Rewarding Learning

ADVANCED
General Certificate of Education
2017

Centre Number

Candidate Number

Chemistry

Assessment Unit A2 1

assessing

Periodic Trends and Further Organic, Physical and Inorganic Chemistry

[AC212]

TUESDAY 13 JUNE, AFTERNOON

MV18

Time

2 hours, plus your additional time allowance.

Instructions to Candidates

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all nineteen** 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 nine** questions in **Section B**.
You must answer the questions in the spaces provided.
Complete in black ink only.

Information for Candidates

The total mark for this paper is 120.
Quality of written communication will be assessed in Question **16(b)**.
In Section A all questions carry equal marks, i.e. **two** marks for each question.
In Section B the figures in brackets printed at the end of each question indicate the marks awarded to each question or part question.
A Periodic Table of 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 X and Y react according to the equation:

$$X + 2Y \rightarrow XY_2$$

The rate equation for the reaction is:

$$\text{Rate} = k[X]^0[Y]^2$$

Which one of the following is the mechanism for the reaction?

A	$X + Y \xrightarrow{\text{fast}} XY$	$XY + Y \xrightarrow{\text{slow}} XY_2$
B	$X + Y \xrightarrow{\text{slow}} XY$	$XY + Y \xrightarrow{\text{fast}} XY_2$
C	$Y + Y \xrightarrow{\text{fast}} Y_2$	$X + Y_2 \xrightarrow{\text{slow}} XY_2$
D	$Y + Y \xrightarrow{\text{slow}} Y_2$	$X + Y_2 \xrightarrow{\text{fast}} XY_2$

2 The pH range and associated colour changes for the indicators methyl red and bromothymol blue are given below.

indicator	**pH range**	**colour change**
methyl red	4.2–6.3	red to yellow
bromothymol blue	6.0–7.6	yellow to blue

A solution which turns both indicators yellow is

A strongly acidic.

B weakly acidic.

C strongly basic.

D weakly basic.

3 The partition coefficient of solute X between trichloroethane and water is 4.
A solution containing 20 g of X in 100 cm^3 of water is extracted with two 100 cm^3 portions of trichloroethane in succession. What mass of X is removed by the trichloroethane?

A 0.8 g

B 4.0 g

C 16.0 g

D 19.2 g

4 Which one of the following alcohols can **not** be oxidised with acidified potassium dichromate solution?

A 2-methylbutan-1-ol

B 2-methylbutan-2-ol

C 3-methylbutan-1-ol

D 3-methylbutan-2-ol

5 Which one of the following molecules, when reduced with lithal, forms optically active isomers?

A $CH_3CH_2CH_2CHO$

B $CH_3CH_2COCH_3$

C $CH_3CH_2CH_2CH_2CHO$

D $CH_3CH_2COCH_2CH_3$

6 Lard has a saponification value of 193. What volume of 0.1 mol dm^{-3} potassium hydroxide solution is required to completely hydrolyse 0.96 g of lard?

A 33.1 cm^3

B 34.5 cm^3

C 331 cm^3

D 345 cm^3

7 Which one of the following reactions will **not** form propanoic acid?

A Acid catalysed hydrolysis of ethyl propanoate

B Acid catalysed hydrolysis of propyl ethanoate

C Acid catalysed hydrolysis of propanenitrile

D Oxidation of propan-1-ol

8 Concentrated sulfuric acid and concentrated nitric acid react to form a nitrating mixture according to the equation:

$$2H_2SO_4 + HNO_3 \rightarrow 2HSO_4^- + NO_2^+ + H_3O^+$$

Which one of the following statements is correct?

A Nitric acid is acting as an acid

B Nitric acid is acting as an oxidising agent

C Sulfuric acid is acting as an acid

D Sulfuric acid is acting as an oxidising agent

9 Ethanoic acid has a K_a of 2×10^{-5} mol dm^{-3}. How many moles of sodium ethanoate must be added to 500 cm^3 of 0.1 mol dm^{-3} ethanoic acid to produce a buffer of pH 5?

