



Cambridge International AS & A Level

CHEMISTRY

9701/11

Paper 1 Multiple Choice

May/June 2024

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.



- 1 Sample X is added to water and made up to a total volume of 200 cm^3 . This gives a solution of $0.100\text{ mol dm}^{-3}\text{ HCl}$.

What is X?

- A 10 cm^3 of $1.00\text{ mol dm}^{-3}\text{ HCl}$
B 30 cm^3 of $0.90\text{ mol dm}^{-3}\text{ HCl}$
C 50 cm^3 of $0.40\text{ mol dm}^{-3}\text{ HCl}$
D 100 cm^3 of $0.30\text{ mol dm}^{-3}\text{ HCl}$
- 2 A mixture of 10 cm^3 of methane and 10 cm^3 of ethane was sparked with an excess of oxygen. After cooling, the residual gas was passed through aqueous potassium hydroxide.

All gas volumes were measured at the same temperature and pressure.

Which volume of gas was absorbed by the alkali?

- A 15 cm^3 B 20 cm^3 C 30 cm^3 D 40 cm^3
- 3 Z is a compound of two elements, X and Y.
- Element X shows a very large increase between its 5th and 6th ionisation energies. It has the second largest 1st ionisation energy in its group.
- Element Y shows a very large increase between its 6th and 7th ionisation energies. It has the largest 1st ionisation energy in its group.

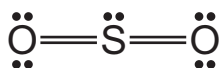
What is compound Z?

- A NO_2 B PCl_5 C P_4O_{10} D SF_6
- 4 Which statement about $^{131}_{53}\text{I}$ is correct?
- A A negative ion of $^{131}_{53}\text{I}$ contains 53 neutrons and 52 electrons.
B A negative ion of $^{131}_{53}\text{I}$ contains 53 neutrons and 54 electrons.
C A negative ion of $^{131}_{53}\text{I}$ contains 78 neutrons and 52 electrons.
D A negative ion of $^{131}_{53}\text{I}$ contains 78 neutrons and 54 electrons.

- 5 When solid aluminium chloride is heated, Al_2Cl_6 is formed.

Which bonding is present in Al_2Cl_6 ?

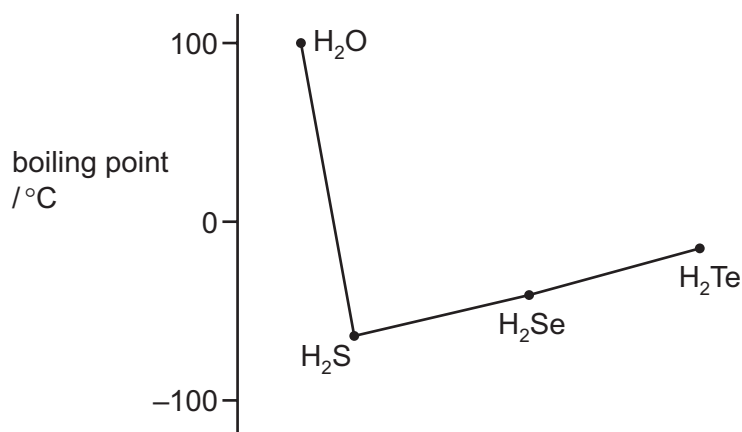
- A covalent and coordinate (dative covalent)
 - B covalent only
 - C ionic and coordinate (dative covalent)
 - D ionic only
- 6 The structure of the sulfur dioxide molecule is shown.



What is the shape of the sulfur dioxide molecule?

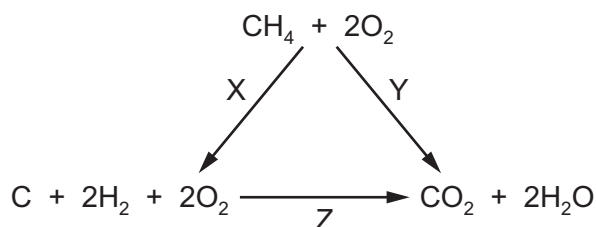
- A linear
 - B non-linear
 - C pyramidal
 - D tetrahedral
- 7 What is the density of a sample of fluorine gas at 32°C and $100\,000\text{Pa}$? Assume fluorine behaves as an ideal gas under these conditions.
- A 1.4 g dm^{-3} B 1.5 g dm^{-3} C 1.6 g dm^{-3} D 1.7 g dm^{-3}

- 8 The graph shows the boiling points of the hydrogen compounds of Group 16 elements.



Which statement correctly explains why water does **not** fit the trend of the other compounds?

