^{-3} sulfuric acid

3 The equation for the reaction between P and Q is

$$2P + Q \rightarrow R + S$$

The rate equation for the reaction is rate = k[P][Q].

Which of the following is the mechanism for the reaction?

A $P + P \xrightarrow{\text{fast}} P_2$ $\quad$ $P_2 + Q \xrightarrow{\text{slow}} R + S$

B $P + P \xrightarrow{\text{slow}} P_2$ $\quad$ $P_2 + Q \xrightarrow{\text{fast}} R + S$

C $P + Q \xrightarrow{\text{fast}} PQ$ $\quad$ $PQ + P \xrightarrow{\text{slow}} R + S$

D $P + Q \xrightarrow{\text{slow}} PQ$ $\quad$ $PQ + P \xrightarrow{\text{fast}} R + S$

4 How many isomers exist with the formula C_3H_6O?

A Fewer than 4

B 4

C 5

D At least 6

5 The alkaline hydrolysis of $(CH_3)_3CCl$

A does not involve the formation of a carbocation.

B has the rate equation, rate = k $[(CH_3)_3CCl][OH^-]$.

C is an S_N1 mechanism.

D proceeds in one step.

[Turn over

6 Which of the following is a conjugate acid-base pair for the reaction?

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

	conjugate acid	conjugate base
A	NH_3	H_2O
B	NH_3	NH_4^+
C	H_2O	NH_4^+
D	H_2O	OH^-

7 Which titration has no suitable indicator?

A 0.1 mol dm^{-3} HCl with 0.1 mol dm^{-3} NH_3

B 0.1 mol dm^{-3} HCl with 0.1 mol dm^{-3} NaOH

C 0.1 mol dm^{-3} CH_3COOH with 0.1 mol dm^{-3} NH_3

D 0.1 mol dm^{-3} CH_3COOH with 0.1 mol dm^{-3} NaOH

8 Which reaction can **not** be used to prepare carboxylic acids?

A Hydrolysis of nitriles

B Hydrolysis of acyl chlorides

C Oxidation of aldehydes

D Oxidation of ketones

9 Which reaction has an increase in entropy?

A $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

B $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

C $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

D $4NO_2(g) + O_2(g) + 2H_2O(g) \rightarrow 4HNO_3(l)$

10 Propanone reacts with iodine as follows:

$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + HI(aq)$

Which statement is correct?

A The brown colour fades

B The pH increases

C The purple colour fades

D This is not a redox reaction

Section B

Answer **all six** questions in this section

11 Barium chloride is formed from its elements as follows:

$$Ba(s) + Cl_2(g) \rightarrow BaCl_2(s) \quad -855\,kJ\,mol^{-1}$$

The following enthalpy changes can be used to calculate the lattice enthalpy of barium chloride:

I $Ba(s) \rightarrow Ba(g)$ $+175\,kJ\,mol^{-1}$

II $Ba(g) \rightarrow Ba^{2+}(g) + 2e^-$ $+1500\,kJ\,mol^{-1}$

III $Cl_2(g) \rightarrow 2Cl(g)$ $+242\,kJ\,mol^{-1}$

IV $Cl(g) + e^- \rightarrow Cl^-(g)$ $-364\,kJ\,mol^{-1}$

(a) What name is given to each of the enthalpy changes **I–IV**?

I _____

II _____

III _____

IV _____ [4]

(b) Explain what is meant by the term **lattice enthalpy**.

_____

_____

_____ [2]

(c) Calculate, to four significant figures, the lattice enthalpy of barium chloride.

_____

_____ [2]

(d) What name is given to the cycle used to calculate lattice enthalpy?

_____ [1]

(e) Given

$Ba^{2+}(g) \rightarrow Ba^{2+}(aq)$ $-1309\,kJ\,mol^{-1}$

$Cl^{-}(g) \rightarrow Cl^{-}(aq)$ $-378\,kJ\,mol^{-1}$

calculate, to an appropriate number of significant figures, the enthalpy of solution of barium chloride and use it to explain why barium chloride is soluble in water.

_____

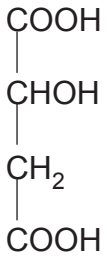
_____

_____

_____ [3]

[Turn over

12 Malic acid is found in some apples, giving them a sour taste.



malic acid

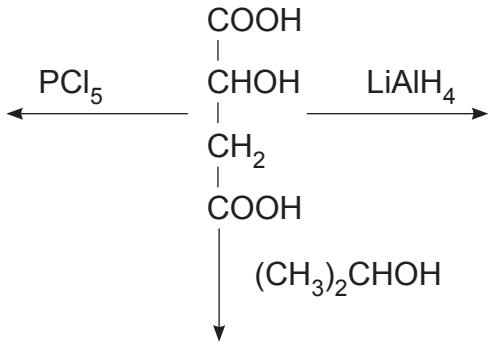
(a) **(i)** Draw the structure of malic acid showing **all** the bonds present.

[1]

(ii) Suggest the IUPAC name for malic acid.

_____ [2]

(b) **(i)** Show the organic products for the reaction of malic acid with an excess of each of the following: PCl_5, $LiAlH_4$ and $CH_3CHOHCH_3$.



