Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **May/June 2021**

1 hour

You must answer on the multiple choice answer sheet.

9003800186

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 is an organic compound that contains 30.6% carbon, 3.8% hydrogen, 20.4% oxygen and 45.2% chlorine by mass.

What is the empirical formula of X?

A C_2H_3OCl **B** C_2H_4OCl **C** C_3H_4OCl **D** $C_4H_3O_2Cl_2$

2 A sample of propane, C_3H_8, with a mass of 9.61 g is completely combusted in an excess of oxygen under room conditions.

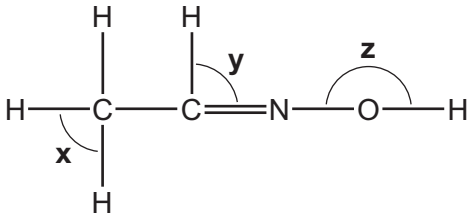
Which volume of carbon dioxide gas is produced?

A 4.89 dm^3 **B** 5.24 dm^3 **C** 14.7 dm^3 **D** 15.7 dm^3

3 Which atom has the same number of electrons as an ammonium ion?

A Mg **B** Na **C** Ne **D** O

4 Ethanal reacts with hydroxylamine, NH_2OH, to form the molecule shown.



What is the order of **increasing** bond angle in this structure from smallest to largest?

A **z**, **x**, **y** **B** **y**, **z**, **x** **C** **x**, **z**, **y** **D** **z**, **y**, **x**

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5 Descriptions of the bonding in three substances are given.

substance 1 strong covalent bonds between atoms, permanent dipole-dipole attractions between molecules

substance 2 strong covalent bonds between atoms, weak forces between molecules

substance 3 strong covalent bonds between atoms, hydrogen bonding between molecules

Which compounds could be substances 1, 2 and 3?

	substance 1	substance 2	substance 3
A	CH_3OH	Al_2Cl_6	CH_2Cl_2
B	Al_2Cl_6	CH_2Cl_2	CH_4
C	CH_2Cl_2	CH_4	CH_3OH
D	CH_4	CH_3OH	H_2O

6 Which type of bonding is **never** found in elements?

A covalent

B ionic

C metallic

D van der Waals' forces

7 Using the information in the table, what is the enthalpy change, q, for the reaction described?

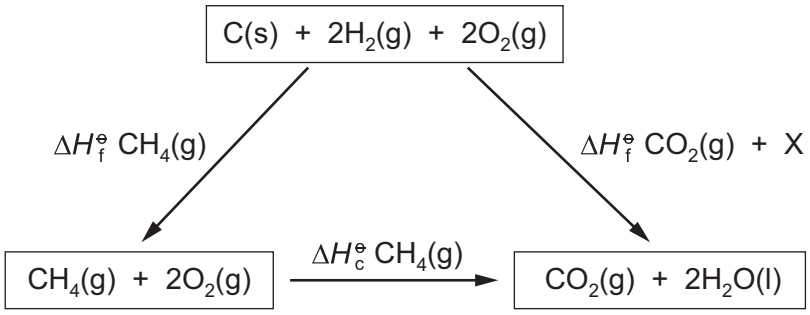
$$Cs^+(g) + Br^-(g) \rightarrow CsBr(s) \qquad \Delta H = q\,kJ\,mol^{-1}$$

standard enthalpy change	value / kJ mol^{-1}
$\Delta H^{\ominus}_{sol}$ CsBr(s)	+25.9
$\Delta H^{\ominus}_{hyd}$ $Cs^+(g)$	–276
$\Delta H^{\ominus}_{hyd}$ $Br^-(g)$	–335

A –636.9 **B** –585.1 **C** +585.1 **D** +636.9

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8 Which enthalpy change is indicated by X in the enthalpy cycle shown?



A $-4 \times$ the enthalpy of combustion of hydrogen

B $+4 \times$ the enthalpy of combustion of hydrogen

C $-2 \times$ the enthalpy of formation of water

D $+2 \times$ the enthalpy of formation of water

9 Copper dissolves in dilute nitric acid producing a blue solution of $Cu(NO_3)_2$, water and nitrogen(II) oxide as the only products.

How many moles of acid react with three moles of copper in the balanced equation?

A 2 **B** 4 **C** 6 **D** 8

10 Nitrogen reacts with hydrogen to produce ammonia.

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

A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 dm^3. It is found that 2.32 mol of nitrogen were present in the equilibrium mixture.

Which expression will give the value of K_c?

