



Cambridge International AS & A Level

CHEMISTRY**9701/13**

Paper 1 Multiple Choice

May/June 2025**1 hour 15 minutes**

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)

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.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **20** pages. Any blank pages are indicated.



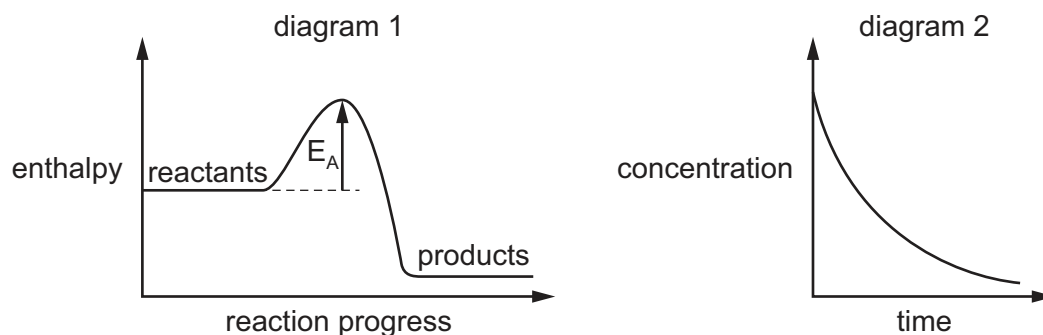
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- 1** Which isolated gaseous atom has a total of five electrons occupying spherically shaped orbitals?
- A** sodium
 - B** fluorine
 - C** boron
 - D** potassium

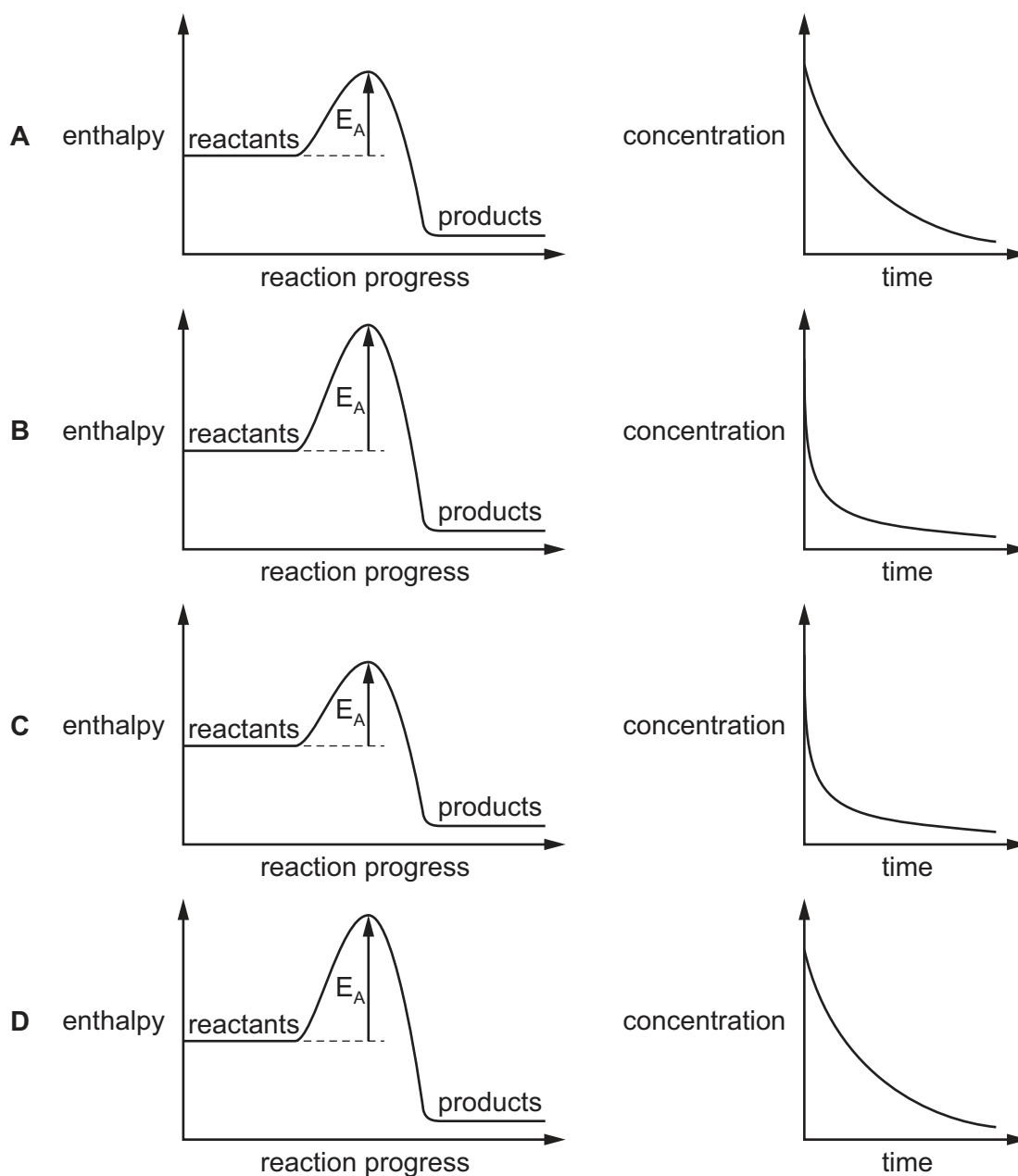
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2 Diagram 1 shows the reaction pathway for a reaction.

