



Cambridge International AS & A Level

CHEMISTRY

9701/11

Paper 1 Multiple Choice

May/June 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.
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- 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.



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 Which contains the largest number of hydrogen atoms?

- A** 0.10 mol of pentane
B 0.20 mol of but-2-ene
C 1.00 mol of hydrogen molecules
D 6.02×10^{23} hydrogen atoms

2 In which pair of species do both species have only one unpaired p electron?

- A** Ar^+ and C^- **B** B and Ti^+ **C** F and Ga **D** Se^- and Si^-

3 Phosphorus forms two chlorides. Phosphorus(III) chloride, PCl_3 , is a covalent liquid.

Phosphorus(V) chloride is an ionic solid. One of the ions present is $[\text{PCl}_4]^+$.

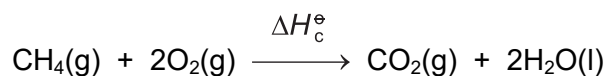
What is the shape of the PCl_3 molecule and the $[\text{PCl}_4]^+$ ion?

	PCl_3	$[\text{PCl}_4]^+$
A	pyramidal	square planar
B	pyramidal	tetrahedral
C	tetrahedral	square planar
D	trigonal planar	tetrahedral

- 4 $\Delta H_1^\ominus$ is the standard enthalpy of formation of methane.

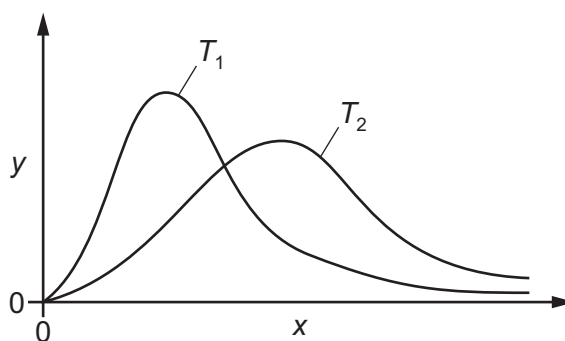
$\Delta H_2^\ominus$ is the standard enthalpy of combustion of carbon.

$\Delta H_3^\ominus$ is the standard enthalpy of combustion of hydrogen.



Which expression is equivalent to $\Delta H_c^\ominus$?

- A** $\Delta H_1^\ominus - \Delta H_2^\ominus + \Delta H_3^\ominus$
- B** $\Delta H_1^\ominus - 2\Delta H_3^\ominus - \Delta H_2^\ominus$
- C** $\Delta H_2^\ominus - \Delta H_3^\ominus + \Delta H_1^\ominus$
- D** $\Delta H_2^\ominus + 2\Delta H_3^\ominus - \Delta H_1^\ominus$
- 5 The diagram shows the Boltzmann distribution for the same gas at two different temperatures, T_1 and T_2 .

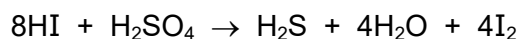


What is plotted on the y-axis and which line represents the higher temperature?

	plotted on y-axis	higher temperature
A	number of molecules	T_1
B	number of molecules	T_2
C	molecular energy	T_1
D	molecular energy	T_2

- 6 What is the minimum mass of oxygen required to ensure the complete combustion of 12 dm^3 of propane measured under room conditions?
- A** 60g **B** 80g **C** 120g **D** 160g

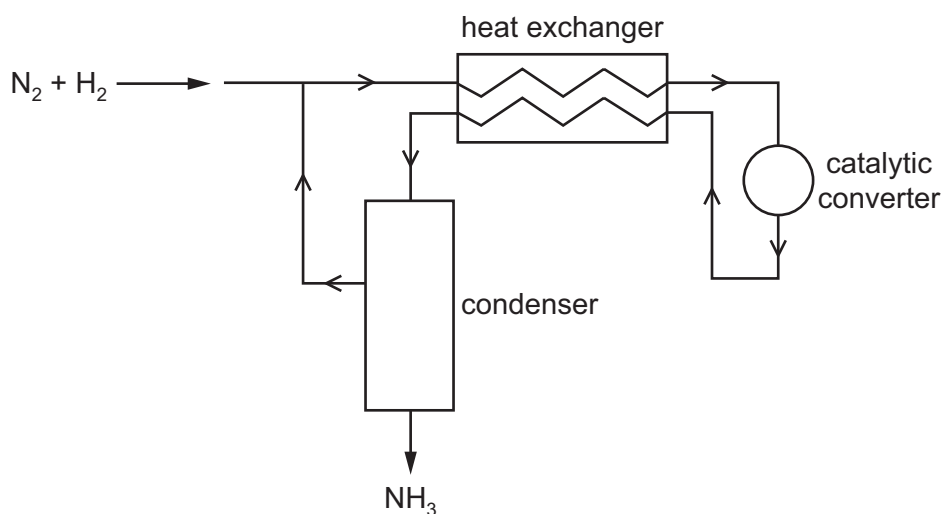
- 7 Why is the first ionisation energy of oxygen less than that of nitrogen?
- A** The nitrogen atom has its outer electron in a different subshell.
- B** The nuclear charge on the oxygen atom is greater than that on the nitrogen atom.
- C** The oxygen atom has a pair of electrons in one p orbital that repel one another.
- D** There is more shielding in an oxygen atom.
- 8 Which gas would behave most like an ideal gas under room conditions?
- A** helium
- B** nitrogen
- C** ammonia
- D** krypton
- 9 When hydrogen iodide is reacted with concentrated sulfuric acid, several reactions occur, including:



Which row gives the change in oxidation number of iodine and of sulfur in this reaction?

	change in oxidation number of iodine	change in oxidation number of sulfur
A	−1	+6
B	−1	+8
C	+1	−6
D	+1	−8

- 10 The diagram represents the Haber process for the manufacture of ammonia from nitrogen and hydrogen.



What is the purpose of the heat exchanger?

- A to cool the incoming gas mixture to avoid overheating the catalyst
 - B to cool the reaction products and separate the NH_3 from unused N_2 and H_2
 - C to warm the incoming gas mixture and shift the equilibrium to give more NH_3
 - D to warm the incoming gas mixture and speed up the reaction
- 11 Which statement about catalysts is correct?
- A They change the reaction pathway by increasing the activation energy.
 - B They increase the rate of reaction by lowering the enthalpy change of the reaction.
 - C They increase the number of particles that have sufficient energy to react.
 - D Heterogeneous catalysts are in the same state as the reactant.
- 12 Element X is in Period 3. Element X forms a solid oxide Y.

Y reacts with hot concentrated hydrochloric acid. Y reacts with hot aqueous sodium hydroxide to form a compound in which X is part of an anion.

How many p electrons does one atom of X have in its outer shell?

- A 0
- B 1
- C 2
- D 3

- 13** The gaseous products of heating a mixture of $\text{Ca}(\text{OH})_2$ and NH_4Cl are passed through solid CaO . A single gaseous product, W, is collected.

A sample of W reacts with $\text{Cl}_2(\text{g})$ to produce two gases, X and Y.

X is an element. Y is acidic.

Y reacts with W to produce Z.

What are X and Z?

	X	Z
A	N_2	CaCl_2
B	N_2	NH_4Cl
C	O_2	CaCl_2
D	O_2	NH_4Cl

- 14** Q is a mixture of a Group 2 oxide and a Group 2 sulfate. Q contains equal amounts of the two compounds.

Q is shaken with water and the resulting mixture filtered; a solid residue is obtained. There is no reaction when the solid residue is shaken with $\text{HCl}(\text{aq})$. Shaking the filtrate with $\text{H}_2\text{SO}_4(\text{aq})$ produces a white precipitate.

What could be Q?

- A** $\text{BaO} + \text{BaSO}_4$
- B** $\text{BaO} + \text{MgSO}_4$
- C** $\text{MgO} + \text{BaSO}_4$
- D** $\text{MgO} + \text{MgSO}_4$
- 15** Which substance will **not** be a product of the thermal decomposition of hydrated magnesium nitrate?
- A** dinitrogen monoxide
- B** magnesium oxide
- C** oxygen
- D** steam

- 16** A 5 cm^3 sample of 0.05 mol dm^{-3} sodium chloride is mixed with a 5 cm^3 sample of 0.05 mol dm^{-3} potassium iodide. 10 cm^3 of acidified 0.05 mol dm^{-3} silver nitrate is then added, followed by concentrated ammonia solution.

