Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/12**

Paper 1 Multiple Choice **October/November 2021**

1 hour

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)
Data booklet

INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.

This document has **16** pages. Any blank pages are indicated.

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Section A

For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

Use of the Data Booklet may be appropriate for some questions.

1 Compound X consists of 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

What is the empirical formula of compound X?

A CH_2O **B** C_2H_2O **C** C_2H_4O **D** CHO

2 Which statement is correct?

A 1.0 g of hydrogen gas contains 3.0×10^{23} atoms.

B 4.0 g of helium gas contains 1.2×10^{24} atoms.

C 16 g of methane gas contains 3.0×10^{24} atoms.

D 44 g of carbon dioxide gas contains 6.0×10^{23} atoms.

3 Technetium (Tc) is a second row transition element that does not occur naturally on Earth. One of its isotopes has 56 neutrons.

What is the nucleon number of this isotope?

A 43 **B** 56 **C** 99 **D** 112

4 Which atom has more unpaired electrons than paired electrons in orbitals of principal quantum number 2?

A carbon

B nitrogen

C oxygen

D fluorine

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5 Atom X is the central atom in a molecule.

In this molecule, atom X has four pairs of valence electrons in its outer shell.

The four pairs of valence electrons include at least one bond pair and at least one lone pair.

What could be a possible shape for the molecule?

A linear

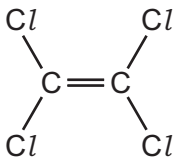
B non-linear

C trigonal bipyramidal

D trigonal planar

6 Which molecule has the largest overall dipole?

A



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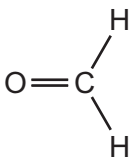

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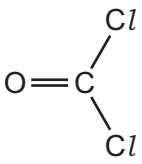

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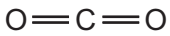

7 The strength of hydrogen bonding increases as the electronegativity of the element bonded to hydrogen increases.

Some information for a range of hydrides is given.

hydride	boiling point / K
PH_3	185
HCl	188
HF	293
H_2O	373

Which statement and reason about these hydrides is correct?

A The boiling point of PH_3 is much lower than the boiling point of H_2O because PH_3 does not form hydrogen bonds or instantaneous dipole-induced dipole forces between its molecules.

B The boiling point of HF is higher than the boiling point of HCl because the bond energy of H–F is greater than the bond energy of H–Cl.

C The boiling point of H_2O is higher than the boiling point of HF because each hydrogen bond between the H_2O molecules is stronger than each hydrogen bond between HF molecules.

D The boiling points of PH_3 and HCl are similar because the molecules of PH_3 and HCl have the same number of electrons and similar intermolecular forces.

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8 The general gas equation can be used to calculate the value of the M_r of a gas.

For a sample of a gas of mass m grams, which expression will give the value of M_r?

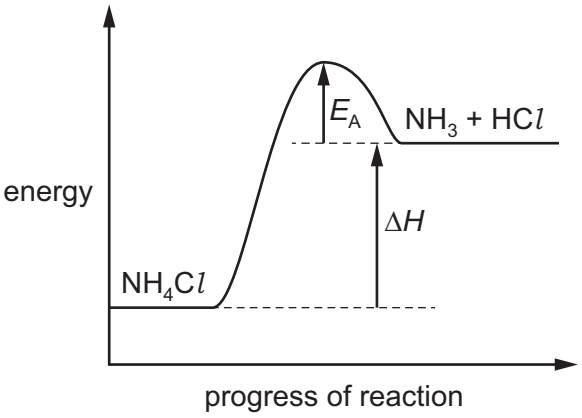
A $M_r = \frac{mRT}{pV}$ **B** $M_r = \frac{pVRT}{m}$ **C** $M_r = \frac{mpV}{RT}$ **D** $M_r = \frac{pV}{mRT}$

9 The equation for the formation of ammonium chloride is shown.

$$NH_3(g) + HCl(g) \rightleftharpoons NH_4Cl(s) \qquad \Delta H = -314\,kJ\,mol^{-1}$$

Which diagram shows the correctly labelled reaction pathway diagram for the decomposition of ammonium chloride?