A $\dfrac{(1.76)^2}{(2.32)(6.96)^3}$

B $\dfrac{(1.76)^2}{(2.32)(6.32)^3}$

C $\dfrac{(2.08)^2}{(2.32)(6.32)^3}$

D $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$

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11 Nitric acid is produced by oxidising ammonia. The first step is to react ammonia with oxygen in the presence of a catalyst to form nitrogen monoxide.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \quad \Delta H = -1636\,kJ\,mol^{-1}$$

Which set of conditions will produce the greatest yield of nitrogen monoxide at equilibrium?

	temperature	pressure
A	high	high
B	high	low
C	low	high
D	low	low

12 The height of the peak of the curve in a Boltzmann distribution represents the number of molecules that have the most probable energy.

A sample of gas has its temperature decreased without changing the number of molecules present.

Which statement correctly describes a feature of the Boltzmann distribution for the gas when the temperature decreases?

A The value of the most probable energy would stay the same.

B The number of molecules with the most probable energy would increase.

C The area under the molecular energy distribution curve would decrease.

D The number of molecules at the very high energy end of the distribution would stay the same.

13 Ammonia exists as simple covalent molecules, NH_3. Ammonia can react with suitable reagents to form products containing ammonium ions, NH_4^+. Ammonia can also react with suitable reagents to form products containing amide ions, NH_2^-.

Which of these nitrogen-containing species are present in an aqueous solution of ammonia?

A ammonia molecules and amide ions

B ammonia molecules and ammonium ions

C ammonia molecules only

D ammonium ions only

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14 Which problem can result if too much NH_4NO_3 is applied to crops by farmers?

A Not all the NH_4NO_3 is used by plants and the excess makes the soil alkaline.

B Rain washes some of the NH_4NO_3 into rivers where it forms a precipitate.

C Some of the NH_4NO_3 dissolves in groundwater which may eventually be used for drinking.

D Ammonia is produced; this lowers the pH of the soil.

15 When descending Group 17 from chlorine to iodine, which statement is correct?

A The hydrides become less thermally stable as they become weaker reducing agents.

B The hydrides become more thermally stable as the reactivity of the elements decreases.

C The volatility of the elements decreases as the van der Waals' forces increase.

D The volatility of the elements increases as the size of the molecules increases.

16 A powder is known to be either a single sodium halide or a mixture of two sodium halides. A sample of the powder was dissolved in water.

Aqueous silver nitrate was added, and a pale yellow precipitate was formed. When concentrated aqueous ammonia was then added, this precipitate partly dissolved leaving a darker yellow precipitate.

What could the powder be?

A sodium bromide only

B sodium iodide only

C a mixture of sodium chloride and sodium bromide

D a mixture of sodium chloride and sodium iodide

17 Which statement is correct?

A Doctors can use the very insoluble $MgSO_4$ to investigate the digestive system.

B Farmers can lower the pH of soil by spreading $CaCO_3$ on it.

C Students can test a solution for SO_4^{2-} ions by using $Ba(NO_3)_2(aq)$ followed by $HNO_3(aq)$.

D The insoluble hydroxide, $Ba(OH)_2$, can be safely used to lower the acidity of the stomach.

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18 A solid, X, was placed in an excess of the liquid Y.

A colourless gas was given off and a white precipitate was seen. The precipitate was not X.

What could be the identities of X and Y?

	X	Y
A	$BaCO_3$	H_2O
B	Ca	dilute H_2SO_4
C	Mg	dilute H_2SO_4
D	$SrCO_3$	dilute HCl

19 Two oxides of Period 3 elements are added separately to water. Both react to form colourless solutions. One solution is alkaline, the other is acidic.

What could be the two oxides?

A Al_2O_3 and SiO_2

B Al_2O_3 and P_4O_{10}

C Na_2O and P_4O_{10}

D Na_2O and SiO_2

20 Which compound shows stereoisomerism?

A 2-methylbut-2-ene

B 2-chloropropan-1-ol

C difluorochlorobromomethane

D pent-1-ene

21 Two carbon-containing products result from the reaction of alkene Z with a hot, concentrated, acidified solution of potassium manganate(VII).

One product forms an orange precipitate with 2,4-dinitrophenylhydrazine reagent. The other product is a gas which gives a white precipitate with aqueous calcium hydroxide.

Which alkene could be alkene Z?