Diagram 2 shows a graph of concentration of reactant against time for the same reaction.

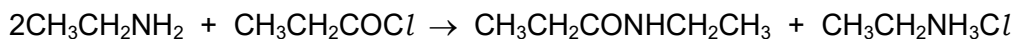


Which diagrams, drawn to the same scale, show the effect of increased temperature on this reaction?

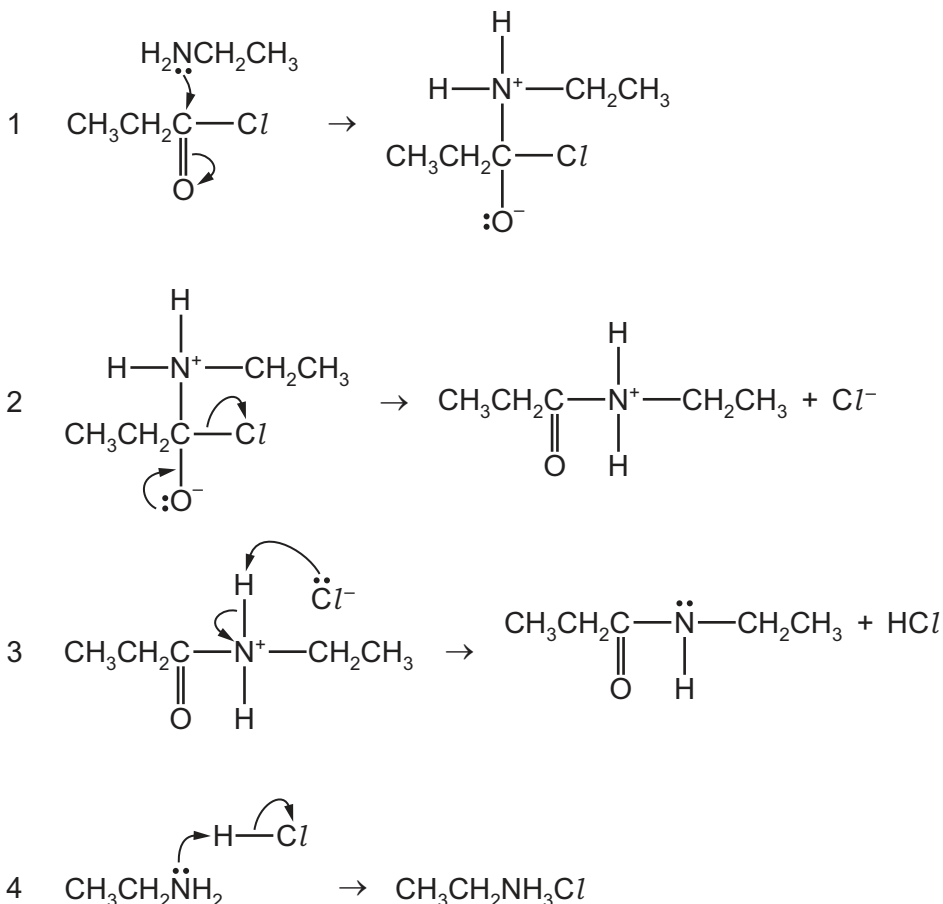


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3 The equation shows the overall reaction between an amine and an acid chloride.