What is seen after the addition of an excess of concentrated ammonia solution?

- A** a cream precipitate
- B** a white precipitate
- C** a yellow precipitate
- D** no precipitate

- 17** The volatility of the Group 17 elements, chlorine, bromine and iodine, decreases down the group.

What is responsible for this trend?

- A** bond length in the halogen molecule
- B** bond strength in the halogen molecule
- C** electronegativity of the halogen atom
- D** number of electrons in the halogen atom

- 18** Acid rain is a dilute solution of sulfuric acid.

Which pollutant also contributes to the formation of acid rain?

- A** carbon monoxide
- B** carbon dioxide
- C** nitrogen dioxide
- D** hydrocarbons

- 19** R is an oxide of Period 3 element T. 5.00 g of R contains 2.50 g of T.

What is T?

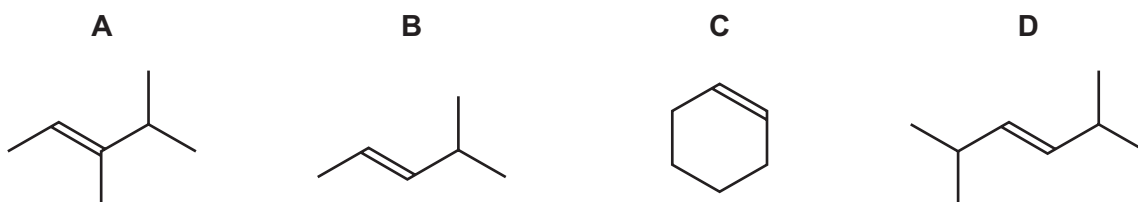
- A** magnesium
- B** aluminium
- C** silicon
- D** sulfur

20 Bromoethane reacts with cyanide ions, producing propanenitrile.

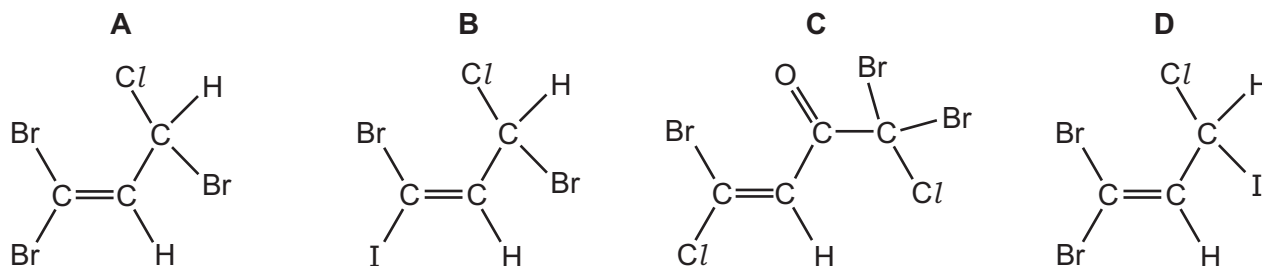
Which statement about the S_N2 mechanism of this reaction is correct?

- A The lone pair of electrons on C of CN^- attacks the carbon atom of the C–Br bond.
- B The lone pair of electrons on C of CN^- attacks the carbocation formed when the C–Br bond breaks.
- C The lone pair of electrons on N of CN^- attacks the carbon atom of the C–Br bond.
- D The lone pair of electrons on N of CN^- attacks the carbocation formed when the C–Br bond breaks.

21 Which compound would produce two different carboxylic acids when treated with hot, concentrated, acidified manganate(VII) ions?

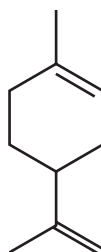


22 Which compound could show **both** *cis-trans* isomerism and optical isomerism?



23 Limonene is a hydrocarbon found in the rind of citrus fruits.

limonene



What is the molecular formula of limonene?

- A $C_{10}H_{12}$
- B $C_{10}H_{14}$
- C $C_{10}H_{16}$
- D $C_{10}H_{18}$

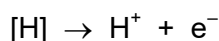
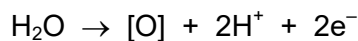
- 24** The compound cetyl palmitate, $C_{15}H_{31}CO_2C_{16}H_{33}$, is a waxy solid.

Cetyl palmitate is heated under reflux with an excess of aqueous sodium hydroxide.

Which products will be formed?

- A** $C_{15}H_{31}ONa$ and $C_{16}H_{33}CO_2Na$
B $C_{15}H_{31}CO_2Na$ and $C_{16}H_{33}ONa$
C $C_{15}H_{31}OH$ and $C_{16}H_{33}CO_2Na$
D $C_{15}H_{31}CO_2Na$ and $C_{16}H_{33}OH$
- 25** When an organic compound is oxidised, any oxygen atom gained by the organic molecule is considered to be from a water molecule also producing $2H^+ + 2e^-$. Any hydrogen atom lost may be considered to be lost as $H^+ + e^-$.

These changes can be represented by the following two equations.



Compound X is oxidised by heating under reflux with hot, acidified potassium dichromate(VI) for one hour. The half-equation for the reduction reaction is shown.

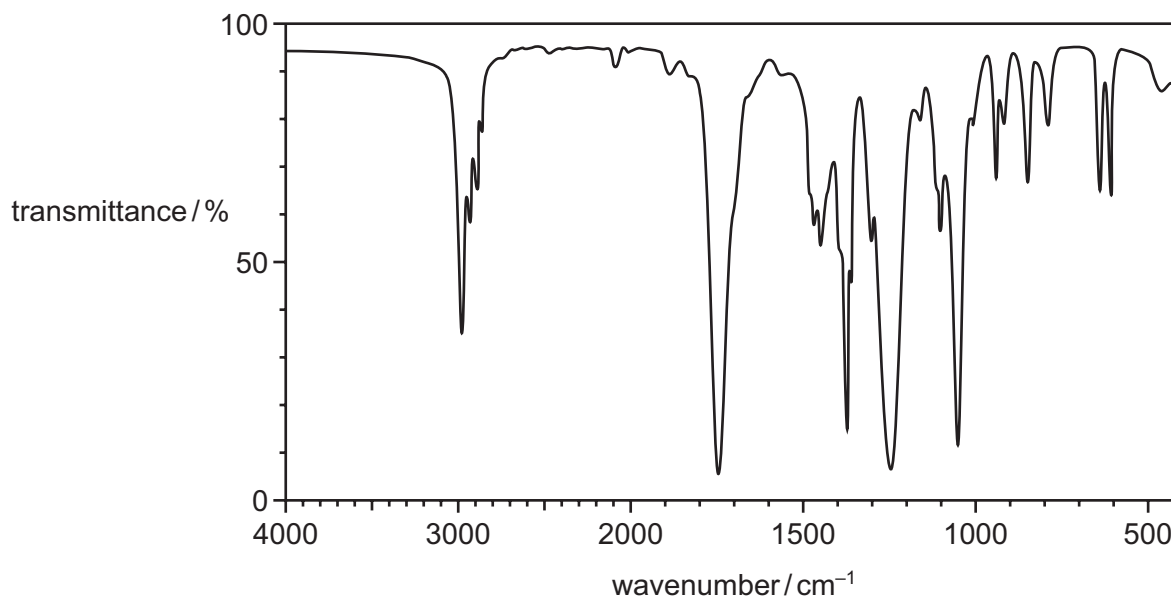


Under these conditions, one mole of potassium dichromate(VI) oxidises three moles of X.