A but-2-ene

B 2-methylpropene

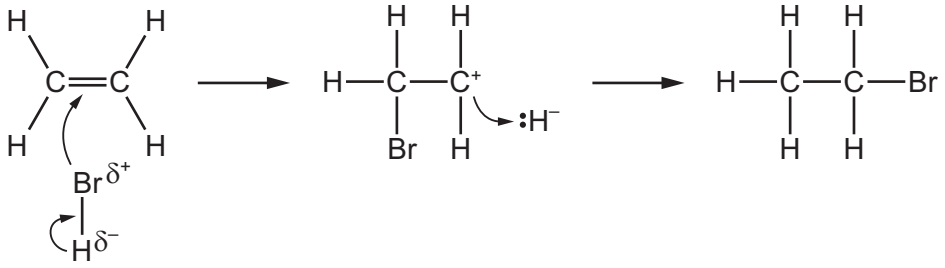
C 2-methylbut-2-ene

D propene

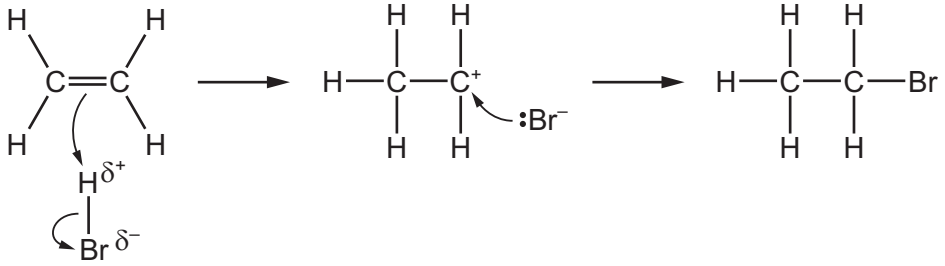
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22 What is the correct mechanism for the addition of hydrogen bromide to ethene?

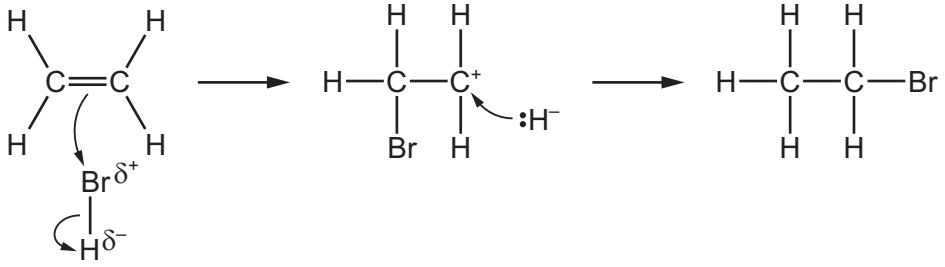
A



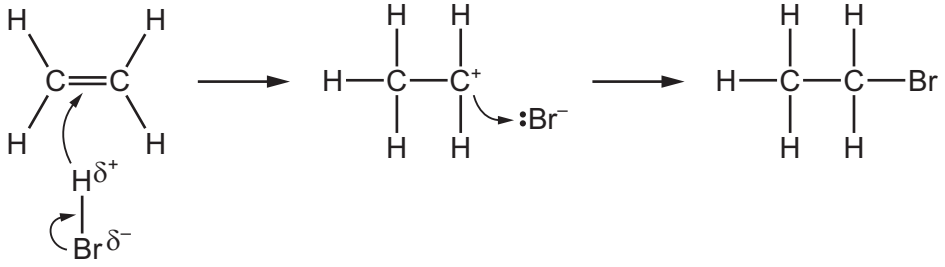
B



C



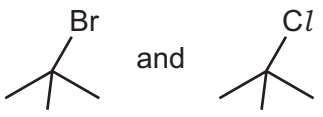
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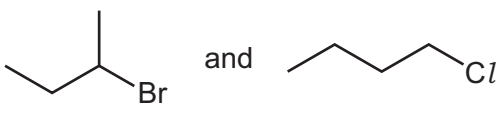
23 Halogenoalkanes react with nucleophiles such as OH^-.

Which pair of halogenoalkanes **both** react via an S_N1 mechanism?

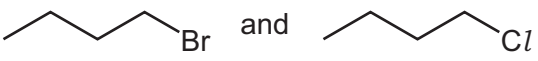
A



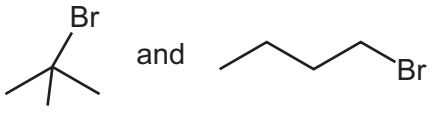
B



C



D



24 A mixture of ethanol and methanol is burned in oxygen to produce 35 cm^3 of CO_2 and 55 cm^3 of H_2O.

Complete combustion occurs and the volumes of both products are measured at 101 kPa and 120 °C.