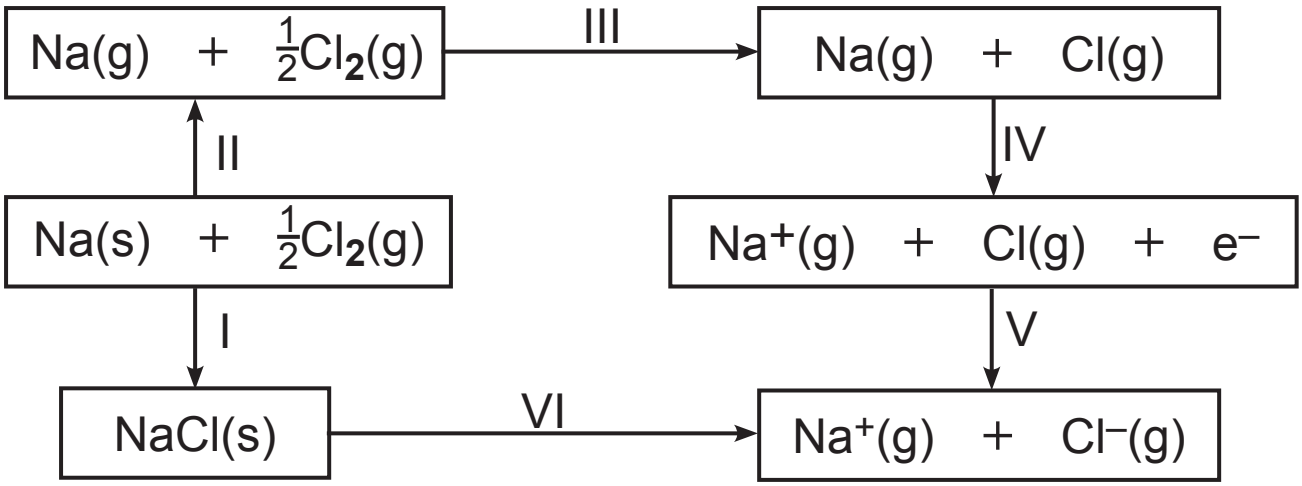
A 0.1

B 0.2

C 0.3

D 0.4

10 The diagram below represents the Born–Haber cycle for sodium chloride.



In which one of the following are both steps exothermic?

A I and V

B II and IV

C IV and VI

D V and VI

Section B

Answer **all nine** questions in this section.

11 (a) Complete the table below for some of the oxides and chlorides in Period 3. [4 marks]

	MgO	**Al_2O_3**	**P_4O_{10}**	**$MgCl_2$**
type of bonding				
approximate pH of aqueous solution, if formed				

(b) Write equations for the following reactions. [1 mark for each]

(i) Magnesium oxide with nitric acid.

_____

(ii) Aluminium oxide with sodium hydroxide solution.

_____

(iii) Phosphorus(V) oxide with water.

_____

(iv) Phosphorus(V) chloride with water.

_____

(c) The lattice enthalpy of magnesium chloride is 2489 kJ mol^{-1}.

(i) Explain what is meant by the term **lattice enthalpy**. [2 marks]

(ii) Use the lattice enthalpy of magnesium chloride and the information below to calculate the enthalpy of hydration for one mole of chloride ions. [2 marks]

Enthalpy of solution of magnesium chloride = −170 kJ mol^{-1}

Enthalpy of hydration of magnesium ions = −1891 kJ mol^{-1}

12 Equilibrium reactions are found in many areas of chemistry.

(a) (i) Bismuth carbonate, $Bi_2(CO_3)_3$, reacts with hydrochloric acid to form a colourless solution of bismuth chloride, $BiCl_3$. Write an equation for the reaction. [2 marks]

_____

(ii) If the bismuth chloride solution is diluted the following equilibrium is set up:

$$BiCl_3(aq) + H_2O(l) \rightleftharpoons BiOCl(aq) + 2HCl(aq)$$

Explain how the following changes affect the position of the equilibrium. [2 marks for each]

Adding water:

_____

_____

Adding sodium hydroxide solution:

_____

_____

(b) A mixture of 2 moles of SO_2 and 1 mole of O_2 were allowed to reach equilibrium in a 2 dm^3 container.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

At equilibrium 75% of the SO_2 was converted to SO_3. Calculate the value of K_c and state its units. [4 marks]

13 Carbon dioxide, CO_2, methane, CH_4, and nitrogen(I) oxide, N_2O, are considered to be greenhouse gases.

(a) (i) State **three** natural processes upon which the concentration of carbon dioxide in the atmosphere depends and how they affect this concentration. [3 marks]

1. _____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

(ii) Suggest how methane and nitrogen(I) oxide act as greenhouse gases. [2 marks]

_____

_____

_____

_____

(b) Nitrogen(I) oxide is approximately 20 times more effective as a greenhouse gas than methane. Suggest why methane is of greater concern as a greenhouse gas than nitrogen(I) oxide. [1 mark]

_____

_____

14 Entropy is an important concept when establishing the feasibility of a reaction.

(a) Explain what is meant by the term **entropy**. [1 mark]

(b) Iron(III) oxide can be reduced to iron.

$$Fe_2O_3(s) + 3H_2(g) \rightarrow 2Fe(s) + 3H_2O(g)$$

The table below gives the enthalpies of formation and the entropies of the reactants and products.