The four steps in the mechanism are as follows.



Which steps are Brønsted–Lowry acid–base reactions?

- A** 1 and 2 **B** 3 and 4 **C** 3 only **D** 4 only

4 Chromium is present in compound X.

- Two moles of compound X react with exactly 3 moles of silicon.
- The only products of this reaction are 4 moles of chromium and 3 moles of a silicon compound in which the oxidation state of the silicon is +4.
- Chromium and silicon are the only elements that change their oxidation states in this reaction.

What could be the identity of compound X?

- A** Cr_2O_3 **B** Cr_2H_6 **C** Cr_2H_4 **D** Cr_2O_4

5

- 5 The reversible reaction shown is in equilibrium at a temperature of 450 °C.



The table shows the equilibrium concentrations in the reaction mixture.

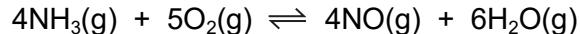
H_2	I_2	HI
1.02 mol dm^{-3}	0.02 mol dm^{-3}	0.98 mol dm^{-3}

The temperature of the reaction mixture is increased at constant volume.

The concentration of one of the components **falls** to 0.80 mol dm^{-3} at equilibrium under these conditions.

What is the concentration of H_2 in the new equilibrium mixture?

- A** 0.80 mol dm^{-3}
B 0.93 mol dm^{-3}
C 1.11 mol dm^{-3}
D 1.20 mol dm^{-3}
- 6 The first stage in the industrial production of nitric acid from ammonia can be represented by the following equation.



Using the following standard enthalpy change of formation data, what is the value of the standard enthalpy change, $\Delta H^\ominus$, for this reaction?

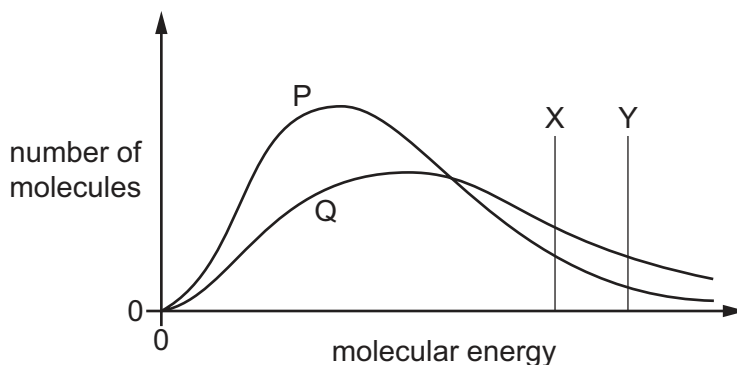
compound	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
$\text{NH}_3(\text{g})$	-46.1
$\text{NO}(\text{g})$	+90.3
$\text{H}_2\text{O}(\text{g})$	-241.8

- A** $+905.2 \text{ kJ mol}^{-1}$
B $-105.4 \text{ kJ mol}^{-1}$
C $-905.2 \text{ kJ mol}^{-1}$
D $-1274.0 \text{ kJ mol}^{-1}$

6

7 The gaseous compound Z decomposes on heating.

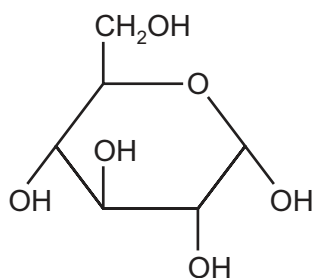
In the diagram, Boltzmann distributions for Z at two different temperatures, P and Q, are shown. The lines X and Y indicate activation energies for the decomposition of Z with and without a catalyst.



Which curve and which line describe the decomposition of Z at a higher temperature and with a catalyst present?

	higher temperature	catalyst present
A	P	X
B	P	Y
C	Q	X
D	Q	Y

8 The structure of a molecule found in food is shown.



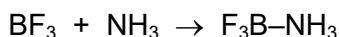
Four statements about the molecule are listed.

- 1 This molecule contains only σ bonds.
- 2 This molecule contains both σ and π bonds.
- 3 The six-membered ring is planar.
- 4 The six-membered ring is non-planar.

