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ADVANCED
General Certificate of Education
2024

Centre Number

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Candidate Number

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Chemistry

StemUp Model Solution

Assessment Unit A2 3

assessing

Further Practical Chemistry

Practical Booklet B (Theory)



[ACH32]

ACH32

FRIDAY 21 JUNE, MORNING

TIME

1 hour 15 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

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 or with a pencil.**

Answer **all four** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 60.

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 (including some data) is provided.



- 1 Butyl ethanoate is a colourless liquid at room temperature and pressure. It can be prepared by reacting ethanoic acid with butan-1-ol in the presence of concentrated sulfuric acid.

Some information on the two organic reactants is given in the table below:

	Ethanoic acid	Butan-1-ol
Melting point /°C	16	−90
Boiling point /°C	118	118
Density of liquid /g cm ^{−3}	1.05	0.81
Solubility in water	soluble	soluble

- (a) The following method may be used to prepare butyl ethanoate:

Mix 15cm³ of ethanoic acid with 30cm³ of butan-1-ol in a round-bottomed flask. Add concentrated sulfuric acid slowly with swirling. Ensuring no loss of reactants or products, heat the mixture for approximately 30 minutes and then allow the mixture to cool. Pour the contents of the round-bottomed flask into a reagent bottle containing cold water. Stopper the bottle, shake the contents and allow to settle.

- (i) Explain why the concentrated sulfuric acid is added slowly with swirling.

The addition of concentrated sulfuric acid is very exothermic;

swirling and adding slowly dissipates the heat so the mixture

does not boil or spit.

[2]



- (ii) Explain why the ethanoic acid for this preparation should **not** be stored in a fridge at 4 °C.

Ethanoic acid melts at 16 °C, so at 4 °C it would freeze and form a solid.

[1]

- (iii) Name the technique used to ensure no loss of reactants or products when heating the mixture.

Heating under reflux

[1]

- (iv) Suggest what should be added to the round-bottomed flask to promote smooth boiling.

Anti-bumping granules

[1]

- (v) After allowing to settle, two layers form in the reagent bottle. Giving practical details, describe how the upper organic layer could be separated into a clean, dry beaker.

Transfer the mixture to a separating funnel, stopper it and allow the layers to settle.

Open the tap and run off the lower (aqueous) layer, then discard it.

Open the tap again and run off the upper organic layer into a clean, dry beaker.

[3]

[Turn over]



(b) The organic layer is the crude product. To remove any remaining traces of acid, it is shaken with sodium carbonate solution. The upper organic layer is then separated from the aqueous layer. The organic product is then dried.

(i) What would indicate that all remaining traces of acid have been removed from the crude product?

No more bubbles (effervescence) are seen when sodium carbonate solution is added.

[1]

(ii) Describe how the organic product is dried.

Place the organic liquid in a conical flask (or beaker).

Add a spatula measure of a drying agent, e.g. anhydrous calcium chloride.

Stopper and swirl (shake) the mixture.

Repeat (add more drying agent) until the liquid changes from cloudy to clear.

Filter or decant the liquid to remove the drying agent.

[5]

(iii) State how you would remove any remaining organic impurities.

Distillation, collecting the fraction at the boiling point of butyl ethanoate.

[1]

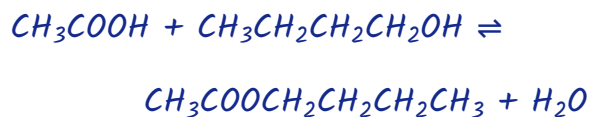
(iv) State the effect of the presence of impurities on the boiling point of an organic liquid.

The boiling point is not sharp: the liquid boils over a range and the boiling point increases.

[1]



- (c) (i) Write an equation for the reaction to produce butyl ethanoate.



[2]

- (ii) Calculate the number of moles of ethanoic acid added in this preparation.

$$\text{mass of ethanoic acid} = 15 \times 1.05 = 15.75 \text{ g}$$

$$M_r \text{ of } \text{CH}_3\text{COOH} = 60$$

$$\text{moles} = 15.75 \div 60 = 0.2625 \text{ mol}$$

Answer 0.2625 mol [2]

- (iii) Calculate the number of moles of butan-1-ol added in this preparation.

$$\text{mass of butan-1-ol} = 30 \times 0.81 = 24.3 \text{ g}$$

$$M_r \text{ of } \text{C}_4\text{H}_9\text{OH} = 74$$

$$\text{moles} = 24.3 \div 74 = 0.3284 \text{ mol}$$

Answer 0.3284 mol [2]

- (iv) Explain, using your answers to (c)(i), (ii) and (iii), why ethanoic acid is the limiting reactant.