[4]

(ii) Name the organic product formed from the reaction with $LiAlH_4$.

_____ [1]

(c) Malic acid melts at 130 °C and has a solubility of 0.558 kg dm^{-3} at 20 °C.

(i) Explain why malic acid has a relatively high melting point.

_____

_____

_____ [2]

(ii) Calculate, to three significant figures, the molarity of a saturated solution of malic acid at 20 °C.

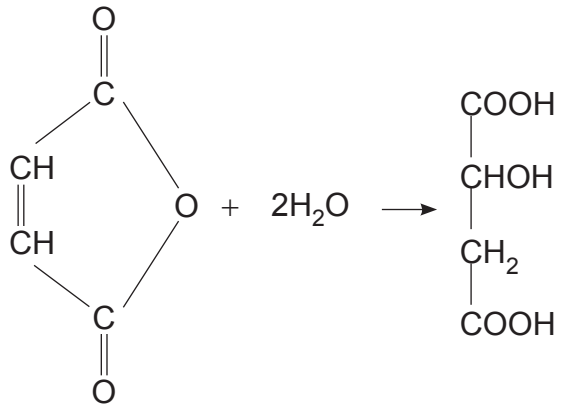
_____

_____

_____ [2]

[Turn over

(d) Malic acid is produced industrially by the double hydration of maleic anhydride. Although malic acid contains an asymmetric centre, the product of this reaction is not optically active.



maleic anhydride

(i) Explain what is meant by the term **optically active**.

_____

_____ [2]

(ii) On the above diagram circle the asymmetric centre on the malic acid. [1]

(iii) What name is given to this type of optically inactive product?

_____ [1]

(iv) Explain why the product in this reaction is not optically active.

_____

_____ [1]

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(Questions continue overleaf)

13 Ethyl ethanoate is hydrolysed in alkaline conditions as follows:

$$CH_3COOC_2H_5 + OH^- \rightarrow CH_3COO^- + C_2H_5OH$$

(a) Explain, giving experimental details, how you would follow the rate of this reaction with respect to hydroxide ions using pH and how you would use your results to find the order of the reaction with respect to hydroxide ions.

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

[6]

(b) The following results were obtained for the reaction.

$[CH_3COOC_2H_5]$ /mol dm^{-3}	$[OH^-]$ /mol dm^{-3}	initial rate of the reaction /mol dm^{-3} s^{-1}
0.152	0.038	1.13×10^{-2}
0.038	0.076	5.65×10^{-3}
0.019	0.152	5.65×10^{-3}

(i) Deduce the rate equation for the reaction.

_____

_____ [2]

(ii) Calculate, to three significant figures, the value of the rate constant and state its units.

_____

_____ [2]

(iii) State and explain the effect of increasing the temperature on the value of the rate constant.

_____

_____ [2]

(c) Ethanoic acid reacts with butan-1-ol to form the ester butyl ethanoate as follows:

$$CH_3COOH(l) + C_4H_9OH(l) \rightleftharpoons CH_3COOC_4H_9(l) + H_2O(l) \quad -39.8\,kJ\,mol^{-1}$$

(i) What mass of butan-1-ol is required to produce 58 g of butyl ethanoate when reacted with 45 g of ethanoic acid in 50 cm^3 of water? Give your answer to two significant figures.

(K_c = 3.0 at 20 °C; the density of water is 1 g cm^{-3})

_____

_____

_____

_____

_____ [4]

[Turn over

(ii) Suggest and explain the effect of increasing the temperature to 40 °C on the position of the equilibrium.

_____

_____ [2]

(iii) Explain why the equilibrium constant has no units.

_____

_____ [1]

(d) The ester tallow is an animal fat which is formed from two molecules of stearic acid, $CH_3(CH_2)_{16}COOH$, and one molecule of oleic acid, $CH_3(CH_2)_7CHCH(CH_2)_7COOH$.

(i) Tallow exists as two isomers. Draw the structure of **one** isomer of tallow.

[2]

(ii) Tallow can undergo transesterification. Explain what is meant by the term **transesterification**.

_____

_____ [2]

(iii) State **two** uses of transesterification reactions.

_____

_____ [2]

[Turn over

14 The buttery flavour of butterscotch is due to the presence of diacetyl, $CH_3COCOCH_3$.

(a) Suggest the IUPAC name for diacetyl.

_____ [1]

(b) Diacetyl can be made from the corresponding alcohol.

(i) Write an equation for the reaction, using [O] to represent the oxidising agent.

_____ [2]

(ii) State the reagent and the condition required for this reaction.

_____

_____ [2]

(iii) Diacetyl is a liquid at room temperature with a melting point of –3 °C and a boiling point of 88 °C. The diacetyl obtained in this reaction contains water. Explain how you would use fractional distillation to purify the diacetyl. Describe how you would dry the diacetyl. State how you would use infrared spectroscopy to confirm the diacetyl is pure.

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

_____

_____

_____

_____

_____

_____

_____

_____ [6]

(c) Diacetyl may react with one or two molecules of 2,4-dinitrophenylhydrazine.