Which two statements are correct?

- A** 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

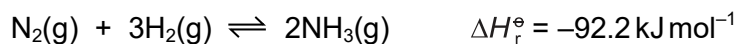
- 9 In which substance are covalent bonds broken as it melts?
- A silicon(IV) oxide
B ice
C iodine
D ethanol
- 10 Why is the second ionisation energy of sodium larger than the second ionisation energy of magnesium?
- A The attraction between the nucleus and the outer electron is greater in Na^+ than in Mg^+ .
B The nuclear charge of Na^+ is greater than that of Mg^+ .
C The outer electron of Na^+ is more shielded than the outer electron of Mg^+ .
D The outer electron of Na is in the same orbital as the outer electron of Mg.
- 11 BF_3 reacts with NH_3 to form a single compound with a simple molecular structure.



Which row describes how the bond angles change during the reaction?

	F–B–F bond angle	H–N–H bond angle
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

- 12 The equation for the reaction of nitrogen with hydrogen is shown.



Which statement is correct?

- A $\Delta H_r^\ominus$ is measured at 298 °C.
B $\Delta H_r^\ominus$ is measured at 101 kPa.
C $\Delta H_r^\ominus$ represents the standard enthalpy change for the formation of ammonia gas.
D $\Delta H_r^\ominus$ represents the enthalpy change when 1.0 mol of $\text{N}_2(\text{g})$ reacts with 1.0 mol of $\text{H}_2(\text{g})$.

- 13** Hydrogen peroxide, H_2O_2 , decomposes into water and oxygen when a suitable catalyst is added.

20.0 cm^3 of aqueous hydrogen peroxide decomposes to produce 600 cm^3 of oxygen at room conditions.

What is the concentration of the aqueous hydrogen peroxide?

- A** 5.00 mol dm^{-3}
B 2.50 mol dm^{-3}
C 1.25 mol dm^{-3}
D 0.625 mol dm^{-3}

- 14** When 0.15 g of an organic compound is vaporised, it occupies a volume of 65.0 cm^3 at 405 K and $1.00 \times 10^5\text{ Pa}$.

Using the expression $pV = nRT$, which expression should be used to calculate the relative molecular mass, M_r , of the compound?

- A** $\frac{0.15 \times 65 \times 10^{-6} \times 1 \times 10^5}{8.31 \times 405}$
B $\frac{0.15 \times 8.31 \times 405}{1 \times 10^5 \times 65 \times 10^{-3}}$
C $\frac{0.15 \times 65 \times 10^{-3} \times 1 \times 10^5}{8.31 \times 405}$
D $\frac{0.15 \times 8.31 \times 405}{1 \times 10^5 \times 65 \times 10^{-6}}$

- 15** A washing powder contains sodium hydrogencarbonate, NaHCO_3 , as one of the ingredients.

In a titration, a solution containing 1.00 g of this washing powder requires 7.15 cm^3 of 0.100 mol dm^{-3} sulfuric acid for complete reaction. The sodium hydrogencarbonate is the only ingredient that reacts with the acid.

What is the percentage by mass of sodium hydrogencarbonate in the washing powder?

- A** 3.0% **B** 6.0% **C** 12.0% **D** 24.0%

16 The flow chart shows some reactions of nitrogen compounds.



Which row identifies gas 1 and salt 2?

	gas 1	salt 2
A	ammonia	ammonium nitrate
B	ammonia	sodium nitrate
C	nitrogen dioxide	ammonium nitrate
D	nitrogen dioxide	sodium nitrate

17 Mixing aqueous silver nitrate and aqueous sodium chloride produces a precipitate.

Addition of which reagent to the mixture gives a colourless solution?

- A aqueous ammonia
- B aqueous potassium iodide
- C dilute hydrochloric acid
- D dilute nitric acid

18 Which statement is correct?

- A Barium oxide reacts with water at room temperature to form barium hydroxide and hydrogen.
- B Calcium oxide does **not** react with water at room temperature.
- C Magnesium hydroxide reacts with steam to form magnesium oxide and hydrogen.
- D Strontium oxide reacts with water at room temperature to form strontium hydroxide only.