	$Fe_2O_3(s)$	$H_2(g)$	$Fe(s)$	$H_2O(g)$
ΔH_f / kJ mol^{-1}	–822	0	0	–242
S / kJ mol^{-1} K^{-1}	0.09	0.13	0.03	0.19

(i) Why are the ΔH_f values of Fe(s) and $H_2(g)$ zero? [1 mark]

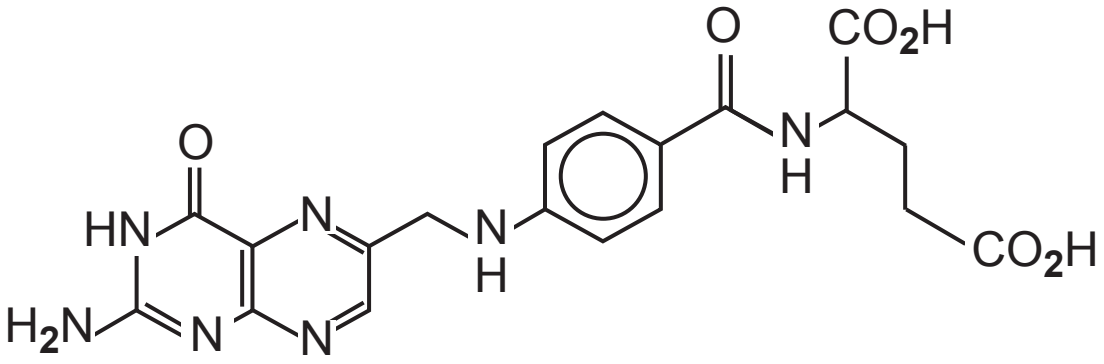
(ii) Calculate the enthalpy change for the reaction. [2 marks]

(iii) Calculate the entropy change for the reaction. [2 marks]

(iv) Use your answers to parts **(ii)** and **(iii)** to calculate the temperature at which the reaction becomes feasible. [2 marks]

(v) Explain why the reaction may not take place at this temperature. [1 mark]

15 Folic acid is an essential nutrient in our diet.



folic acid

(a) Folic acid contains an asymmetric centre, making it optically active.

(i) Explain what is meant by the term **asymmetric centre**. [1 mark]

_____

_____

(ii) Explain what is meant by the term **optically active**. [2 marks]

_____

_____

(iii) On the diagram of folic acid above, circle the asymmetric centre. [1 mark]

(b) (i) What is the molecular formula of folic acid?
[1 mark]

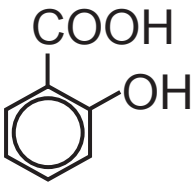
(ii) The solubility of folic acid is 6.1×10^{-3} g dm^{-3}.
Calculate the molarity of this solution of folic acid.
[2 marks]

(c) The first pK_a of folic acid is 4.65.

(i) Explain why folic acid has more than one pK_a.
[1 mark]

(ii) Using the first pK_a, calculate the pH of a 1×10^{-5} mol dm^{-3} solution of folic acid.
[3 marks]

16 Salicylic acid can be esterified to form 'oil of wintergreen' and aspirin.



salicylic acid

(a) (i) 'Oil of wintergreen' is made by esterification of salicylic acid with methanol. Draw the structure of 'oil of wintergreen'. [1 mark]

(ii) Suggest the non-systematic name for the ester 'oil of wintergreen'. [1 mark]

_____

(iii) Aspirin can be made by esterification of salicylic acid with ethanoic acid. Draw the structure of aspirin. [1 mark]

(iv) Suggest an alternative reagent to ethanoic acid in the formation of aspirin and give **one** advantage of using this reagent. [2 marks]

(b) An impure sample of 'oil of wintergreen' was obtained in a round-bottom flask by reacting methanol with salicylic acid in the presence of concentrated sulfuric acid. Give experimental details of how a sample of 'oil of wintergreen' could be obtained from the reaction mixture. Explain how the sample could be further purified by removing acidic impurities and water. [5 marks]

Quality of written communication [2 marks]

(c) (i) Write the equation for the reaction of salicylic acid with thionyl chloride. [2 marks]

(ii) Write an equation for the reaction of salicylic acid with lithal.
(Use [H] to represent lithal.) [2 marks]

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(Questions continue overleaf)

17 Fats and vegetable oils are triesters formed from fatty acids and propane-1,2,3-triol.

(a) Palmitic acid, $CH_3(CH_2)_{14}COOH$, and oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$, are fatty acids. Suggest why palmitic acid is a solid at room temperature and oleic acid is a liquid. [2 marks]

(b) Cervonic acid is an unsaturated fatty acid.

$HOOC(CH_2)_2(CH{=}CHCH_2)_6CH_3$

cervonic acid

Unsaturated fats can be hardened by catalytic hydrogenation.