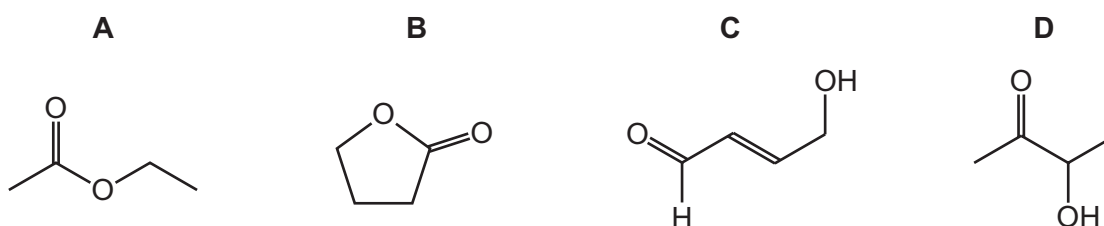
What could X be?

- A** propanal
B propan-1-ol
C propan-1,2-diol
D propan-1,3-diol

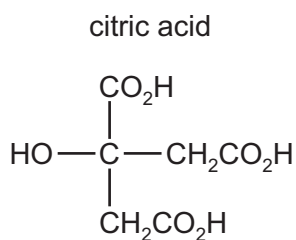
26 Compound X has the empirical formula C_2H_4O . Its infra-red spectrum is shown.



What could be the skeletal formula of compound X?



27 How many moles of hydrogen, H_2 , are evolved when an excess of sodium metal is added to one mole of citric acid?



- A** 0.5 **B** 1.5 **C** 2 **D** 4

28 Which statement is correct for the reaction of carbonyl compounds with HCN?

- A** The reaction is catalysed by concentrated H_2SO_4 .
B Pentan-2-one and HCN react to give a chiral product.
C The reaction is a condensation reaction.
D The reaction is nucleophilic substitution.

29 The table describes four reactions of propene.

Which row is correct?

	reagent used	name of main organic product
A	aqueous bromine	2-bromopropane
B	cold acidified aqueous potassium manganate(VII)	propane-1,3-diol
C	hydrogen chloride	2-chloropropane
D	steam	propan-1-ol

30 Butanoic acid is prepared from 1-bromopropane.

This synthesis requires a sequence of two reactions.

Which compound is prepared in the first stage of the synthesis?

- A** 1-aminopropane
- B** propan-1-ol
- C** butanal
- D** butanenitrile

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).

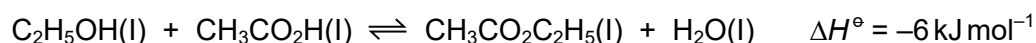
The responses **A** to **D** should be selected on the basis of

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 Ethanol combines with ethanoic acid to form ethyl ethanoate according to the following reaction.



9.2 g ethanol, 12 g ethanoic acid and 8.8 g ethyl ethanoate are mixed and allowed to stand at 298 K, until equilibrium is reached.

(M_r : $\text{C}_2\text{H}_5\text{OH}$, 46; $\text{CH}_3\text{CO}_2\text{H}$, 60; $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$, 88)

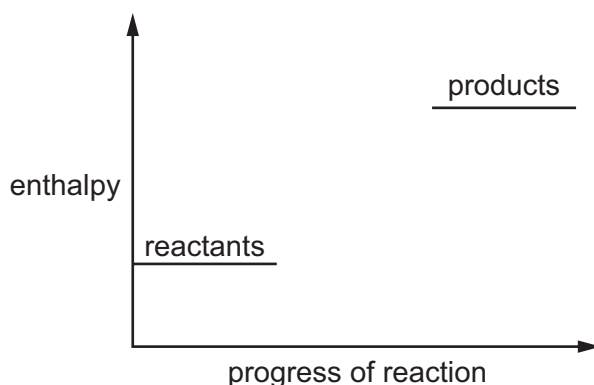
The resulting equilibrium mixture is found to contain 4.8 g ethanoic acid.

The experiment is repeated at 323 K.

Which statements are correct?

- 1** There are 0.22 moles of ethyl ethanoate in the mixture at equilibrium at 298 K.
- 2** The equilibrium mixture at 323 K will contain more than 4.8 g of ethanoic acid.
- 3** If a small amount of water is added at the start of either experiment the value of K_c would not be affected.

32 The diagram shows an incomplete energy profile diagram for a reaction.



Which reactions could this diagram refer to?

- 1 $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- 2 $\text{H}_2(\text{g}) \rightarrow 2\text{H}(\text{g})$
- 3 $\text{Cl}^-(\text{aq}) \rightarrow \text{Cl}^-(\text{g}) + \text{aq}$

33 A gaseous hydrocarbon has a density of 2.42 g dm^{-3} under room conditions.

What could be the skeletal formula of this hydrocarbon?

- 1
- 2
- 3

34 Which molecules contain at least one bond angle of 120° ?

- 1 C_2H_4
- 2 PF_5
- 3 NCl_3

35 Which statements are correct going across Period 3 from sodium to chlorine?

- 1 The charge on the nucleus increases, pulling the electrons closer to it.
- 2 The radius of the most common ion of each element decreases.
- 3 The shielding caused by inner electrons decreases, so the outer electrons are pulled closer to the nucleus.

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 are correct?

- 1** Magnesium carbonate decomposes at a lower temperature than calcium carbonate.
- 2** Calcium hydroxide is more soluble in water than magnesium hydroxide.
- 3** Calcium is a stronger reducing agent than magnesium.

37 Which statements are correct?

- 1** 1,1-difluoroethane is less reactive than 1,1-dichloroethane.
- 2** 1,1-difluoroethane is polar.
- 3** The C–F bond is stronger than the C–Cl bond.

38 Which pairs of compounds may be distinguished by testing with alkaline aqueous iodine?

- 1** butanal and butanone
- 2** pentan-2-one and pentan-3-ol
- 3** propanone and propan-2-ol

39 Which reactions have a coloured organic product?

- 1** ethanal + 2,4-dinitrophenylhydrazine reagent
- 2** ethanol + acidified potassium dichromate(VI)
- 3** ethene + cold dilute acidified potassium manganate(VII)

40 Propanoic acid is reacted with an excess of lithium aluminium hydride. The organic product of this reaction is reacted with ethanoic acid in the presence of concentrated sulfuric acid, forming product X.

What are major commercial uses of X?

- 1** fuel
- 2** solvent
- 3** flavouring

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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.

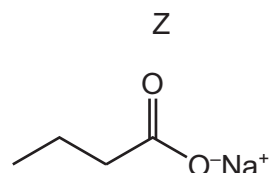
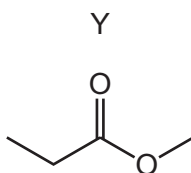
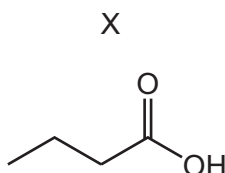
1 Which statement about the Avogadro constant is correct?

- A** It is the mass of one mole of any element.
- B** It is the mass of 6.02×10^{23} atoms of any element.
- C** It is the number of atoms in one mole of neon.
- D** It is the number of atoms in 12 g of any element.

2 Which equation represents the first ionisation energy of iodine?

- A** $\frac{1}{2} \text{I}_2(\text{g}) + \text{e}^- \rightarrow \text{I}^-(\text{g})$
- B** $\text{I}(\text{g}) + \text{e}^- \rightarrow \text{I}^-(\text{g})$
- C** $\frac{1}{2} \text{I}_2(\text{g}) \rightarrow \text{I}^+(\text{g}) + \text{e}^-$
- D** $\text{I}(\text{g}) \rightarrow \text{I}^+(\text{g}) + \text{e}^-$

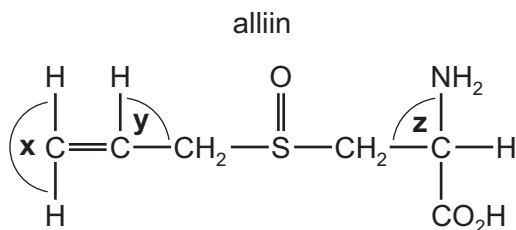
3 The structures represent three compounds, each with four carbon atoms per molecule.



Which row is correct?

	lowest boiling point	→	highest boiling point
A	X	Y	Z
B	Y	X	Z
C	Z	X	Y
D	Z	Y	X

- 4 The structural formula of alliin is shown.