19 Which statement about the properties of halogens and hydrogen halides is correct?

- A A chloride ion is a stronger reducing agent than an iodide ion.
- B Chlorine is more volatile than bromine because chlorine has stronger intermolecular forces.
- C Hydrogen bromide is more thermally stable than hydrogen iodide because it has a stronger covalent bond.
- D Iodine is less reactive than bromine because iodine has weaker covalent bonds.

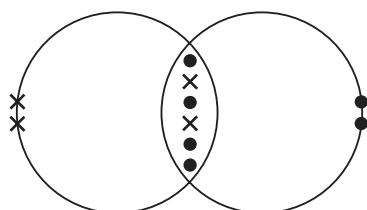
20 Three statements about the chemical periodicity of Period 3 oxides are listed.

- 1 The maximum oxidation state of the Period 3 elements in their oxides increases from sodium to phosphorus, then decreases from phosphorus to sulfur.
- 2 The oxides from sodium to aluminium dissolve in water without hydrolysis; from silicon to sulfur they are hydrolysed by water.
- 3 The structure and bonding changes from giant ionic to giant covalent to simple molecular.

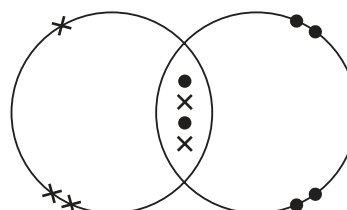
Which statements are correct?

- A** 1, 2 and 3 **B** 1 only **C** 2 and 3 only **D** 3 only

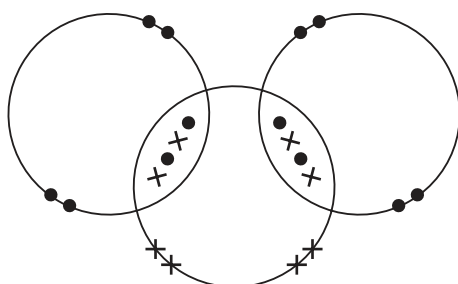
21 Which dot-and-cross diagrams represent molecules that can react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, a component of photochemical smog?



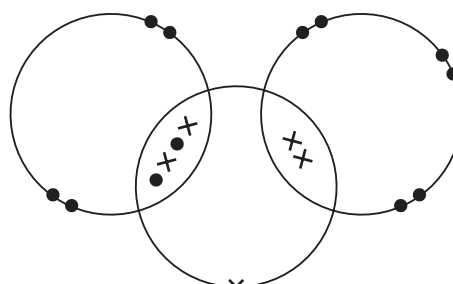
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3



4

- A** 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

22 Which set of three elements contains a single element that has **both** the highest melting point **and** the lowest electrical conductivity of the three elements in the set?

- A** magnesium, aluminium and silicon
B aluminium, silicon and phosphorus
C sodium, magnesium and aluminium
D silicon, phosphorus and chlorine

23 In which row do the particles increase in size?

	smallest	→	largest
A	N	O	F
B	N^{3-}	O^{2-}	F^-
C	Na^+	Mg^{2+}	Al^{3+}
D	Na^+	Ne	F^-

24 W, X, Y and Z are Group 2 elements barium, calcium, magnesium and strontium but not in that order.

W reacts faster with dilute hydrochloric acid than Y.

The hydroxide of X is less soluble in water than the hydroxide of W.

The sulfate of Y is the most soluble of the sulfates of W, X, Y and Z.

The carbonate of Z decomposes more slowly than the carbonate of W at the same temperature.

What is the M_r of the nitrate of W?

- A** 148.3 **B** 164.1 **C** 211.6 **D** 261.3

25 Polymer J has repeat unit $-\text{[CH(C}_2\text{H}_5\text{)CH(CH}_3\text{)]}-$.

Polymer K has repeat unit $-\text{[CH(CH}_3\text{)CH(CH}_3\text{)]}-$.

Which row is correct?

	monomer from which polymer J is produced	monomer from which polymer K is produced
A	pent-1-ene	but-1-ene
B	pent-1-ene	but-2-ene
C	pent-2-ene	but-1-ene
D	pent-2-ene	but-2-ene

26 0.200 mol ethanenitrile reacts with an excess of dilute sodium hydroxide. The reaction produces organic compound S and ammonia gas only.

The reaction has an 80.0% yield.