- A There are fewer electrons in the oxygen atoms so there is less shielding of the nuclear charge.
 - B There are strong hydrogen bonds in water but **not** in the other compounds.
 - C The covalent bonds in water are much stronger than in the other compounds.
 - D The water molecules are smaller and so have stronger van der Waals' forces.
- 9 An energy cycle is shown.



The energy changes involved are X, Y and Z.

The numerical value of energy change Y is either -890 or +890.

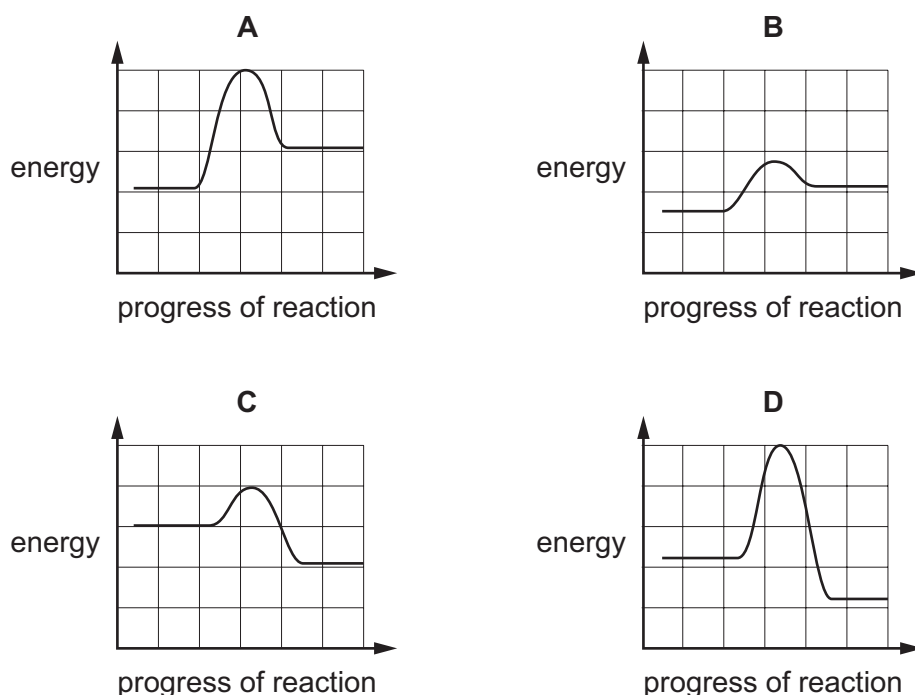
The numerical value of energy change Z is either -964 or +964.

Which of the three values are negative?

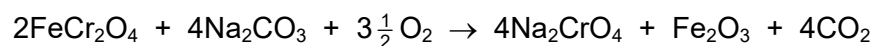
- A X and Z
- B X only
- C Y and Z
- D Y only

- 10 For a certain endothermic reaction, the activation energy is numerically equal to twice the enthalpy change of reaction.

Which reaction pathway diagram is correct for this reaction?



- 11 Sodium chromate(VI), Na_2CrO_4 , is manufactured by heating chromite, FeCr_2O_4 , with sodium carbonate in an oxidising atmosphere. Chromite contains $\text{Cr}_2\text{O}_4^{2-}$ ions.



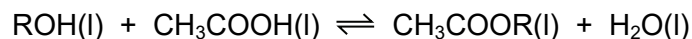
What happens in this reaction?

- A** Chromium and iron are the only elements oxidised.
- B** Chromium, iron and carbon are oxidised.
- C** Only chromium is oxidised.
- D** Only iron is oxidised.
- 12 Oxygen can be prepared by the reaction of potassium manganate(VII), KMnO_4 , hydrogen peroxide, H_2O_2 , and sulfuric acid, H_2SO_4 . Each H_2O_2 molecule loses two electrons in this reaction. The other products of the reaction are potassium sulfate, manganese(II) sulfate and water.

How many moles of oxygen gas are produced when 1.0 mol of KMnO_4 reacts with an excess of H_2O_2 in acidic conditions?

- A** 2.0 mol **B** 2.5 mol **C** 4.5 mol **D** 5.0 mol

- 13 An alcohol, ROH, reacts reversibly with ethanoic acid to produce an ester.