What are the approximate bond angles **x**, **y** and **z** in a molecule of alliin?

	x	y	z
A	90°	90°	109°
B	120°	109°	90°
C	120°	120°	109°
D	180°	109°	109°

- 5 Flask Q contains 5 dm³ of helium at 12 kPa pressure. Flask R contains 10 dm³ of neon at 6 kPa pressure.

If the flasks are connected at constant temperature, what is the final pressure?

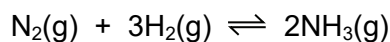
- A** 8 kPa **B** 9 kPa **C** 10 kPa **D** 11 kPa

- 6 Sodium chloride, water and air represent three states of matter – solid, liquid and gas.

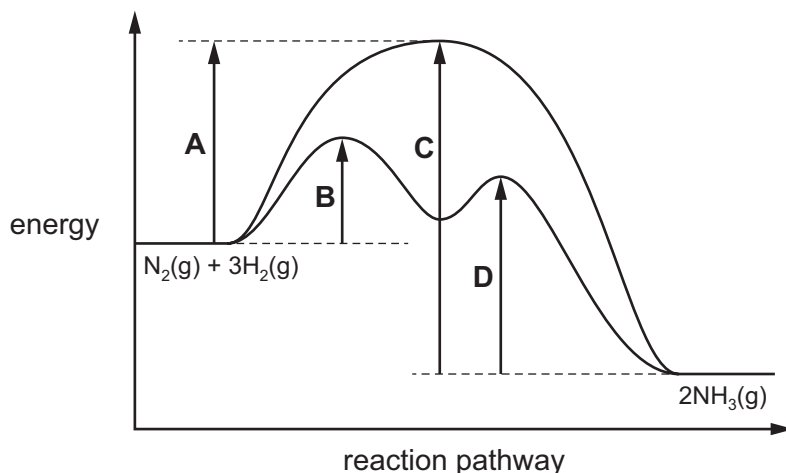
Which row is correct?

	sodium chloride	water	air
A	particles held in rigid structure	can easily be compressed	can easily be compressed
B	particles stationary	particles move	cannot easily be compressed
C	particles stationary	particles stationary	particles move
D	resistant to change of shape	cannot easily be compressed	can easily be compressed

- 7 The reaction pathway diagram for the catalysed reaction and the uncatalysed reaction between N_2 and H_2 is shown.



Which letter represents the activation energy for the first step in the decomposition of NH_3 in the presence of a catalyst?



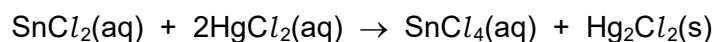
- 8 Nitrogen and oxygen can react together to form nitrogen monoxide, NO .



What is the bond energy of the bond between the atoms in NO ?

- A** 630 kJ mol^{-1} **B** 810 kJ mol^{-1} **C** 1260 kJ mol^{-1} **D** 1620 kJ mol^{-1}

- 9 The equation for a redox reaction is shown.

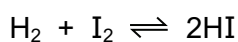


Which species is being oxidised in this reaction?

- A** Sn^{2+} **B** Cl^- **C** Hg^+ **D** Hg^{2+}

- 10 3.60 moles of hydrogen gas and 2.00 moles of iodine vapour are placed in a reaction vessel which is then sealed and maintained at a constant temperature.

The equation for the reaction is shown.



At equilibrium, 3.20 moles of hydrogen remain. All reactants and products are gaseous.

What is the value of K_p under these conditions?

- A** 0.0313 **B** 0.125 **C** 0.156 **D** 8.00

11 Two chemicals, X and Y, react together in solution to give product Z.

The rate of formation of product Z at the start of the reaction was measured in five experiments, 1–5, using various concentrations of X and Y. The results are shown.

experiment number	starting concentration of X / mol dm ⁻³	starting concentration of Y / mol dm ⁻³	rate of formation of Z at the start / mol dm ⁻³ s ⁻¹
1	0.10	0.10	0.0001
2	0.10	0.20	0.0004
3	0.10	0.40	0.0016
4	0.20	0.10	0.0001
5	0.40	0.10	0.0001

Which statement is correct?

- A The rate of the reaction is directly proportional to the concentration of reagent X.
- B The rate of the reaction is directly proportional to the concentration of reagent Y.
- C The rate of the reaction is **not** affected by the concentration of reagent X.
- D The rate of the reaction is **not** affected by the concentration of reagent Y.

12 A sample of SiCl₄ is added to cold water.

Which statement describes the mixture formed at the end of the reaction?

- A acidic solution with no precipitate
- B acidic solution with white precipitate
- C neutral solution with no precipitate
- D neutral solution with white precipitate

13 L and M are elements in Period 3 of the Periodic Table.

- The oxide of L is a solid at room temperature. This oxide has a giant structure.
- The chloride of L does not react with water.
- Argon is the only element in Period 3 with a lower melting point than M.

Which formula represents a compound of elements L and M?

- A Al₂S₃ B MgS C NaCl D PCl₅

14 A farmer requires a solid compound to raise the pH of the soil in a field from 5.5 to above 6.0.

Which compound could the farmer use?

- A (NH₄)₂SO₄ B NH₄NO₃ C Ca(OH)₂ D Ca(NO₃)₂

- 15 Z is an anhydrous compound of a Group 2 element. When it is heated, Z undergoes thermal decomposition to produce two different gases. Z has relatively low thermal stability compared to other Group 2 compounds containing the same anion as Z.

What is compound Z?

- A barium carbonate
- B barium nitrate
- C magnesium carbonate
- D magnesium nitrate

- 16 Which row gives mixtures that **both** result in the oxidation of a halide ion?

	mixture 1	mixture 2
A	$\text{AgNO}_3(\text{aq})$ and $\text{NaCl}(\text{aq})$	concentrated $\text{H}_2\text{SO}_4(\text{aq})$ and $\text{HI}(\text{aq})$
B	$\text{Br}_2(\text{aq})$ and $\text{NaCl}(\text{aq})$	concentrated $\text{H}_2\text{SO}_4(\text{aq})$ and $\text{HCl}(\text{aq})$
C	$\text{Cl}_2(\text{aq})$ and $\text{NaBr}(\text{aq})$	$\text{CH}_3\text{CHBrCH}_3(\text{l}) + \text{NaOH}$ (ethanolic)
D	$\text{Br}_2(\text{aq})$ and $\text{NaI}(\text{aq})$	concentrated $\text{H}_2\text{SO}_4(\text{aq})$ and $\text{NaBr}(\text{s})$

- 17 Chlorine gas is widely used to treat contaminated water.

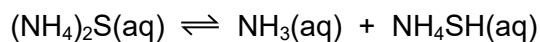
When chlorine is added to water, which chemical species present is responsible for killing bacteria?

- A ClO_2^-
- B Cl^-
- C HCl
- D ClO^-

- 18 What is an environmental consequence of the uncontrolled use of nitrate fertilisers?

- A acid rain
- B low oxygen levels in streams
- C ozone depletion
- D the greenhouse effect

- 19 Ammonia gas, NH_3 , and hydrogen sulfide gas, H_2S , react together to form the salt ammonium sulfide, $(\text{NH}_4)_2\text{S}$. Ammonium sulfide dissolves in water to produce an orange alkaline solution.



The addition of $\text{NaOH}(\text{aq})$ to this solution produces a gas, X.

The addition of $\text{HCl}(\text{aq})$ to a separate portion of this solution produces a gas, Y.

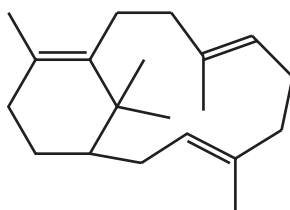
X and Y could represent different gases or identical gases.

What are the identities of X and Y?

	X	Y
A	H_2S	H_2S
B	H_2S	NH_3
C	NH_3	H_2S
D	NH_3	NH_3

- 20 Compound P is treated with an excess of hydrogen gas in the presence of a nickel catalyst. The product Q is fully saturated.