The acid and the alcohol react in a 1 : 1 ratio (equation in
(c)(i)).

Moles of butan-1-ol (0.3284) > moles of ethanoic acid (0.2625),

so butan-1-ol is in excess and ethanoic acid is limiting. [2]

[Turn over]



- (v) 12.2 g of butyl ethanoate were obtained. Calculate the percentage yield, giving your answer to the nearest whole number.

theoretical yield = 0.2625 mol of butyl ethanoate

M_r of $\text{CH}_3\text{COOC}_4\text{H}_9 = 116$

theoretical mass = $0.2625 \times 116 = 30.45 \text{ g}$

% yield = $12.2 \div 30.45 \times 100 = 40.07 = 40 \%$

Answer 40 % [3]





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(Questions continue overleaf)

14247

[Turn over



2 Transition metal ions form coloured complexes.

- (a) A few spatula measures of a cobalt(II) compound were dissolved in approximately 50 cm³ of deionised water and a series of tests were carried out on portions of the resulting pink solution.

A few drops of aqueous ammonia were added to a portion of the solution and a blue precipitate formed. On addition of excess aqueous ammonia, the blue precipitate disappeared and a yellow solution formed. The yellow solution was shaken, allowed to stand and observed over a period of several minutes.

A few drops of silver nitrate solution were added to a separate portion of the pink solution. A white precipitate formed.

- (i) Write an ionic equation for the formation of the blue precipitate.



- (ii) Give the formula of the complex present in the yellow solution.



- (iii) What will be observed when the yellow solution is allowed to stand?

The yellow solution changes to brown (oxidised by air). [1]

- (iv) Name the cobalt(II) compound.

cobalt(II) chloride [1]

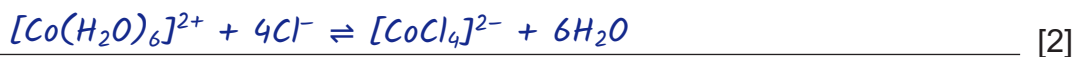
- (b) A few cm³ of concentrated hydrochloric acid were added to a portion of the original pink solution from (a) in a boiling tube. A ligand replacement reaction occurred and the colour of the solution changed to blue. When water was added to the boiling tube, the solution changed back to pink.

- (i) Based on these observations, what can you deduce about the reaction?

The reaction is reversible. [1]



- (ii) Write an ionic equation for the reaction which occurred when the concentrated hydrochloric acid was added.



- (iii) State the change in co-ordination number and the change in shape of the complexes in the ligand replacement reaction when concentrated hydrochloric acid was added.

Change in co-ordination number: changes from 6 to 4

Change in shape: changes from octahedral to tetrahedral

[2]

- (c) Nickel(II) ions form a variety of complexes with different ligands.

- (i) State the colour change observed when an excess of aqueous ammonia is added to an aqueous solution of nickel(II) sulfate.

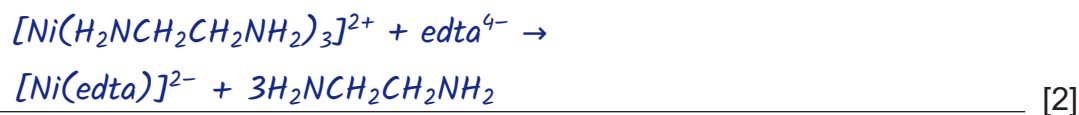
green solution changes to blue

[1]

- (ii) When excess 1,2-diaminoethane is added to an aqueous solution of nickel(II) sulfate, a ligand replacement reaction occurs and a purple complex forms. Write the formula of the purple complex.



- (iii) Addition of a solution containing the edta^{4-} ligand to the purple solution formed in (c)(ii) results in a purple to blue colour change. Write an ionic equation for the reaction which occurs.