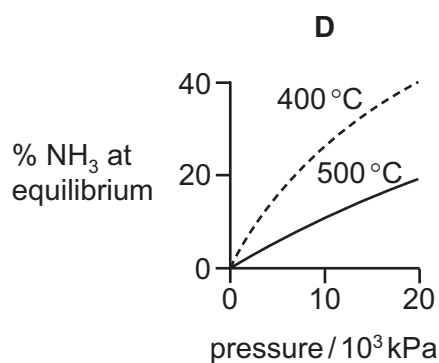
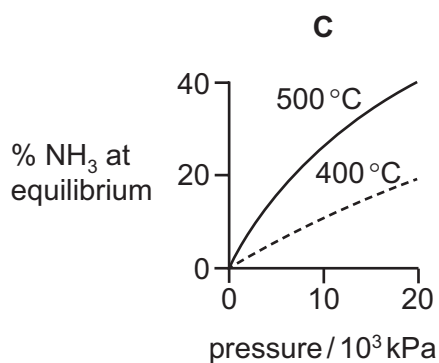
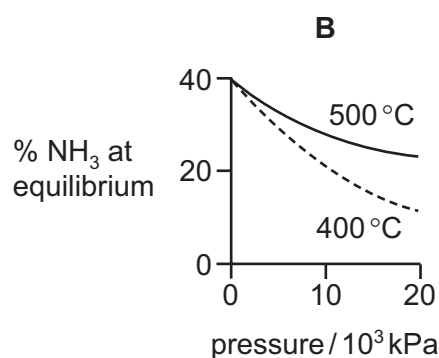
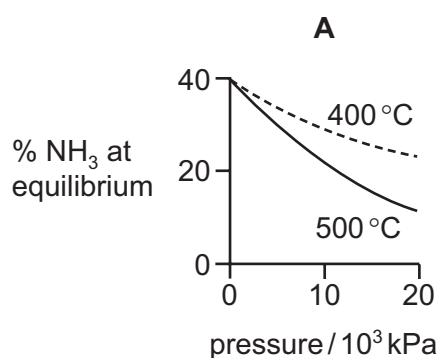


3.0 mol of ROH, 2.0 mol of ethanoic acid and 1.0 mol of water are mixed together. At equilibrium, 1.5 mol of CH₃COOR is present.

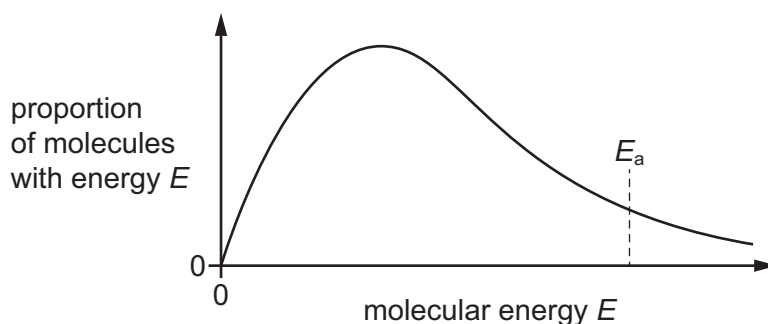
What is the value of the equilibrium constant, K_c , for this reaction?

- A 0.20 B 0.25 C 2.00 D 5.00
- 14 Graphs can be drawn to show the percentage of ammonia at equilibrium when nitrogen and hydrogen are mixed at different temperatures and pressures.

Which diagram correctly represents these two graphs?



- 15 The Boltzmann distribution for the hydrogenation of an alkene at a particular temperature in the absence of a catalyst is shown.



Which row correctly describes the effects of adding a nickel catalyst to the reaction vessel?

	the shape of the Boltzmann distribution	activation energy, E_a
A	changes	decreases
B	changes	increases
C	does not change	decreases
D	does not change	increases

- 16 Elements Y and Z are both in Period 3 of the Periodic Table.

When the chloride of element Y is added to water, it reacts and a solution of pH 2 is produced.

When the chloride of element Z is added to water, it dissolves and a solution of pH 7 is produced.

Which statement explains these observations?

- A** Both chlorides hydrolyse in water.
- B** Element Y is magnesium and element Z is sodium.
- C** Element Y is phosphorus and element Z is aluminium.
- D** Element Y is silicon and element Z is sodium.
- 17 Aluminium, silicon and phosphorus are elements in Period 3 of the Periodic Table. Each element forms an oxide.

Which row is correct?

	Al_2O_3	SiO_2	P_4O_{10}
A	basic	amphoteric	acidic
B	giant ionic	giant ionic	simple molecular
C	high melting point	high melting point	low melting point
D	vigorous reaction with water	slight reaction with water	vigorous reaction with water

18 Which statement is correct?

- A The atomic radius of silicon is larger than that of aluminium.
- B The boiling point of chlorine is higher than that of silicon.
- C The first ionisation energy of sulfur is greater than that of phosphorus.
- D The electrical conductivity of magnesium is greater than that of sodium.