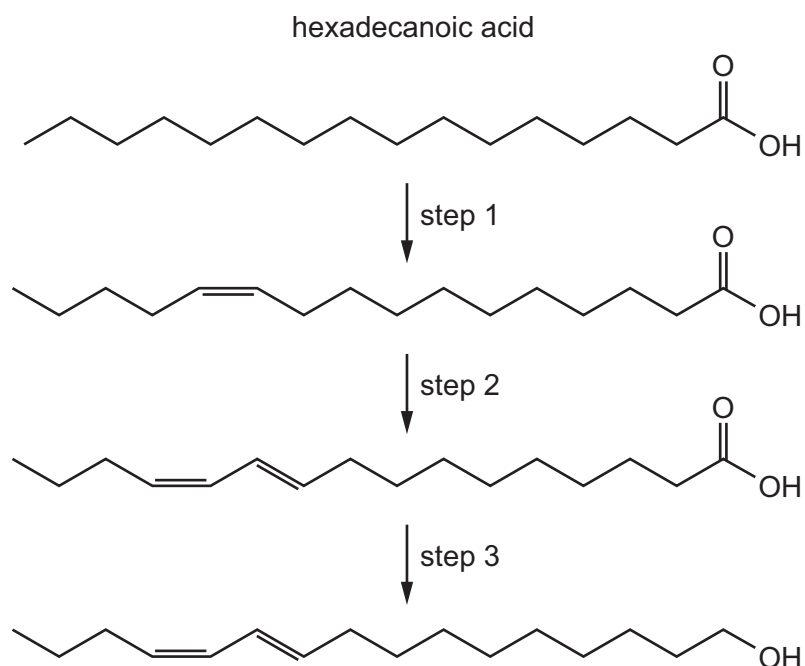
compound P



What is the number of chiral carbon atoms in the product Q?

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

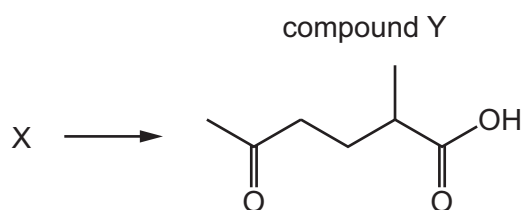
- 21 Hexadeca-10,12-dien-1-ol is produced by silk moths from hexadecanoic acid in a three-step enzymic process.



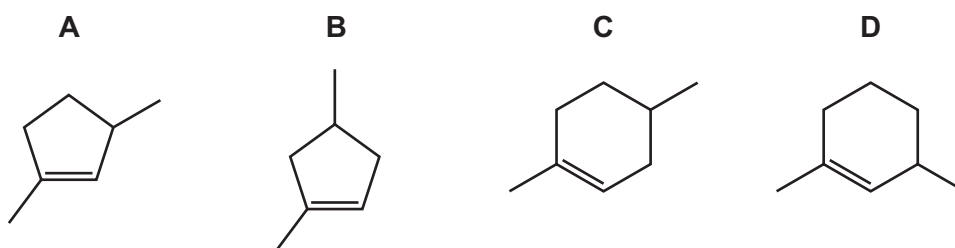
Which row contains correct descriptions of the three steps?

	step 1	step 2	step 3
A	elimination	elimination	dehydration
B	elimination	reduction	reduction
C	oxidation	elimination	oxidation
D	oxidation	oxidation	reduction

- 22 Compound X can be converted into compound Y in a single step.



What could be the identity of X?



23 Methane and bromine react by free radical substitution.

P and Q are involved in the reaction mechanism.

P and Q:

- are **both** involved in propagation steps as reactants
- are **both** involved in termination steps as reactants.

What could be P and Q?

A Br and H **B** Br and CH₃ **C** Br and C₂H₆ **D** CH₃ and CH₃Br

24 A few drops of 2-bromopropane were placed in a test-tube. An equal volume of aqueous silver nitrate was added. A precipitate was formed.

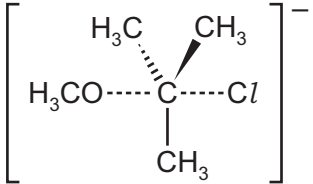
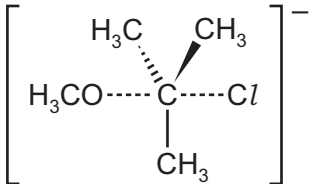
The experiment was repeated with 2-iodopropane.

Which row is correct?

	colour of precipitate from 2-bromopropane + AgNO ₃ (aq)	faster rate of reaction
A	cream	2-bromopropane + AgNO ₃ (aq)
B	yellow	2-bromopropane + AgNO ₃ (aq)
C	cream	2-iodopropane + AgNO ₃ (aq)
D	yellow	2-iodopropane + AgNO ₃ (aq)

- 25** Sodium methoxide, $\text{Na}^+\text{CH}_3\text{O}^-$, reacts with 2-chloro-2-methylpropane in a nucleophilic substitution reaction. The nucleophile is the CH_3O^- ion.

Which row is correct?

	intermediate or transition state	product
A	$(\text{CH}_3)_3\text{C}^+$	$(\text{CH}_3)_3\text{COCH}_3$
B	$(\text{CH}_3)_3\text{C}^+$	$(\text{CH}_3)_3\text{CCH}_2\text{OH}$
C		$\text{HOCH}_2\text{C}(\text{CH}_3)_3$
D		$\text{H}_3\text{COC}(\text{CH}_3)_3$

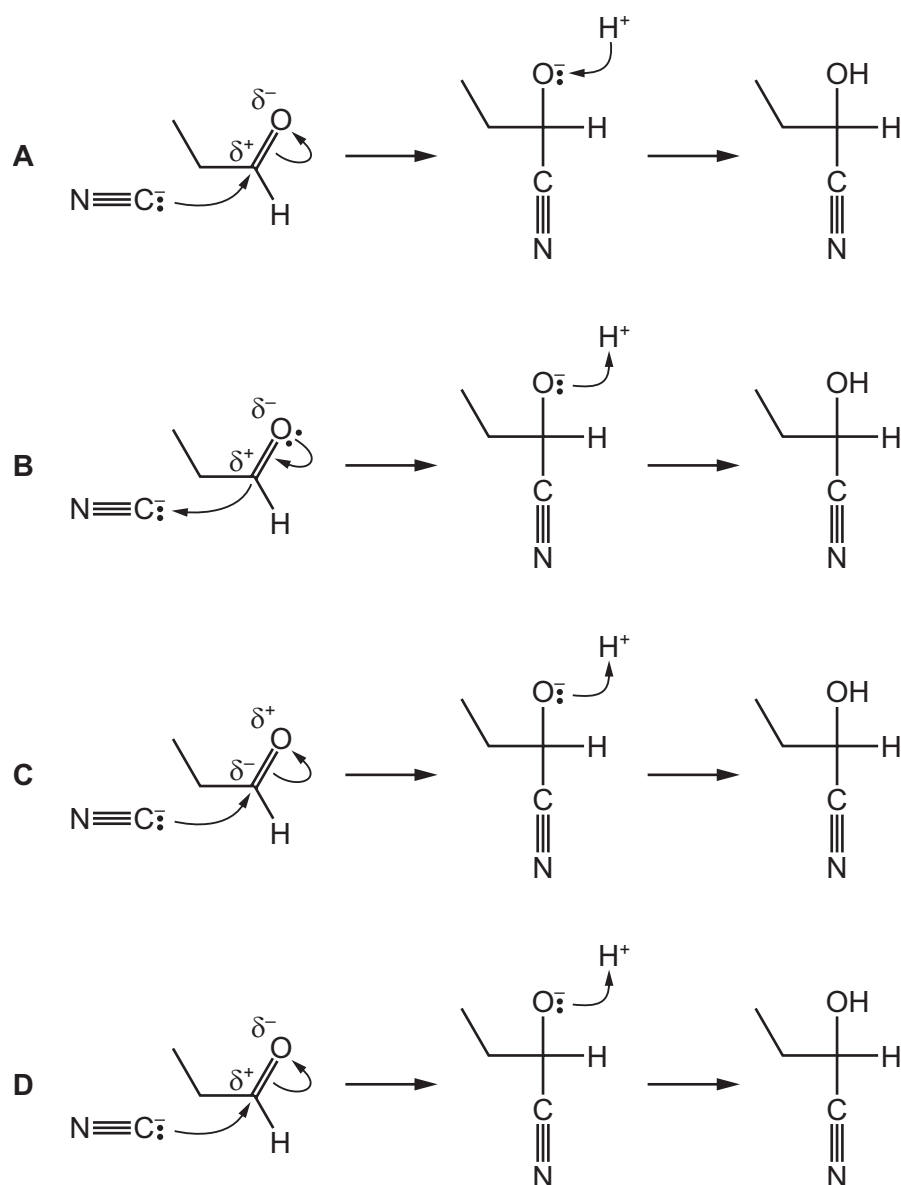
- 26** Alcohol X reacts with concentrated sulfuric acid to produce a mixture of products.