[Turn over]



3 A student investigated the chemistry of ethanamide and ethylamine by carrying out the following procedures.

(a) Dissolve 0.5g of ethanamide in 3 cm³ of deionised water. Add drops of the resulting solution onto both red and blue litmus paper.

(i) On carrying out this procedure, it was found that the aqueous solution of ethanamide had no effect on red or blue litmus paper. What can be concluded about the aqueous solution?

The solution is neutral.

[1]

(ii) What would you expect to observe if a solution of ethylamine was used in place of ethanamide with red and blue litmus paper?

red litmus paper: *turns blue*

blue litmus paper: *stays blue*

[1]

(b) To 1 cm³ of a solution of ethylamine, add a spatula measure of sodium nitrite and 1 cm³ of hydrochloric acid.

On carrying out this procedure, bubbles of gas were formed. Identify the gas and name the organic product.

Gas: nitrogen (N₂)

Organic product: ethanol

[2]



- (c) Add half a spatula measure of ethanamide to about 5 cm³ of dilute sodium hydroxide in a boiling tube. Warm the boiling tube gently.

On carrying out this procedure, a gas with a characteristic smell was produced. Identify the gas and name the other product.

Gas: ammonia (NH₃)

Other product: sodium ethanoate [2]

- (d) Add a spatula measure of ethanamide to about 5 cm³ of dilute hydrochloric acid in a boiling tube. Boil the contents of the boiling tube.

Name the two products of this reaction.

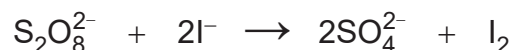
ethanoic acid

ammonium chloride [2]

[Turn over]



- 4 Iodide ions in aqueous solution can be oxidised to iodine using a solution containing peroxodisulfate ions ($\text{S}_2\text{O}_8^{2-}$).



- (a) At room temperature, the reaction is relatively slow. It is much faster in the presence of iron(II) ions.

- (i) Based on the equation above, suggest why the reaction is relatively slow.

*Both ions are negatively charged, so they repel each other and
collide less often successfully.*

[1]

- (ii) Suggest the role played by the iron(II) ions in this reaction.

The iron(II) ions act as a (homogeneous) catalyst.

[1]



(b) When a colourless solution of potassium peroxodisulfate is added to a colourless solution of potassium iodide, a slow and gradual colour change is observed.

(i) State the colour change observed.

colourless to brown [1]

(ii) In the presence of a small amount of sodium thiosulfate, the colour change in (b)(i) is delayed. Explain, using an ionic equation, why the presence of a small amount of sodium thiosulfate delays the colour change.

Sodium thiosulfate reacts with the iodine as it is produced, so no

brown colour appears until all the thiosulfate is used up:

$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$ [2]

(iii) In the presence of a small amount of sodium thiosulfate and starch, a different, more immediate, colour change is observed. State the colour change.

colourless to blue-black [1]

[Turn over]



(c) 250 cm³ of a 0.02 mol dm⁻³ solution of sodium thiosulfate were prepared from hydrated sodium thiosulfate, Na₂S₂O₃·5H₂O.

(i) Calculate the mass of hydrated sodium thiosulfate required to prepare 250 cm³ of this solution.

$$\text{moles} = 0.02 \times 250 \div 1000 = 5 \times 10^{-3} \text{ mol}$$

$$M_r \text{ of Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O} = 248$$

$$\text{mass} = 5 \times 10^{-3} \times 248 = 1.24 \text{ g}$$

Answer 1.24 g [2]

(ii) Describe how the solution of sodium thiosulfate was prepared using the mass calculated in (c)(i).

Weigh 1.24 g of the solid accurately into a beaker.

Dissolve the solid in a small volume of deionised water, stirring with a glass rod.

Transfer the solution to a 250 cm³ volumetric flask using a funnel, adding the washings from the beaker and rod.

Make up to the mark with deionised water until the bottom of the meniscus is on the mark.

Stopper the flask and invert several times to mix.

[4]





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Question Number	Examiner Mark	Remark
1		
2		
3		
4		
Total Marks		

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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 dm³

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

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ m s}^{-1}$



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	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

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

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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

I	II	THE PERIODIC TABLE OF ELEMENTS	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								

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series

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

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