A



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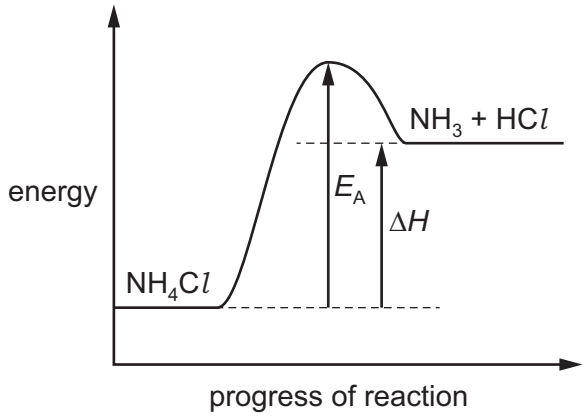

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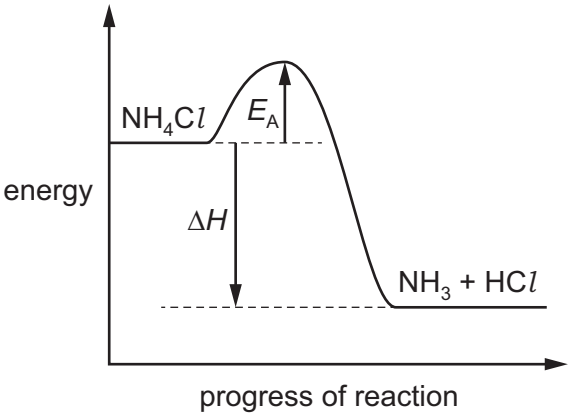

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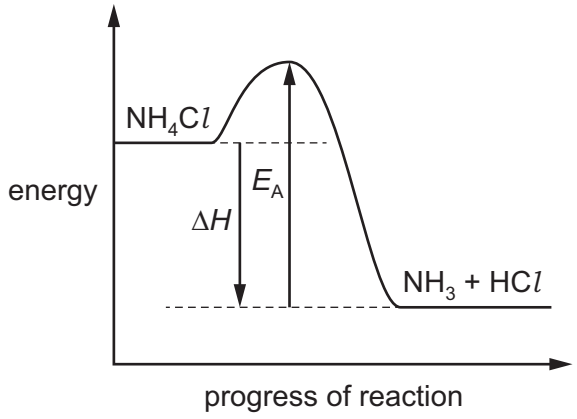

10 In a catalytic converter in the exhaust system of a car, carbon monoxide is oxidised to carbon dioxide, and nitrogen monoxide is reduced to nitrogen.

What are the changes in oxidation number of carbon and nitrogen in these two processes?

	carbon	nitrogen
A	–2	+2
B	–1	+1
C	+1	–1
D	+2	–2

11 NO and NO_2 are both present in the lower atmosphere as pollutants.

The reaction sequence shows the production of ozone from oxygen in the lower atmosphere.

This sequence repeats many times.

$$NO_2(g) \rightarrow NO(g) + O(g)$$

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$$

$$O_2(g) + O(g) \rightarrow O_3(g)$$

Which statement about this reaction sequence is correct?

A NO is acting as a catalyst, but NO_2 is not acting as a catalyst.

B NO_2 is acting as a catalyst, but NO is not acting as a catalyst.

C Neither NO nor NO_2 are acting as catalysts.

D Both NO and NO_2 are acting as catalysts.

12 A mixture of two Period 3 oxides are added to water. A solution forms with a pH of just below 7.

What could be the constituents of the mixture?

A Al_2O_3 and MgO

B Na_2O and MgO

C Na_2O and P_4O_{10}

D SO_3 and P_4O_{10}

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13 Which statement about the compounds of the Group 2 metals is correct?

A Barium carbonate is less thermally stable than strontium carbonate.

B Barium sulfate is less soluble than magnesium sulfate.

C Calcium hydroxide is less soluble than magnesium hydroxide.

D Calcium nitrate is more thermally stable than strontium nitrate.

14 A 0.005 mol sample of anhydrous calcium carbonate is completely thermally decomposed to give 100 cm^3 of gas.

In a separate experiment carried out under the same conditions, a 0.005 mol sample of anhydrous calcium nitrate is completely thermally decomposed. The volume of gaseous products is measured.

What total volume of gaseous products is produced from the calcium nitrate?

A 50 cm^3 **B** 100 cm^3 **C** 200 cm^3 **D** 250 cm^3

15 Redox reactions are common in the chemistry of Group 17 elements.

Which statement is correct?

A Br^- ions will reduce Cl_2 but not I_2.

B Cl_2 will oxidise Br^- ions but not I^- ions.

C F_2 is the weakest oxidising agent out of F_2, Cl_2, Br_2 and I_2.