(i) Explain what is meant by the term **hydrogenation**. [1 mark]

(ii) Name the catalyst used in the hardening of unsaturated fatty acids. [1 mark]

(iii) Calculate the iodine value for cervonic acid. [3 marks]

(c) Explain the role of polyunsaturates and polysaturates in a healthy diet. [3 marks]

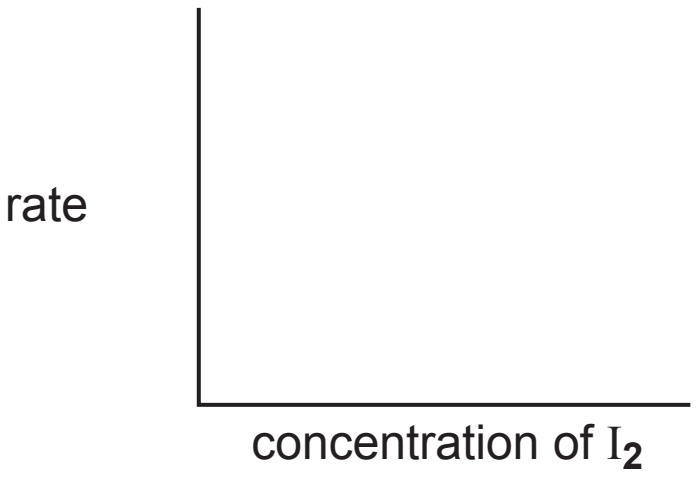
18 (a) The reaction between propanone and iodine is catalysed by acid.

$$(CH_3)_2CO(aq) + I_2(aq) \xrightarrow{H^+} ICH_2COCH_3(aq) + HI(aq)$$

(i) State how the reaction could be "quenched" i.e. stopped without interfering with any of the reactants or products. [1 mark]

(ii) Explain how you could determine the rate of the reaction by an acid–base titration. [4 marks]

(iii) The reaction is zero order with respect to the iodine. Sketch a "rate against concentration" graph. [1 mark]



(b) Phosphinate ions, $H_2PO_2^-$, are found in insecticides and herbicides. The rate of the reaction between phosphinate ions and hydroxide ions was investigated.

$$H_2PO_2^-(aq) + OH^-(aq) \rightarrow HPO_3^{2-}(aq) + H_2(g)$$

The following results were obtained.

$[H_2PO_2^-(aq)]$ /mol dm^{-3}	**$[OH^-(aq)]$ /mol dm^{-3}**	**initial rate of $H_2(g)$ formation /cm^3 min^{-1}**
0.1	0.1	2.4
0.1	0.2	9.6
0.2	0.3	43.2

(i) Deduce the rate equation. [2 marks]

(ii) What is the overall order of the reaction? [1 mark]

(iii) Calculate the rate constant and state its units. [2 marks]

(iv) Suggest the disadvantages of using artificial phosphate fertiliser. [2 marks]

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(Questions continue overleaf)

19 Glutaraldehyde, $OHC(CH_2)_3CHO$, is used to sterilise dental equipment.

(a) Suggest the systematic name for glutaraldehyde. [1 mark]

_____

(b) Explain why glutaraldehyde is soluble in water. [1 mark]

_____

_____

(c) **(i)** State the colour change observed when glutaraldehyde is reacted with Fehling's solution. [1 mark]

_____

(ii) Give the formulae of the metal ions responsible for the colour change. [1 mark]

_____

(d) Glutaraldehyde can be formed by oxidising the corresponding alcohol.

(i) Write an equation, using [O] to represent the oxidising agent, for the formation of glutaraldehyde from the alcohol. [1 mark]

_____

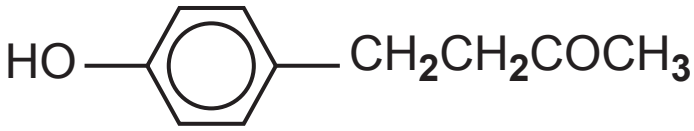
(ii) The oxidising agent is acidified potassium dichromate. State the condition necessary for this reaction. [1 mark]

_____

(iii) State the colour change that would be observed during the reaction. [1 mark]

_____

(e) The smell and flavour of raspberries is due in part to the 'raspberry ketone'.



'raspberry ketone'

(i) Draw the mechanism for the reaction of 'raspberry ketone' with hydrogen cyanide. Use $RCOCH_3$ to represent the ketone. [3 marks]

(ii) Write the equation for the reaction of 'raspberry ketone' with 2,4-dinitrophenylhydrazine. Use $RCOCH_3$ to represent the ketone. [2 marks]

(iii) Suggest how the product of the reaction in part **(ii)** could be used to confirm the identity of the 'raspberry ketone'. [1 mark]

THIS IS THE END OF THE QUESTION PAPER

For Examiner's use only	
Question Number	**Marks**
Section A	
1–10	
Section B	
11	
12	
13	
14	
15	
16	
17	
18	
19	
Total Marks	

Examiner Number

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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.

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chemistry (advanced)

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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