19 All solubility data in this question is given at the same temperature.

The table gives some data for compounds of calcium and for compounds of X, an unidentified element in Group 2.

element	decomposition temperature of carbonate / °C	solubility of sulfate / mol per 100 g of water	solubility of hydroxide / mol per 100 g of water
Ca	840	4.66×10^{-3}	1.53×10^{-3}
X	1150		

What is the missing data for element X?

	solubility of sulfate / mol per 100 g of water	solubility of hydroxide / mol per 100 g of water
A	7.11×10^{-5}	2.00×10^{-5}
B	7.11×10^{-5}	3.37×10^{-3}
C	1.83×10^{-1}	2.00×10^{-5}
D	1.83×10^{-1}	3.37×10^{-3}

20 What is the total volume of gas produced, measured at room conditions, when 0.010 mol of anhydrous magnesium nitrate is completely decomposed by heating?

- A 240 cm³ B 480 cm³ C 600 cm³ D 720 cm³

- 21** A solid sodium halide, NaX, is reacted with concentrated sulfuric acid. The **lowest** oxidation state of sulfur in the products is +4.

Halogen Y₂ is less volatile than halogen X₂.

What are the identities of sodium halide NaX and halogen Y₂?

	sodium halide NaX	halogen Y ₂
A	sodium bromide	chlorine
B	sodium bromide	iodine
C	sodium iodide	bromine
D	sodium iodide	astatine

- 22** Compound Q dissolves in water. Q(aq) does **not** react with dilute sulfuric acid.

Q(aq) forms a precipitate when aqueous silver nitrate is added. This precipitate is partially soluble in aqueous ammonia.

What could be compound Q?

- A** barium bromide
- B** barium iodide
- C** magnesium bromide
- D** magnesium iodide
- 23** Nitrogen dioxide is a gas that contributes to air pollution. It is produced in internal combustion engines.

Which statement is correct?

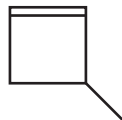
- A** Nitrogen dioxide acts as a catalyst in the atmospheric oxidation of sulfur dioxide to sulfur trioxide.
- B** Nitrogen dioxide reacts to form nitrogen monoxide in the catalytic converter of a car exhaust system.
- C** PAN forms when nitrogen dioxide reacts with the gases formed by complete combustion of the fuel.
- D** Under high pressure in an internal combustion engine, nitrogen dioxide forms from impurities in the fuel.
- 24** What is the bond angle in the ammonium ion?

- A** 90° **B** 107° **C** 109.5° **D** 120°

- 25** Structural isomerism and stereoisomerism should be taken into account when answering this question.

The structure of 3-methylcyclobutene is shown.

3-methylcyclobutene

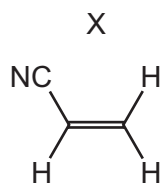


A mixture containing all stereoisomers of 3-methylcyclobutene is treated with HBr. This produces a mixture of isomeric bromomethylcyclobutanes.

How many stereoisomers does 3-methylcyclobutene have, and how many isomeric bromomethylcyclobutanes are present in the product mixture?

	3-methylcyclobutene	bromomethylcyclobutanes
A	2	4
B	2	6
C	4	4
D	4	8

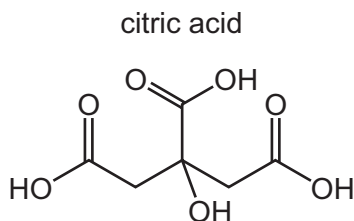
- 26** The diagram shows the structure of X.



Which row is correct?

	number of σ bonds in X	type of hybridisation of the carbon atoms in X
A	4	sp and sp ²
B	4	sp ² and sp ³
C	6	sp and sp ²
D	6	sp ² and sp ³

27 The diagram shows the skeletal formula of citric acid.



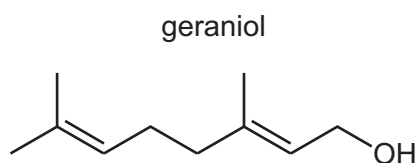
What is the molecular formula of citric acid?