Two of the products are structural isomers of each other.

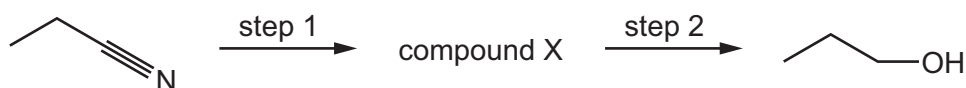
What could be X?

- A** hexan-2-ol
- B** pentan-1-ol
- C** pentan-3-ol
- D** propan-2-ol
- 27** Which reaction will form a strong organic base?
- A** ethanol and acidified sodium dichromate
- B** ethanol and hot aluminium oxide
- C** ethanol and sodium
- D** ethanol and hydrogen chloride

28 Which reaction mechanism for the formation of $\text{C}_2\text{H}_5\text{CH}(\text{OH})(\text{CN})$ is correct?



29 The synthesis shown may be used for the production of propan-1-ol.

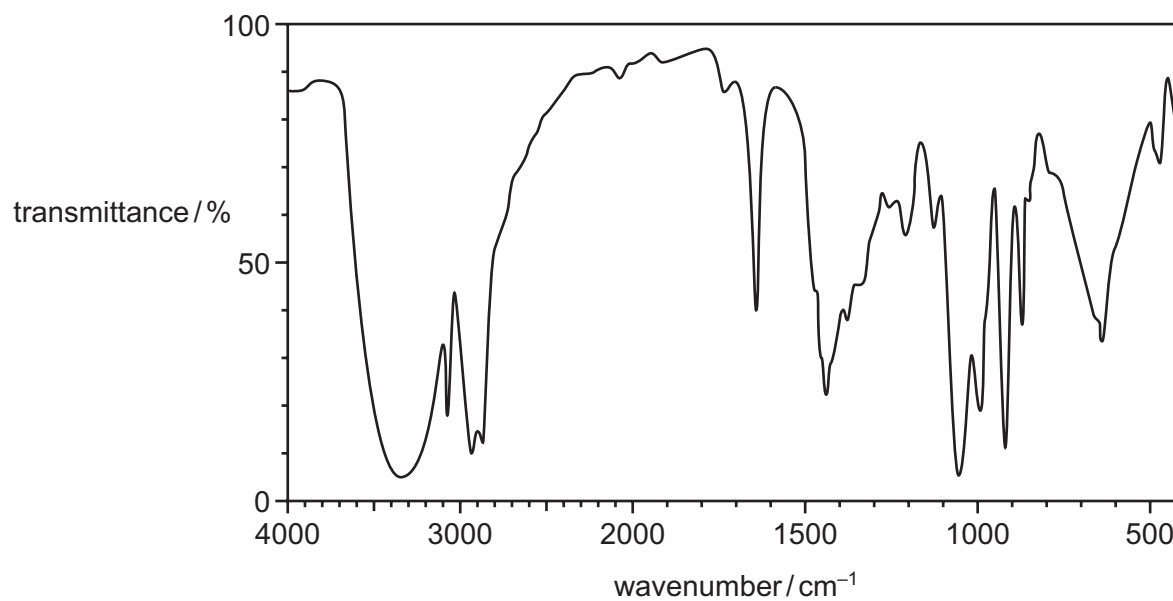


Which row gives the correct reagents for steps 1 and 2?

	step 1	step 2
A	$\text{HCl}(\text{aq})$	$\text{H}_2 + \text{Ni}$
B	$\text{HCl}(\text{aq})$	LiAlH_4
C	$\text{NaOH}(\text{aq})$	$\text{H}_2 + \text{Ni}$
D	$\text{NaOH}(\text{aq})$	NaBH_4

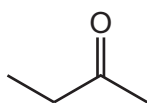
30 The molecular formula of Z is C_4H_8O .

The infra-red spectrum of Z is shown.

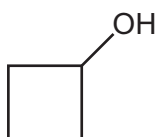


What could be Z?

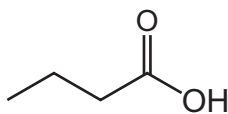
A



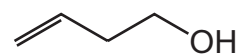
B



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 In which ions are the number of electrons equal to the number of neutrons?

- 1** $^{19}_{9}\text{F}^{-}$
- 2** $^{31}_{15}\text{P}^{-}$
- 3** $^{23}_{11}\text{Na}^{+}$

32 Compound X is a straight chain hydrocarbon with an M_r of 84.

What can be determined about X?

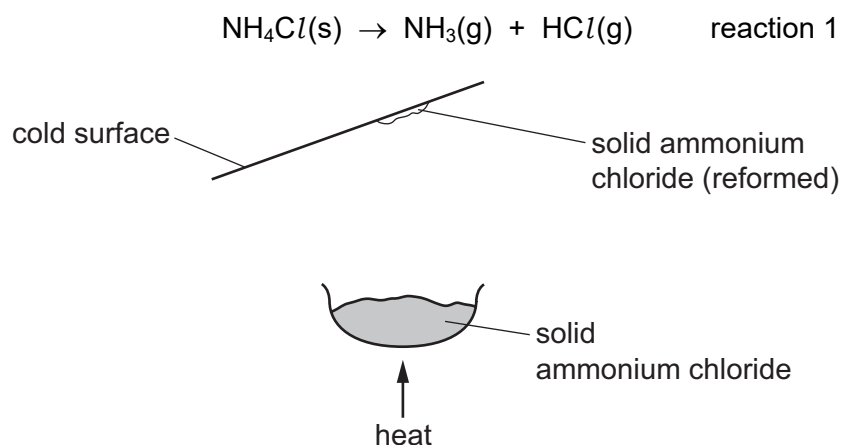
- 1** empirical formula
- 2** molecular formula
- 3** whether X contains a C=C bond or not

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.

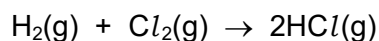
- 33** When a sample of ammonium chloride is warmed it decomposes into ammonia and hydrogen chloride gas.



When the mixture of hot ammonia and hydrogen chloride gases hit a cold surface, a white solid of ammonium chloride reforms.

Which statements are correct?

- 1** Reaction 1 is in dynamic equilibrium.
 - 2** Reaction 1 is reversible.
 - 3** Reaction 1 is an endothermic reaction.
- 34** Hydrogen chloride gas is formed by the reaction shown.



What will change the average kinetic energy of the reacting gas particles?

- 1** increasing the temperature and increasing the concentration of hydrogen
- 2** cooling the reaction mixture and adding a catalyst
- 3** adding a catalyst and increasing the concentration of chlorine

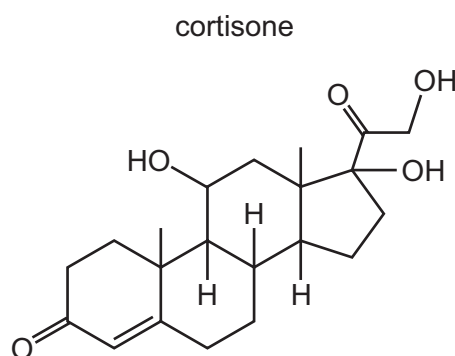
35 Which oxides will cause a change in pH when added to water?