D I^- ions are the weakest reducing agent out of F^-, Cl^-, Br^- and I^-.

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16 Silver chloride and silver iodide form equilibria when added to water.

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \qquad K_c = K_1$$

$$AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq) \qquad K_c = K_2$$

Each equilibrium position lies well to the **left**.

Silver iodide will not dissolve in aqueous ammonia. Silver chloride will dissolve in aqueous ammonia. Another equilibrium is formed.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \qquad K_c = K_3$$

The position of this equilibrium lies to the **right**.

What is the order of magnitude for these three equilibrium constants?

	smallest ⟶		largest
A	K_3	K_2	K_1
B	K_3	K_1	K_2
C	K_2	K_1	K_3
D	K_1	K_2	K_3

17 X is the ion of a metal which burns with a red flame.

Y is an ion that reacts with concentrated H_2SO_4 to produce H_2S.

What could be the formula of a compound containing X and Y?

A $BaBr_2$ **B** BaI_2 **C** $SrBr_2$ **D** SrI_2

18 Oxides of nitrogen are present in the environment due to natural and man-made sources.

Which row is correct?

	natural source of nitrogen oxides	man-made source of nitrogen oxides
A	electrical discharges in the atmosphere	internal combustion engines
B	electrical discharges in the atmosphere	as a by-product of the Haber process
C	decomposition of dead plants in rivers	internal combustion engines
D	decomposition of dead plants in rivers	as a by-product of the Haber process

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19 Magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride.

Which statement explains this observation?

A The ionic radius of the NH_4^+ ion is similar to that of Mg^{2+} but not that of Na^+.

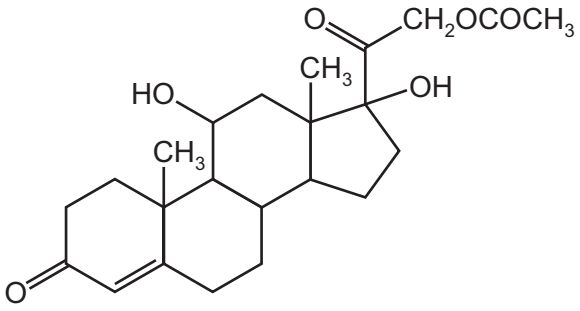
B NH_4Cl dissociates less fully than $NaCl$.

C The Na^+ and Mg^{2+} ions have the same number of electrons.

D The NH_4^+ ion can donate a proton.

20 The formula of hydrocortisone acetate is shown.

hydrocortisone acetate



Which row is correct?

	number of C atoms in one molecule	number of chiral atoms in one molecule
A	22	7
B	22	8
C	23	7
D	23	8

21 Bromomethane, CH_3Br, decomposes in the stratosphere forming methyl free radicals and bromine free radicals.

Which row correctly describes this decomposition?

	type of bond fission	number of electrons in a bromine free radical
A	homolytic	35
B	heterolytic	35
C	homolytic	36
D	heterolytic	36

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22 Structural and stereoisomerism should be taken into account when answering this question.

Y is a gaseous hydrocarbon which decolourises aqueous bromine. It contains no rings.

10.0 g of Y occupies a volume of 3.43 dm^3 under room conditions.

How many isomeric structures are possible for Y?

A 4 **B** 5 **C** 6 **D** 7

23 Which equation represents a valid propagation step in the chlorination of ethane?

A $C_2H_5Cl + Cl\bullet \rightarrow C_2H_4Cl\bullet + HCl$

B $C_2H_6 + Cl\bullet \rightarrow C_2H_5Cl + H\bullet$

C $C_2H_5Cl + H\bullet \rightarrow C_2H_5\bullet + HCl$

D $C_2H_5\bullet + Cl\bullet \rightarrow C_2H_5Cl$

24 Butanoic acid can be made from 1-bromopropane in two stages.

stage 1 $CH_3CH_2CH_2Br \rightarrow CH_3CH_2CH_2CN$

stage 2 $CH_3CH_2CH_2CN \rightarrow CH_3CH_2CH_2CO_2H$

Which types of reaction are stage 1 and stage 2?

	stage 1	stage 2
A	electrophilic addition	hydrolysis
B	electrophilic addition	oxidation
C	nucleophilic substitution	hydrolysis
D	nucleophilic substitution	oxidation

25 A halogenoalkane has the molecular formula $C_5H_{11}Br$. The halogenoalkane does **not** form an alkene when treated with ethanolic sodium hydroxide.