- A** $C_6H_8O_7$ **B** $C_6H_4O_7$ **C** $C_8H_8O_7$ **D** $C_{10}H_8O_7$

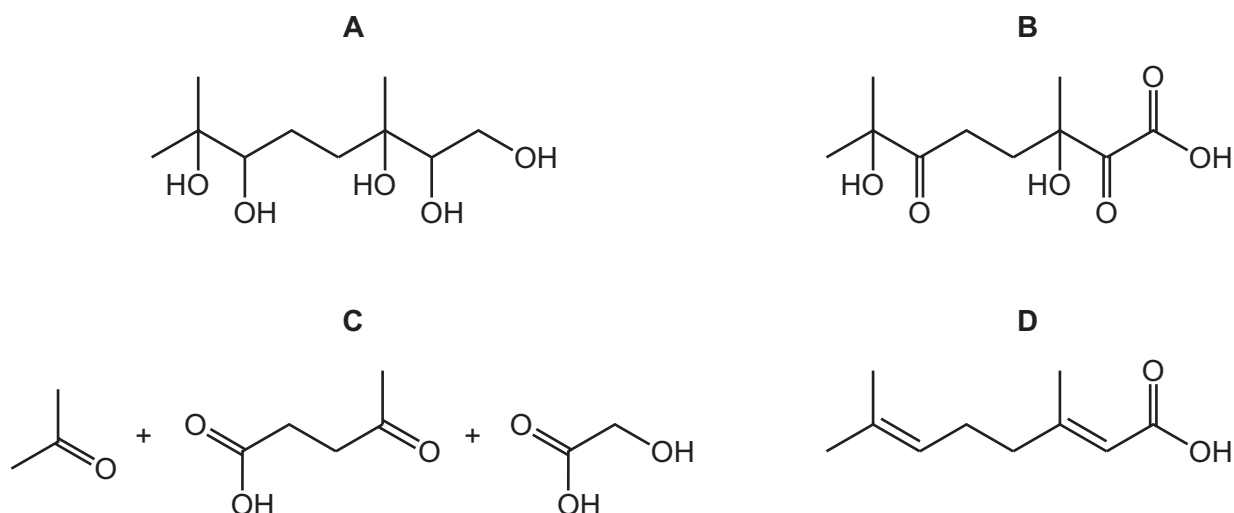
28 Which reaction occurs when ethane and chlorine are mixed in diffused sunlight?

- A** a free-radical substitution with hydrogen given off
B a free-radical substitution with hydrogen chloride given off
C a free-radical substitution with no gas given off
D a nucleophilic substitution with hydrogen chloride given off

29 A molecule of geraniol is shown.



What is formed when geraniol is reacted with an excess of cold dilute acidified MnO_4^- ?



- 30 Q is either a primary or a tertiary halogenoalkane. Q undergoes hydrolysis with aqueous sodium hydroxide.

The first step in the mechanism of this reaction involves two species reacting together.

Which row is correct?

	Q	behaviour of hydroxide ion
A	primary halogenoalkane	electrophile
B	primary halogenoalkane	nucleophile
C	tertiary halogenoalkane	electrophile
D	tertiary halogenoalkane	nucleophile

- 31 2-bromopropane is converted to 1,2-dibromopropane in a pathway involving two reactions.

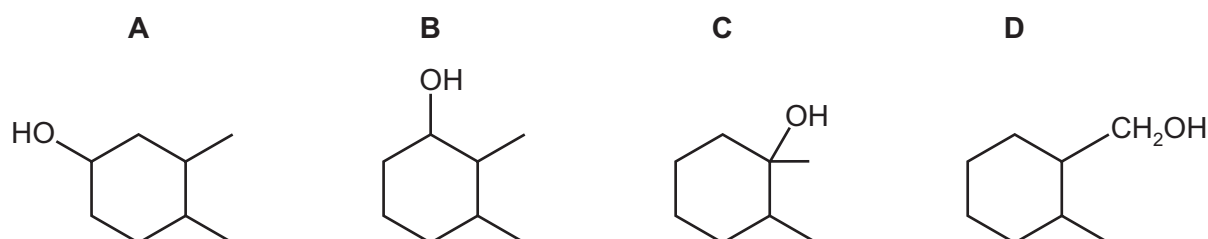


What are the reagents and conditions for the two reactions?

	reaction 1	reaction 2
A	heat under reflux with aqueous NaOH	HBr(g) at room temperature
B	heat under reflux with aqueous NaOH	Br ₂ (l) at room temperature
C	heat under reflux with ethanolic NaOH	HBr(g) at room temperature
D	heat under reflux with ethanolic NaOH	Br ₂ (l) at room temperature

- 32 Compound X is a single, pure, optical isomer. Compound X is heated with an excess of concentrated H₂SO₄. Only **one** organic product is formed.

What is compound X?



- 33 Which reagents could be used to form 2-bromobutane from butan-1-ol?