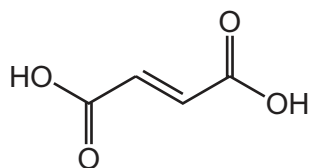
Which mass of S is produced?

- A** 9.60 g **B** 13.1 g **C** 15.4 g **D** 16.4 g

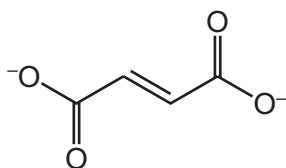
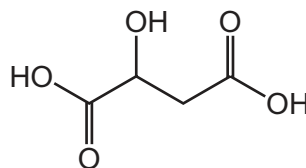
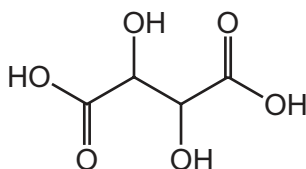
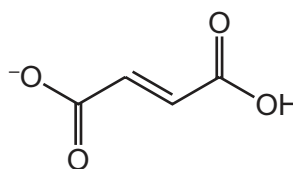
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27 The structure of butenedioic acid is shown.

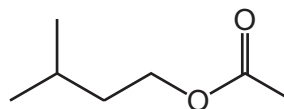
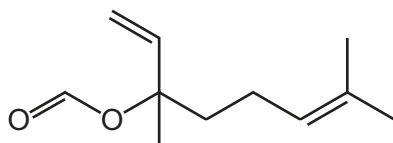
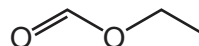
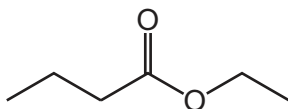
butenedioic acid



When an excess of NaOH(aq) is added to butenedioic acid, which organic product is formed?

A**B****C****D**

28 Four organic compounds are shown.



A mixture of these four compounds reacts with hot aqueous sodium hydroxide.

The products of this reaction are acidified.

Which organic acids are present in the products?

- A** butanoic, ethanoic and propanoic acids
- B** butanoic, ethanoic and methanoic acids
- C** ethanoic, 3-methylbutanoic and propanoic acids
- D** methanoic, 3-methylbutanoic and propanoic acids

- 29 Ethanal reacts with KCN dissolved in liquid HCN. This reaction involves the formation of an intermediate.

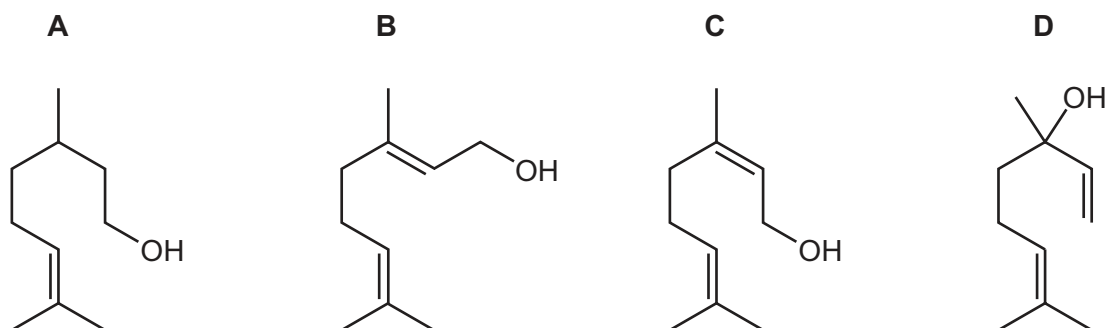
Which statement is correct?

- A** HCN does **not** have any lone pairs of electrons and so CN^- is the catalyst.
- B** The $\text{O}^{\delta-}$ of $\text{C}=\text{O}$ attacks K^+ in a nucleophilic attack.
- C** A proton from HCN is transferred to the intermediate.
- D** The reaction is a nucleophilic substitution.
- 30 What is formed when propanone is heated under reflux with a solution of NaBH_4 ?
- A** propan-2-ol
- B** propan-1-ol
- C** propanal
- D** propane

- 31 The compounds shown are all produced by plants.

Each compound is warmed with acidified $\text{K}_2\text{Cr}_2\text{O}_7$.

Which compound will give a different observation to the other three?

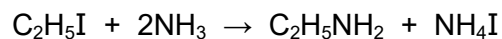


- 32 Structural and stereoisomerism should be considered when answering this question.