What could be the halogenoalkane?

A 1-bromo-2-methylbutane

B 2-bromo-2-methylbutane

C 3-bromopentane

D 1-bromo-2,2-dimethylpropane

26 Compound P is heated under reflux with an excess of acidified potassium dichromate(VI) to form compound Q.

Compound Q has a **lower** boiling point than compound P.

What could be compound P?

A 2-methylbutan-1-ol

B 2-methylbutan-2-ol

C pentan-1-ol

D pentan-2-ol

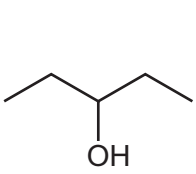
27 Structural and stereoisomerism should be taken into account when answering this question.

An organic compound, X, is dehydrated by heating with concentrated phosphoric(V) acid.

Only **two** organic products are formed.

What could be X?

A



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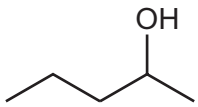

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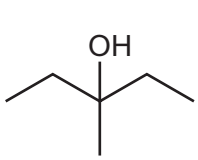

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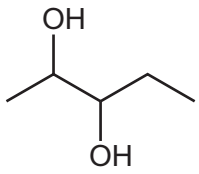

28 Which compound produces a precipitate with 2,4-dinitrophenylhydrazine reagent **and** also with alkaline aqueous iodine?

A butan-2-ol

B butanal

C butanone

D pentan-3-one

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29 Organic compound Z has an alcohol group and a carboxylic acid group.

Compound Z reacts with magnesium carbonate to make a salt with a relative formula mass of 230.3.

Compound Z does **not** react with acidified potassium manganate(VII).

What could be the identity of compound Z?

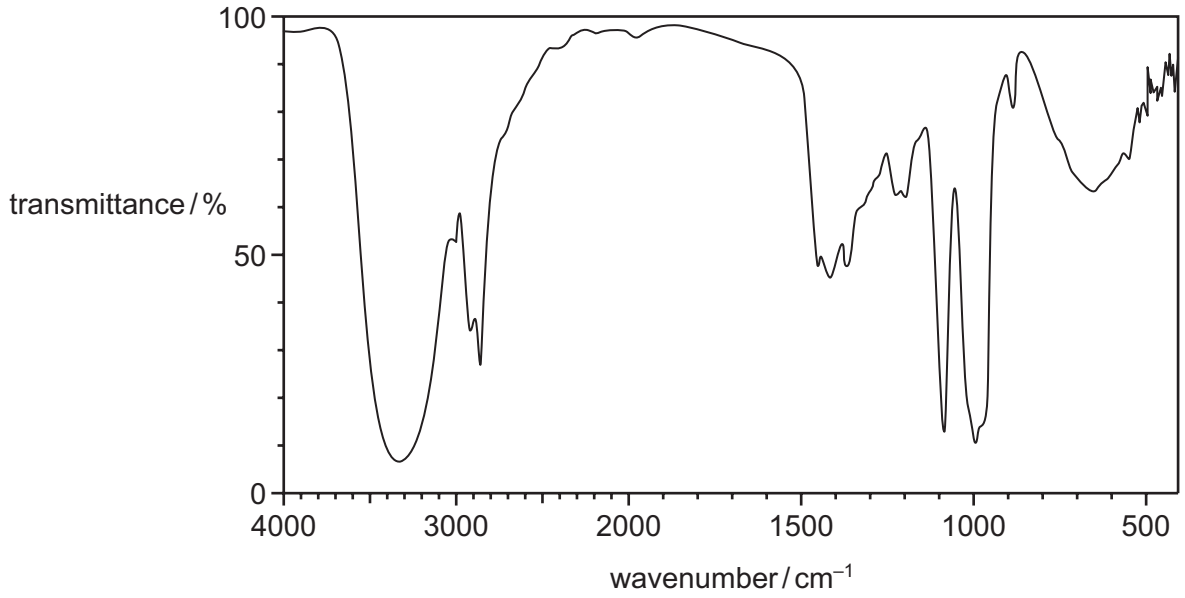
A 2-hydroxy-2-methylbutanoic acid

B 2-hydroxy-2-methylpropanoic acid

C 3-hydroxy-2-methylbutanoic acid

D 3-hydroxy-2-methylpropanoic acid

30 The infra-red spectrum of Y is shown.



What could Y be?