- A bromine and ultraviolet light
- B concentrated sulfuric acid with potassium bromide, under reflux
- C concentrated sulfuric acid followed by bromine
- D concentrated sulfuric acid followed by hydrogen bromide

34 X is a non-cyclic ketone with a single carbonyl group and no other functional groups. Ketone X has the following properties.

- When ketone X is treated with NaBH_4 , the organic product has a M_r 2.3256% greater than the M_r of ketone X.
- Ketone X gives a yellow precipitate with alkaline $\text{I}_2(\text{aq})$.

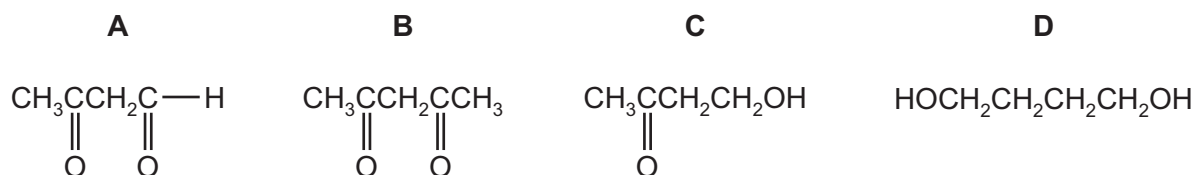
How many isomeric ketones could be ketone X?

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

35 Compound Y:

- changes the colour of acidified $\text{K}_2\text{Cr}_2\text{O}_7$ from orange to green
- has no effect on Fehling's reagent
- produces an orange precipitate with 2,4-dinitrophenylhydrazine reagent.

What is compound Y?



36 The product of the reaction between propanone and hydrogen cyanide is hydrolysed under acidic conditions.

What is the formula of the final product?

- A** $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$
B $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$
C $(\text{CH}_3)_2\text{CHCONH}_2$
D $(\text{CH}_3)_2\text{C}(\text{OH})\text{COOH}$

37 P is a carboxylic acid with molecular formula $C_5H_{10}O_2$.

Carboxylic acid P reacts with an excess of $LiAlH_4$ to form compound Q.

Which pairs of molecules could be carboxylic acid P and compound Q?

	carboxylic acid P	compound Q
1	$CH_3(CH_2)_3COOH$	$CH_3(CH_2)_3OH$
2	$CH_3(CH_2)_3COOH$	$CH_3(CH_2)_3CHO$
3	$(CH_3)_3CCOOH$	$(CH_3)_3CCH_2OH$

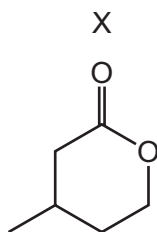
A 1 and 2

B 1 and 3

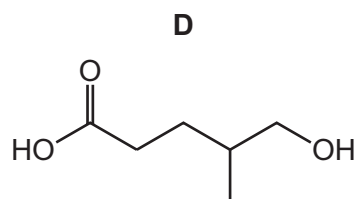
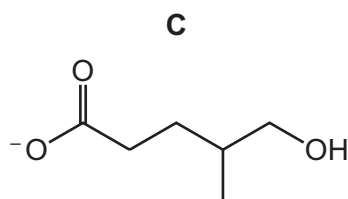
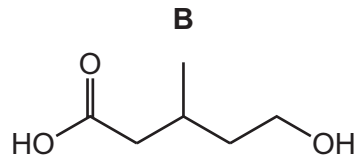
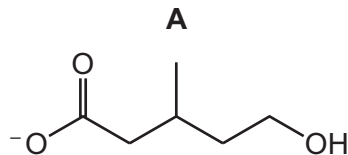
C 2 and 3

D 3 only

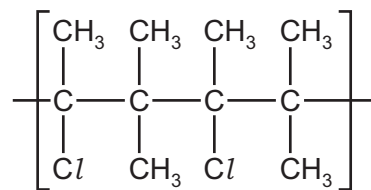
38 Compound X is treated with an excess of dilute aqueous potassium hydroxide.



What is the structure of the organic product?



- 39 A section showing two repeat units of an addition polymer is shown.



What is the identity of the monomer that produced this polymer?

- A 2-chloro-3-methylbutane
- B 2-chloro-3-methylbut-2-ene
- C 2-chloropent-2-ene
- D 2,4-dichloro-3,3,4,5-tetramethylhexane

- 40 The relative atomic mass of antimony is 121.76.

Antimony has **two** isotopes. The mass numbers of the two isotopes differ by two. The isotope with the lower mass number is the more abundant.

What is the percentage abundance of the isotope with the **higher** mass number?