How many alcohols with the molecular formula $\text{C}_5\text{H}_{12}\text{O}$ give a yellow precipitate with alkaline $\text{I}_2(\text{aq})$?

- A** 2 **B** 3 **C** 4 **D** 5

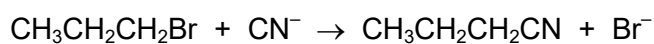
33 An amine is produced in the following reaction.



What is the mechanism?

- A electrophilic addition
- B free-radical substitution
- C nucleophilic addition
- D nucleophilic substitution

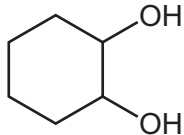
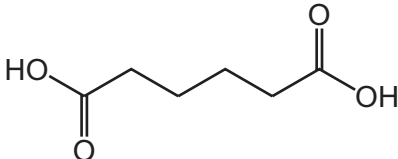
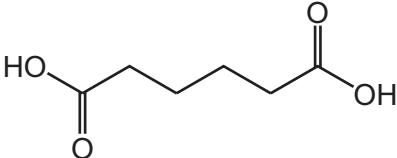
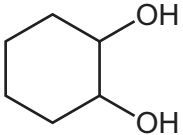
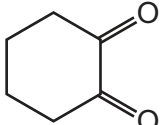
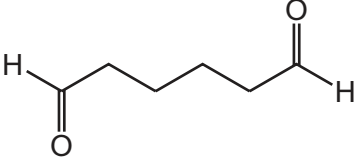
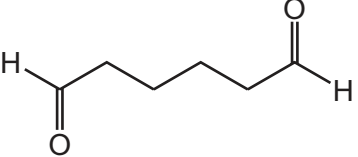
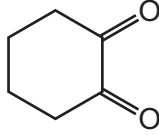
34 The reaction shown can be used to lengthen a carbon chain.



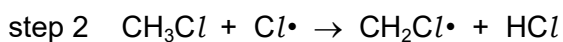
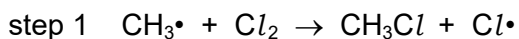
Which row shows the correct reagent and conditions for this reaction?

	reagent	conditions
A	KCN	heat under reflux in dilute sulfuric acid
B	KCN	heat under reflux in ethanol
C	HCN	heat under reflux in dilute sulfuric acid
D	HCN	heat under reflux in ethanol

- 35** Which row shows the products formed when cyclohexene reacts with acidified KMnO_4 under different conditions?

	product formed on reaction with cold, dilute acidified KMnO_4	product formed on reaction with hot, concentrated acidified KMnO_4
A		
B		
C		
D		

- 36** Two steps in the free-radical substitution reaction between methane and chlorine are shown.

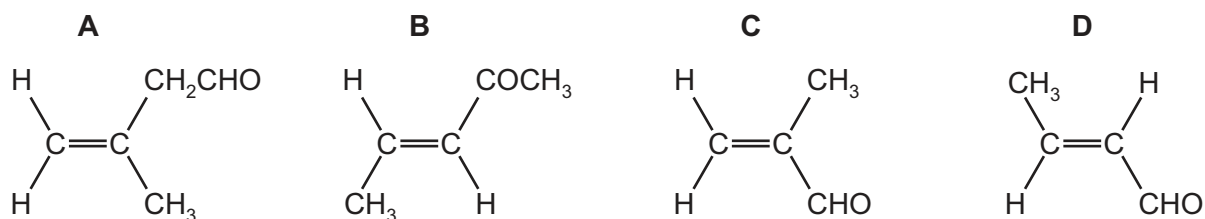


Which statement is correct?

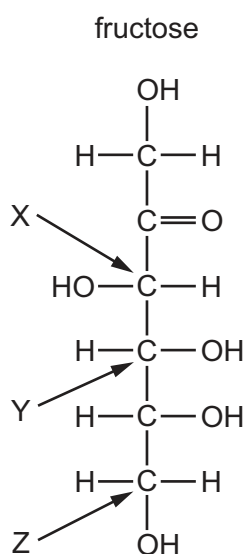
- A** Step 1 is initiation and step 2 is propagation.
- B** Step 1 is propagation and step 2 is termination.
- C** Step 1 is initiation and step 2 is termination.
- D** Both steps are propagation.