What is the molar ratio, ethanol : methanol, in the mixture?

A 1 : 3 **B** 2 : 3 **C** 3 : 2 **D** 3 : 1

25 Two reactions are shown. Only one product is identified in each reaction.

ethanol + acidified $Cr_2O_7^{2-}$ → ethanal

ethanol + sodium → sodium ethoxide

Which statement about these reactions is correct?

A The formations of both ethanal and sodium ethoxide are redox reactions.

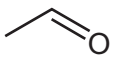
B The formations of both ethanal and sodium ethoxide result in colour changes.

C The formation of ethanal is catalysed by potassium dichromate.

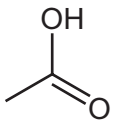
D The formation of sodium ethoxide is a dehydration reaction.

26 The skeletal formulae of three compounds are shown.

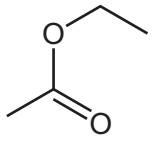
R



S



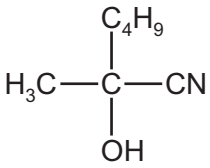
T



Which compounds will give a positive test with 2,4-dinitrophenylhydrazine reagent?

A R only **B** R and S only **C** S and T only **D** R, S and T

27 The diagram shows the structure of a compound formed by the reaction of HCN with a carbonyl compound, X.



What is the mechanism of this reaction and what is the functional group in X?

	mechanism of reaction	functional group in X
A	electrophilic addition	aldehyde
B	electrophilic addition	ketone
C	nucleophilic addition	aldehyde
D	nucleophilic addition	ketone

28 Compound Y is treated with a single reagent under suitable conditions. 2-methylbutanoic acid is produced.

What could compound Y be?

A pentan-2-one

B 2-methylbutan-2-ol

C 2-methylbutanenitrile

D methylpropanenitrile

29 Two reactions are shown.

$$(CH_3)_2CHCO_2H \xrightarrow{LiAlH_4} \text{alcohol P}$$

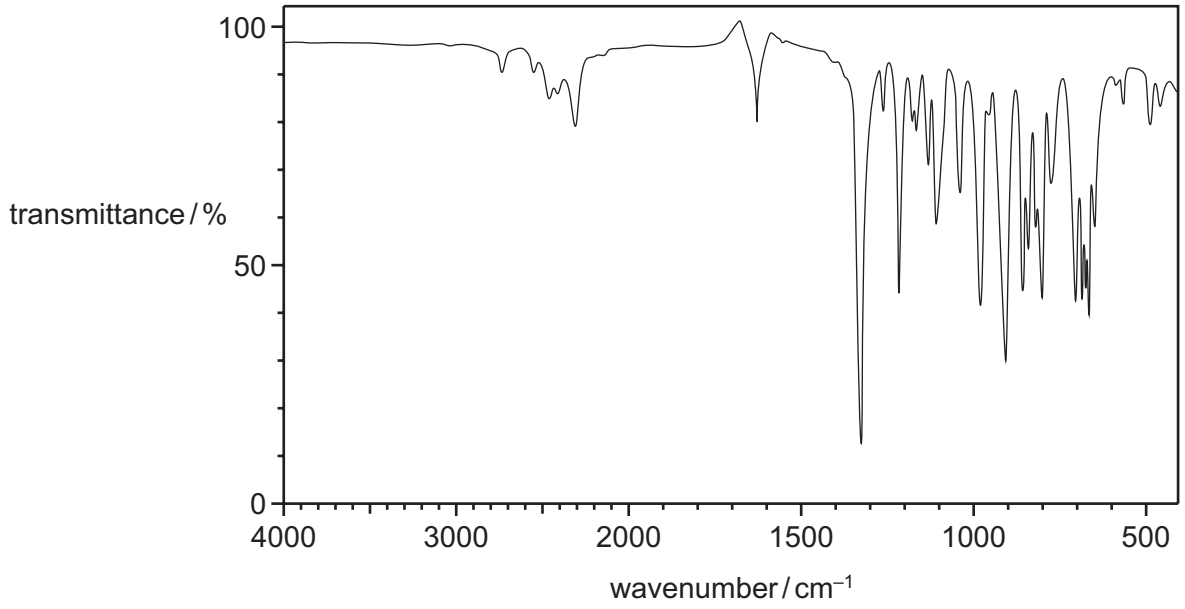
$$CH_3CO_2CH(CH_3)_2 \xrightarrow{\text{hydrolysis}} \text{alcohol Q + acid R}$$

To which classes of alcohol do P and Q belong?