- A 12%
- B 38%
- C 62%
- D 88%

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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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Group																		
1	2	Key														17	18	
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0				
3 Li lithium 6.9	4 Be beryllium 9.0																	
11 Na sodium 23.0	12 Mg magnesium 24.3																	
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8	
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3	
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —

lanthanoids

actinoids

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.4	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	europlum	152.0	64	Gd	gadolinium	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	yterbium	173.1	71	Lu	lutetium	175.0
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	mendelevium	—	102	No	nobelium	—	103	Lr	lawrencium	—



Cambridge International AS & A Level

CHEMISTRY

9701/12

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May/June 2024

1 hour 15 minutes

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- Important values, constants and standards are printed in the question paper.

This document has **16** pages.



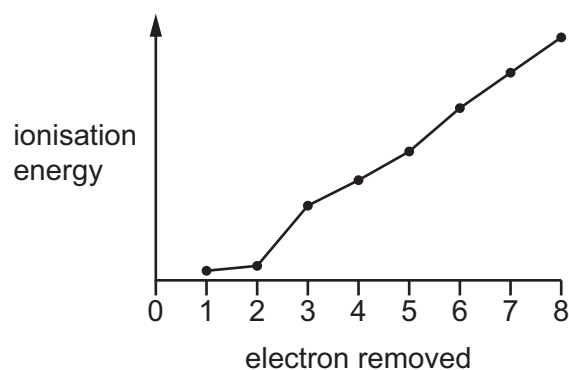
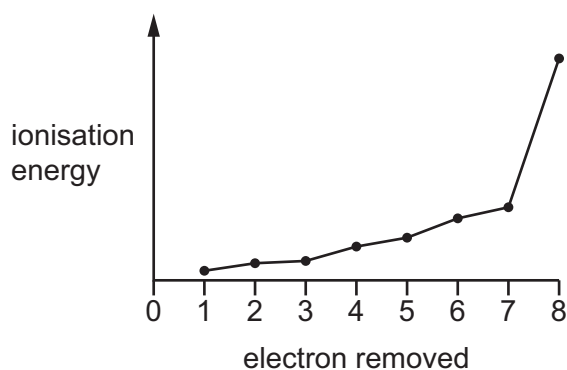
1 Which pair of formulae is correct?

- A Ag_2CO_3 and $(\text{NH}_4)_3\text{NO}_3$
 B K_2HCO_3 and $\text{Zn}_3(\text{PO}_4)_2$
 C AgHCO_3 and K_3PO_4
 D ZnCO_3 and $(\text{NH}_4)_2\text{PO}_4$

2 How many molecules are present in 62 g of solid white phosphorus, P_4 ?

- A L B $2L$ C $\frac{L}{2}$ D $\frac{L}{4}$

3 The first eight successive ionisation energies for two elements of Period 3 of the Periodic Table are shown in the graphs.



What is the formula of the ionic compound formed from these elements?

- A MgCl_2 B CaBr_2 C Na_2S D K_2Se

4 In which pairs are **both** species free radicals?

- 1 Cl and O
 2 Cl^- and O^{2-}
 3 Cl and O^-
 4 Cl^+ and O^{2+}

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

5 Which shape is correctly predicted by VSEPR theory?

	number of bonded electron pairs	number of lone pairs	shape
A	2	2	linear
B	2	2	tetrahedral
C	3	1	pyramidal
D	3	1	trigonal planar

6 In which species does the underlined atom have an incomplete outer shell?

- A** $\underline{\text{B}}\text{F}_3$ **B** $\underline{\text{C}}\text{H}_3^-$ **C** $\text{F}_2\underline{\text{O}}$ **D** $\text{H}_3\underline{\text{O}}^+$

7 In this question it should be assumed that nitrogen behaves as an ideal gas under the conditions stated.

Which volume is occupied by 1.00 g of nitrogen at 50.0 °C and at a pressure of 120 kPa?

- A** 0.124 dm³ **B** 0.799 dm³ **C** 1.60 dm³ **D** 22.4 dm³

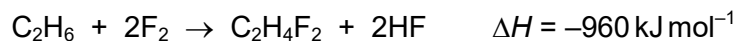
8 Consider the following four compounds.

- 1 $(\text{CH}_3)_3\text{CH}$
- 2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- 3 $\text{CH}_3\text{CH}_2\text{CH}_2\text{SH}$
- 4 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

What is the order of increasing boiling point of the compounds (lowest first)?