A $CH_3CO_2C_2H_5$

B $CH_2(OH)CH{=}CHCH_2OH$

C $CH_3(CH_2)_2CO_2H$

D $CH_2(OH)(CH_2)_2CHO$

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

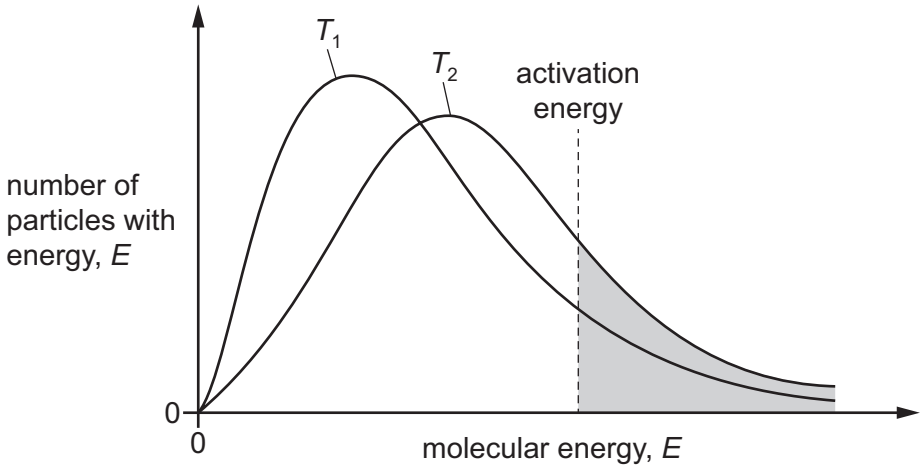
The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

Use of the Data Booklet may be appropriate for some questions.

31 The Boltzmann distribution diagram shows a fixed amount of a gas at two different temperatures, T_1 and T_2.



Which statements correctly describe the features of this diagram?

1 Temperature T_1 is lower than temperature T_2.

2 The shaded area indicates the particles that have sufficient energy to react at T_2.

3 The total area under each curve is the same for both temperatures.

32 Four solutions, each of concentration 0.1 mol dm^{-3}, were tested with a pH meter. The results are shown.

solution	formula of acid or base	pH
acid 1	CH_3CO_2H	4
acid 2	HNO_3	1
base 1	CH_3NH_2	11
base 2	NaOH	14

Which statements explain these results?

1 Acid 2 has a lower pH than acid 1 because it is more soluble.

2 Base 2 has a higher concentration of hydroxide ions in solution than base 1.

3 Acid 1 dissociates less than acid 2.

33 Which reactions are redox reactions?

1 $Mg + 2HCl \rightarrow MgCl_2 + H_2$

2 $2K_2CrO_4 + 2H^+ \rightarrow K_2Cr_2O_7 + 2K^+ + H_2O$

3 $CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$

34 When the liquid N_2F_4 is heated, it decomposes into a **single** product, X.

Which statements are correct?

1 N–F bonds are broken during this decomposition.

2 The enthalpy change when N_2F_4 decomposes into X is approximately +160 kJ mol^{-1}.

3 Molecules of X are non-linear.

35 The following statements compare some properties of the oxides and chlorides of sodium and silicon.

Which statements are correct?

1 The melting point of $SiCl_4$ is higher than the melting point of SiO_2.

2 $SiCl_4$ reacts with water, NaCl does not.

3 The melting point of $SiCl_4$ is lower than the melting point of NaCl.

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The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

36 Which statements about ammonium chloride are correct?

1 It reacts with hot aqueous sodium hydroxide to produce an alkaline gas.

2 In solution, it reacts with aqueous silver nitrate to produce a white precipitate.

3 When solid, it reacts with concentrated sulfuric acid to produce chlorine.

37 What is the same for a pair of optical isomers?

1 their empirical formula

2 their functional groups

3 their structural formula

38 Which of the molecular formulae represent at least one compound that can undergo addition polymerisation?

1 C_4H_8

2 C_2H_3Cl

3 C_3H_6O

39 Which of the reactions give products containing a chiral centre?

1 $CH_2(OH)COCO_2H$ + an excess of HCN

2 $CH_2(OH)COCO_2H$ + an excess of $NaBH_4$

3 $CH_2(OH)COCO_2H$ + an excess of $LiAlH_4$

40 Ethyl butanoate is heated with a dilute aqueous solution of sodium hydroxide.

Which substances are products of this reaction?

1 sodium butanoate

2 water

3 sodium ethanoate

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