- 1 CaO
- 2 Al_2O_3
- 3 SiO_2

36 Which reaction routes can be used to make a pure sample of barium sulfate?

- 1 Ba $\xrightarrow[\text{in } O_2]{\text{heat}}$ product $\xrightarrow[HCl]{\text{dilute}}$ product $\xrightarrow[H_2SO_4]{\text{dilute}}$ product $\xrightarrow[\text{and dry}]{\text{filter, wash}}$
- 2 $Ba(NO_3)_2 \xrightarrow[\text{heat in air}]{\text{strong}}$ solid product $\xrightarrow[\text{of water}]{\text{an excess}}$ product $\xrightarrow[H_2SO_4]{\text{dilute}}$ product $\xrightarrow[\text{and dry}]{\text{filter, wash}}$
- 3 $Ba(OH)_2 \xrightarrow[HNO_3]{\text{dilute}}$ product $\xrightarrow[H_2SO_4]{\text{dilute}}$ product $\xrightarrow[\text{and dry}]{\text{filter, wash}}$

37 Cortisone is a synthetic hormone.



Which classes of alcohol does this molecule contain?

- 1 primary alcohol
- 2 secondary alcohol
- 3 tertiary alcohol

38 Which changes are commonly involved in the formation of an addition polymer?

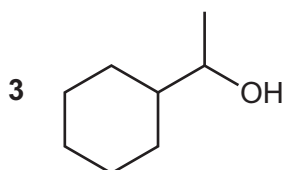
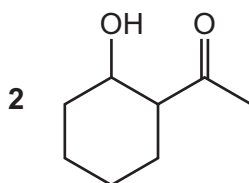
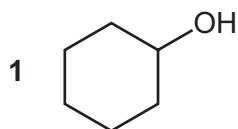
- 1 the formation of a σ -bond
- 2 the breaking of a π -bond
- 3 the change in hybridisation of the orbitals of a carbon atom from sp^2 to sp^3

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

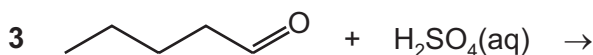
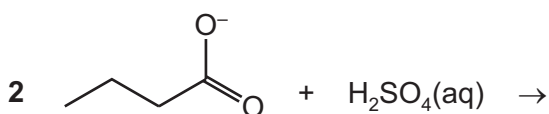
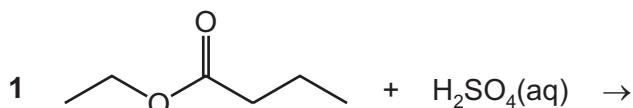
A	B	C	D
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

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

39 Which alcohols can be oxidised to form an organic compound which will give coloured precipitates with both 2,4-dinitrophenylhydrazine reagent and alkaline aqueous iodine?



40 Which mixtures form a carboxylic acid as one of the products?



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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.

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.

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.

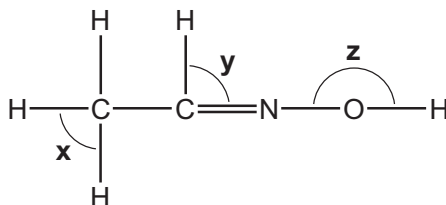
Which volume of carbon dioxide gas is produced?

- 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

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 ₃ OH	Al ₂ Cl ₆	CH ₂ Cl ₂
B	Al ₂ Cl ₆	CH ₂ Cl ₂	CH ₄
C	CH ₂ Cl ₂	CH ₄	CH ₃ OH
D	CH ₄	CH ₃ OH	H ₂ O

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

- A** covalent
- B** ionic
- C** metallic
- D** van der Waals' forces

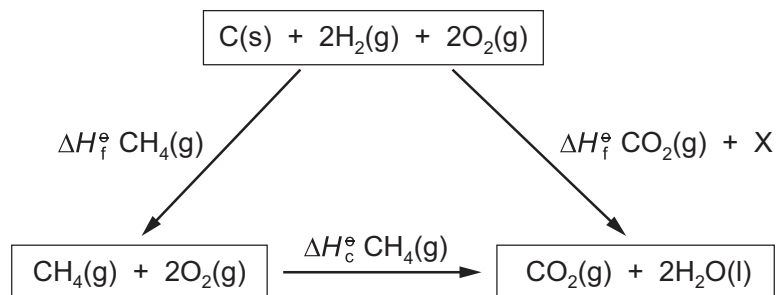
7 Using the information in the table, what is the enthalpy change, q , for the reaction described?



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

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

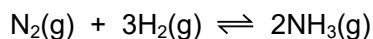
- 8 Which enthalpy change is indicated by X in the enthalpy cycle shown?



- 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 $\text{Cu(NO}_3)_2$, 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.

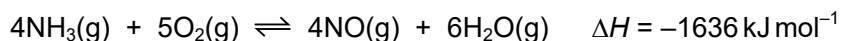


A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 dm^3 . It is found that 2.32 mol of nitrogen were present in the equilibrium mixture.

Which expression will give the value of K_c ?

- A $\frac{(1.76)^2}{(2.32)(6.96)^3}$
 B $\frac{(1.76)^2}{(2.32)(6.32)^3}$
 C $\frac{(2.08)^2}{(2.32)(6.32)^3}$
 D $\frac{(2.40)^2}{(2.32)(6.00)^3}$

- 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.



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

- 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 $\text{Ba}(\text{NO}_3)_2(\text{aq})$ followed by $\text{HNO}_3(\text{aq})$.
 - D** The insoluble hydroxide, $\text{Ba}(\text{OH})_2$, can be safely used to lower the acidity of the stomach.

- 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 ₂ O
B	Ca	dilute H ₂ SO ₄
C	Mg	dilute H ₂ SO 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?

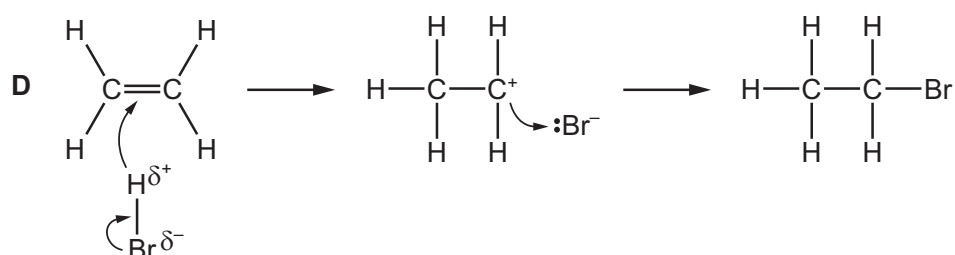
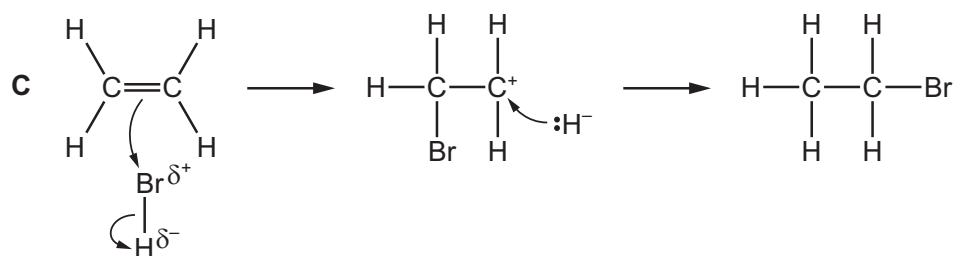
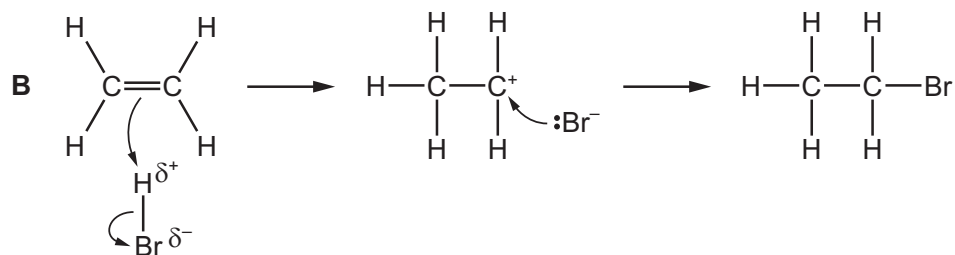
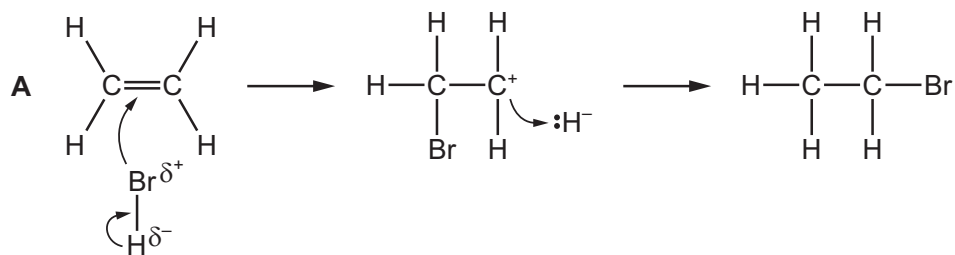
- A** Al₂O₃ and SiO₂
- B** Al₂O₃ and P₄O₁₀
- C** Na₂O and P₄O₁₀
- D** Na₂O and SiO₂
- 20** Which compound shows stereoisomerism?
- A** 2-methylbut-2-ene
- B** 2-chloropropan-1-ol
- C** difluorochlorobromomethane
- D** pent-1-ene
- 21** Two carbon-containing products result from the reaction of alkene 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?