(i) Write the equation for the reaction of diacetyl with one molecule of 2,4-dinitrophenylhydrazine.

[2]

(ii) Describe the appearance of the product.

_____ [1]

(iii) Explain why the melting point of the product formed with one molecule of 2,4-dinitrophenylhydrazine would differ from that formed from the reaction with two molecules of 2,4-dinitrophenylhydrazine.

_____

_____

_____

_____ [2]

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(Questions continue overleaf)

15 Phenylethanone, $C_6H_5COCH_3$, used in making resins and pharmaceuticals can be made by reacting benzene with ethanoyl chloride.

(a) The reaction is described as electrophilic substitution.

(i) Explain what is meant by the term **electrophile**.

_____

_____ [2]

(ii) Explain why the reaction is described as a substitution.

_____

_____ [1]

(b) **(i)** Write the equation for the formation of ethanoyl chloride from ethanoic acid.

_____ [1]

(ii) Why is this reaction carried out under anhydrous conditions?

_____ [1]

(c) **(i)** Write an equation for the formation of the electrophile when benzene reacts with ethanoyl chloride using a catalyst.

_____ [1]

(ii) Draw the mechanism for the catalysed reaction using curly arrows.

[4]

16 Ammonium perchlorate, NH_4ClO_4, is used in solid rocket fuels. It can be formed by reacting ammonia with the strong acid perchloric acid as follows:

$$NH_3 + HClO_4 \rightarrow NH_4ClO_4$$

(a) **(i)** What is the oxidation number of chlorine in ammonium perchlorate?

_____ [1]

(ii) Explain whether a solution of ammonium perchlorate is acidic, alkaline or neutral.

_____

_____

_____ [2]

(b) Ammonium perchlorate decomposes, when heated, to produce a mixture of hydrogen chloride, nitrogen, oxygen and water.

(i) Write the equation for the thermal decomposition of ammonium perchlorate.

_____ [2]

(ii) Calculate, to two significant figures, the volume of gas produced by the complete decomposition of 11.75 g of ammonium perchlorate at 250 °C and one atmosphere pressure.

(1 mole of a gas occupies 42 dm^3 at 250 °C and one atmosphere pressure)

_____

_____

_____

_____ [3]

(c) Ammonia solution can be used to make buffers by adding ammonium chloride.

(i) Explain what is meant by the term **buffer solution**.

_____

_____ [2]

(ii) Explain, including equations, how a mixture of ammonia and ammonium chloride solutions acts as a buffer.

_____

_____

_____

_____

_____ [4]

(d) Ammonia is produced by the Haber process as follows:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The table below gives the $\Delta_f H$ and S values for the reactants and products.

	$\Delta_f H$ /kJ mol^{-1}	S /J mol^{-1} K^{-1}
N_2	0	192
H_2	0	131
NH_3	–46.2	193

(i) Calculate, to three significant figures, ΔS for the reaction.

_____

_____ [1]

(ii) Calculate, to three significant figures, ΔG for the reaction at 298 K.

_____

_____ [2]

(iii) At what temperature does the reaction become feasible? Give your answer to three significant figures.

_____

_____ [2]

(iv) State **one** factor which may prevent the reaction from occurring at the temperature calculated in part **(iii)**.

_____ [1]

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SYMBOLS OF SELECTED IONS

Positive ions

Name	Symbol
Ammonium	NH_4^+
Chromium(III)	Cr^{3+}
Copper(II)	Cu^{2+}
Iron(II)	Fe^{2+}
Iron(III)	Fe^{3+}
Lead(II)	Pb^{2+}
Silver	Ag^+
Zinc	Zn^{2+}

Negative ions

Name	Symbol
Butanoate	$C_3H_7COO^-$
Carbonate	CO_3^{2-}
Dichromate	$Cr_2O_7^{2-}$
Ethanoate	CH_3COO^-
Hydrogencarbonate	HCO_3^-
Hydroxide	OH^-
Methanoate	$HCOO^-$
Nitrate	NO_3^-
Propanoate	$C_2H_5COO^-$
Sulfate	SO_4^{2-}
Sulfite	SO_3^{2-}

SOLUBILITY IN COLD WATER OF COMMON SALTS, HYDROXIDES AND OXIDES

Soluble
All sodium, potassium and ammonium salts
All nitrates
Most chlorides, bromides and iodides EXCEPT silver and lead chlorides, bromides and iodides
Most sulfates EXCEPT lead and barium sulfates Calcium sulfate is slightly soluble

Insoluble
Most carbonates EXCEPT sodium, potassium and ammonium carbonates
Most hydroxides EXCEPT sodium, potassium and ammonium hydroxides
Most oxides EXCEPT sodium, potassium and calcium oxides which react with water

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Rewarding Learning

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Science: Chemistry,
Science: Double Award
or Science: Single Award

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

gcse examinations

chemistry

For first teaching from September 2017

THE PERIODIC TABLE OF ELEMENTS

Group

1	2											3	4	5	6	7	0
							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 X b

a = relative atomic mass (approx)
x = atomic symbol
b = atomic number