	P	Q
A	primary	primary
B	primary	secondary
C	secondary	primary
D	secondary	secondary

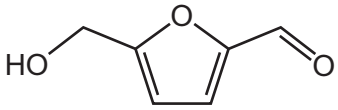
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30 The infra-red spectrum of molecule Z is shown.

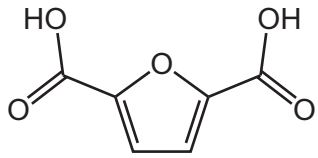


What could be the identity of Z?

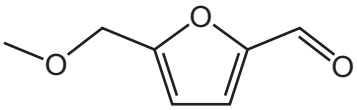
A



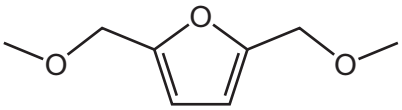
B



C



D



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 Which statements about first ionisation energies are correct?

1 They are always endothermic.

2 They decrease down Group 2.

3 They decrease across Period 3.

32 The equation shows the decomposition of three moles of an ion containing chromium in an acid solution.

$$3CrO_4^{3-}(aq) + 8H^+(aq) \rightarrow 2CrO_4^{2-}(aq) + Cr^{3+}(aq) + 4H_2O(l)$$

Which statements are correct?

1 One mole of CrO_4^{3-} is reduced.

2 Two moles of CrO_4^{3-} are oxidised.

3 Three moles of electrons are transferred.

33 Disaccharides are hydrolysed in slightly acidic solutions. This reaction is very slow.

A biological catalyst is added to a slightly acidic mixture of three disaccharides, sucrose, maltose and lactose. The hydrolysis reaction remains slow for sucrose and maltose but is now much faster for lactose.

Which statements about the catalyst are correct?

1 The catalyst increases the activation energy of all three hydrolysis reactions.

2 The catalyst shows specificity.

3 The hydrolysis of lactose using a catalyst has a different mechanism to the hydrolysis of lactose without a catalyst.

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34 Element X is a solid under room conditions. It occurs as a contaminant of fossil fuels.

Its oxide, Y, is formed when fossil fuels are burned.

In the atmosphere, Y can be further oxidised to Z.

Which statements about X, Y and Z are correct?

1 Atoms of X have paired p electrons.

2 The atmospheric oxidation of Y to Z is a catalysed reaction.

3 With water, Z forms a strong acid.

35 Which reagents produce a solution of sodium chlorate(V)?

1 chlorine and hot concentrated sodium hydroxide solution

2 chlorine and cold dilute sodium hydroxide solution

3 chlorine dissolved in water at room temperature

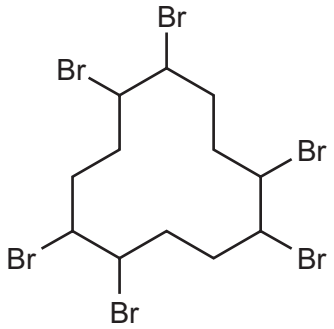
36 Which statements help to explain the increase in melting point from sodium to aluminium?

1 The charge on the metal ion increases.

2 There are more delocalised electrons per metal ion.

3 The radius of the metal ion decreases.

37 The diagram shows a molecule of a compound used as a flame retardant.



Which statements about this structure are correct?

1 Each brominated C atom is chiral.

2 The molecular formula is $C_{12}H_{20}Br_6$.

3 The C–C–C bond angles are all 120°.

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.

38 Bromoethane reacts with NaOH in different ways depending on the solvent used.

Which rows about these reactions are correct?

	solvent used	organic product
1	water	ethan-1,2-diol
2	ethanol	ethene
3	water	ethanol

39 Three compounds, X, Y and Z, are shown.

X	Y	Z
$C_2H_5COCH_3$	C_2H_5CHO	CH_3CO_2H

Which statements about X, Y and Z are correct?

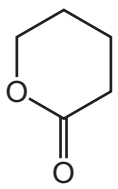
1 X reacts with alkaline aqueous iodine.

2 Y reacts with Tollens' reagent.

3 Z does **not** react with alkaline aqueous iodine.

40 5-hydroxypentanoic acid is readily converted into the cyclic compound L.

L



Which statements about this reaction are correct?

1 Acidified sodium dichromate(VI) is used as a reagent.

2 A water molecule is produced in the reaction.

3 The reaction can be catalysed by concentrated H_2SO_4.

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