- 37** Compound P displays cis/trans isomerism and gives a red-brown precipitate with Fehling's solution.

What is P?



- 38** Fructose is a sugar with more than one chiral centre. The fructose molecule is shown with X, Y and Z indicating three carbon atoms.



Which carbon atoms are chiral centres?

- A** X, Y and Z **B** X and Y only **C** X only **D** Y only
- 39** An organic compound, T, contains only one functional group.

Compound T has the empirical formula C_2H_4O .

Some functional groups are listed.

- 1 alcohol
- 2 aldehyde
- 3 ester
- 4 ketone

Which functional groups are possible for compound T?

- A** 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

40 The mass spectrum of an organic compound has the following features.

- The molecular ion peak is at $m/e = 60$. This peak has a relative intensity = 100.
- There is a peak at $m/e = 61$, which has a relative intensity = 2.2.
- There is **no** fragment peak at $m/e = 17$.
- There is a fragment peak at $m/e = 31$.

What could be the identity of the organic compound?

- A** methyl methanoate, HCOOCH_3
- B** methoxyethane, $\text{CH}_3\text{OC}_2\text{H}_5$
- C** ethanoic acid, CH_3COOH
- D** propan-2-ol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

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Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

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The Periodic Table of Elements

Group																	
1	2		131415161718														
Key atomic number atomic symbol name relative atomic mass			1Hhydrogen1.0														
3Li lithium 6.9	4Be beryllium 9.0																
11Na sodium 23.0	12Mg magnesium 24.3																
19K potassium 39.1	20Ca calcium 40.1	21Sc scandium 45.0	22Ti titanium 47.9	23V vanadium 50.9	24Cr chromium 52.0	25Mn manganese 54.9	26Fe iron 55.8	27Co cobalt 58.9	28Ni nickel 58.7	29Cu copper 63.5	30Zn zinc 65.4	31Ga gallium 69.7	32Ge germanium 72.6	33As arsenic 74.9	34Se selenium 79.0	35Br bromine 79.9	36Kr krypton 83.8
37Rb rubidium 85.5	38Sr strontium 87.6	39Y yttrium 88.9	40Zr zirconium 91.2	41Nb niobium 92.9	42Mo molybdenum 95.9	43Tc technetium —	44Ru ruthenium 101.1	45Rh rhodium 102.9	46Pd palladium 106.4	47Ag silver 107.9	48Cd cadmium 112.4	49In indium 114.8	50Sn tin 118.7	51Sb antimony 121.8	52Te tellurium 127.6	53I iodine 126.9	54Xe xenon 131.3
55Cs caesium 132.9	56Ba barium 137.3	57–71 lanthanoids		72Ta tantalum 180.9	73W tungsten 183.8	74Re rhenium 186.2	75Os osmium 190.2	76Ir iridium 192.2	77Pt platinum 195.1	78Au gold 197.0	79Hg mercury 200.6	80Tl thallium 204.4	81Pb lead 207.2	82Bi bismuth 209.0	83Po polonium —	84At astatine —	86Rn radon —
87Fr francium —	88Ra radium —	89–103 actinoids		104Rf rutherfordium —	105Db dubnium —	106Sg seaborgium —	107Bh bohrium —	108Hs hassium —	109Mt meitnerium —	110Ds darmstadtium —	111Rg roentgenium —	112Cn copernicium —	113Fl flerovium —	114Mc moscovium —	115Lv livermorium —	117Ts tennessine —	118Og ognesson —
lanthanoids																	
57La lanthanum 138.9	58Ce cerium 140.1	59Pr praseodymium 140.9	60Nd neodymium 144.2	61Pm promethium —	62Sm samarium 150.4	63Eu europium 152.0	64Gd gadolinium 157.3	65Tb terbium 158.9	66Dy dysprosium 162.5	67Ho holmium 164.9	68Er erbium 167.3	69Tm thulium 168.9	70Yb ytterbium 173.1	71Lu lutetium 175.0			
89Ac actinium —	90Th thorium 232.0	91Pa protactinium 231.0	92U uranium 238.0	93Np neptunium —	94Pu plutonium —	95Am americium —	96Cm curium —	97Bk berkelium —	98Cf californium —	99Es einsteinium —	100Fm fermium —	101Md mendelevium —	102No nobelium —	103Lr lawrencium —			
actinoids																	