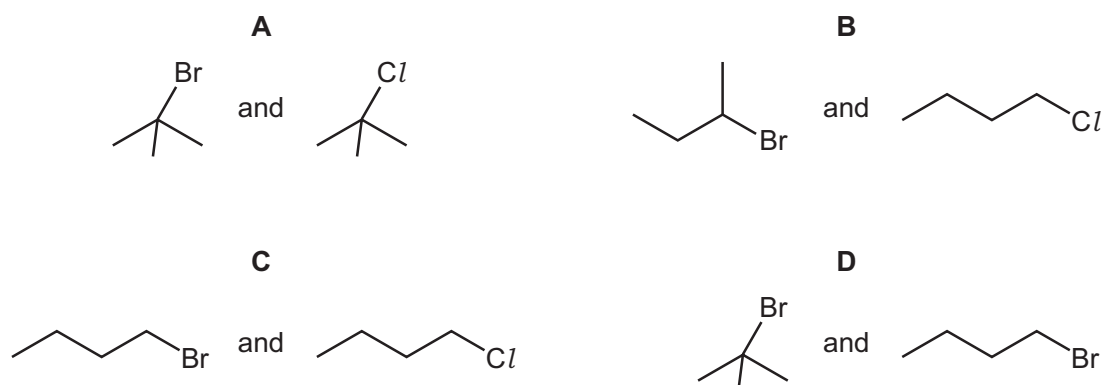
- A** but-2-ene
- B** 2-methylpropene
- C** 2-methylbut-2-ene
- D** propene

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



23 Halogenoalkanes react with nucleophiles such as OH^- .

Which pair of halogenoalkanes **both** react via an $\text{S}_{\text{N}}1$ mechanism?



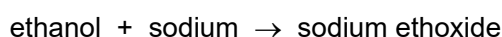
- 24** A mixture of ethanol and methanol is burned in oxygen to produce 35 cm^3 of CO_2 and 55 cm^3 of H_2O .

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

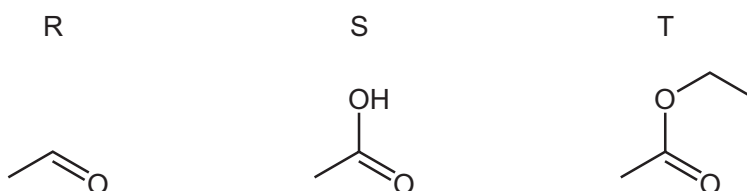
- 25** Two reactions are shown. Only one product is identified in each reaction.



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.

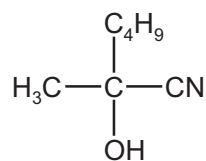
- 26** The skeletal formulae of three compounds are shown.



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?

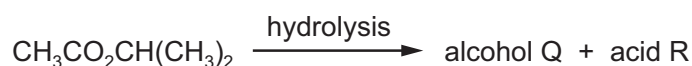
	mechanism of reaction	functional group in X
A	electrophilic addition	aldehyde
B	electrophilic addition	ketone
C	nucleophilic addition	aldehyde
D	nucleophilic addition	ketone

- 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

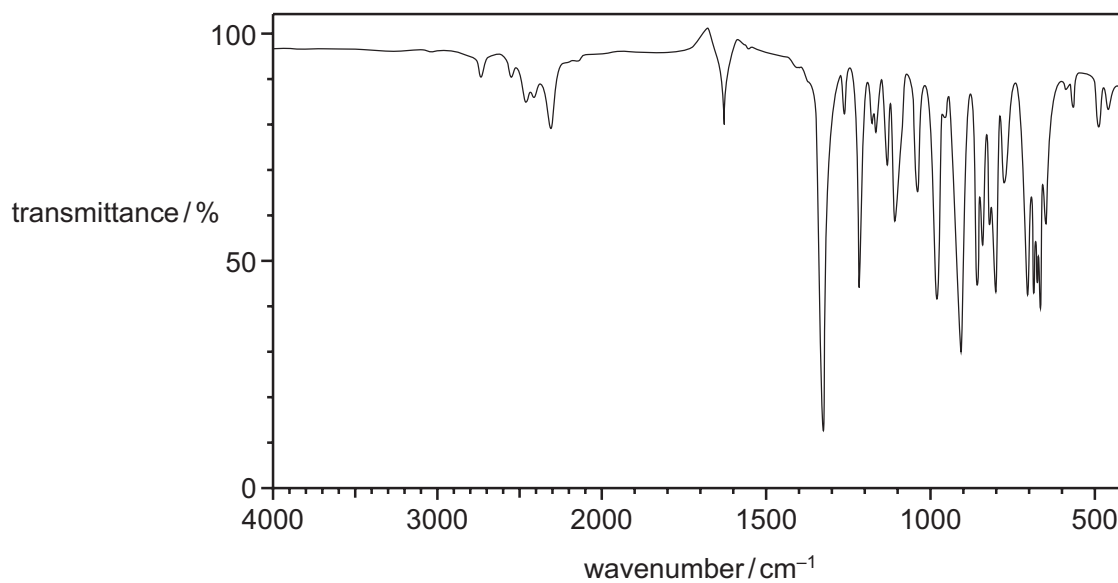
- 29 Two reactions are shown.



To which classes of alcohol do P and Q belong?

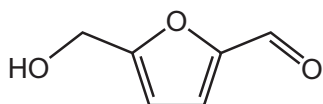
	P	Q
A	primary	primary
B	primary	secondary
C	secondary	primary
D	secondary	secondary

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

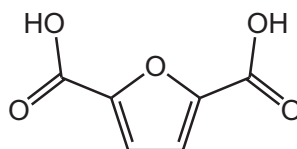


What could be the identity of Z?

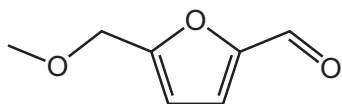
A



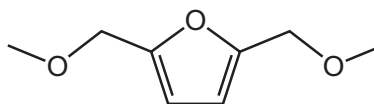
B



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.



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.

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.

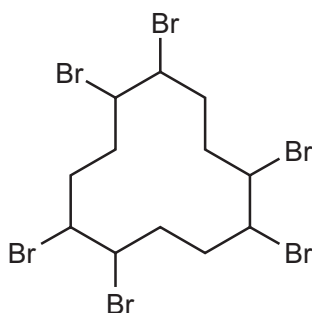
35 Which reagents produce a solution of sodium chlorate(V)?

- 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

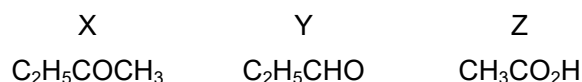
No other combination of statements is used as a correct response.

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

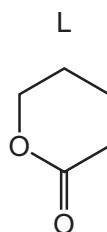
39 Three compounds, X, Y and Z, are shown.



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.



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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