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

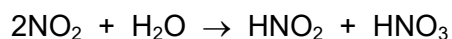
- 9 Ethane can react with fluorine to produce 1,2-difluoroethane, $\text{C}_2\text{H}_4\text{F}_2$.



bond	energy / kJ mol^{-1}
C–H	410
C–C	350
F–F	158
H–F	562

What is the bond energy of the C–F bond in 1,2-difluoroethane?

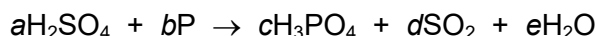
- A** 407 kJ mol^{-1} **B** 474 kJ mol^{-1} **C** 486 kJ mol^{-1} **D** 972 kJ mol^{-1}
- 10 Which equation has an enthalpy change equal to the standard enthalpy of formation of sodium oxide?
- A** $\text{Na(s)} + \frac{1}{4} \text{O}_2(\text{g}) \rightarrow \frac{1}{2} \text{Na}_2\text{O(s)}$
- B** $\text{Na(s)} + \text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{O(s)}$
- C** $2\text{Na(s)} + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{O(s)}$
- D** $4\text{Na(s)} + \text{O}_2(\text{g}) \rightarrow 2\text{Na}_2\text{O(s)}$
- 11 Nitrogen dioxide reacts with water.



Which statement about this reaction is correct?

- A** Both products are formed because oxygen atoms gain electrons.
- B** Nitrogen atoms undergo disproportionation.
- C** The oxidation number of hydrogen is increased.
- D** Water acts as an oxidising agent.

- 12 Phosphorus reacts with concentrated sulfuric acid to produce phosphoric acid, sulfur dioxide and water.



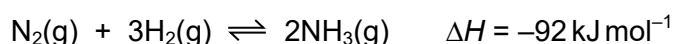
a , b , c , d and e are all whole numbers.

The equation can be balanced by using oxidation numbers.

What is the value of the sum $a + b + c + d + e$?

- A 10 B 14 C 15 D 16

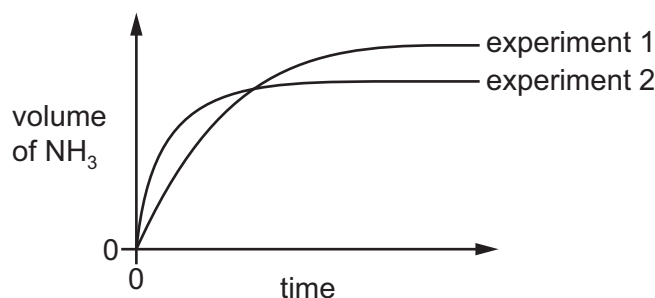
- 13 The volume of ammonia produced against time is measured in two experiments.



In experiment 1, 3 mol of $\text{H}_2(\text{g})$ and 1 mol of $\text{N}_2(\text{g})$ react together at 45°C and a pressure of 200 atm.

A graph showing the volume of ammonia produced against time is plotted.

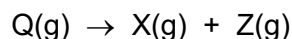
Experiment 2 is then performed. Experiment 2 differs from experiment 1 in **one** condition only.



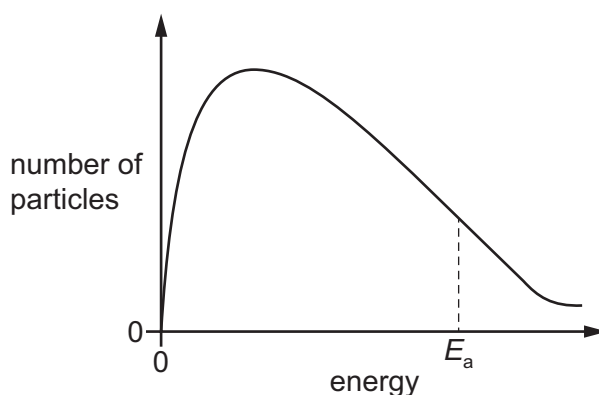
How does experiment 2 differ from experiment 1?

- A An iron catalyst is present in experiment 2.
 B 2 mol of helium gas is present in the reaction mixture in experiment 2.
 C A pressure of 250 atm is used in experiment 2.
 D A temperature of 600°C is used in experiment 2.
- 14 Which reaction has an equilibrium constant, K_p , that has no units?
- A $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$
 B $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
 C $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$
 D $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

- 15 Gas Q decomposes slowly at room temperature.



The Boltzmann distribution curve for gas Q at room temperature is shown.



Which change occurs when a catalyst is added to gas Q?

- A The peak of the curve moves to the right on the diagram.
 - B The number of particles with enough energy to decompose increases.
 - C The kinetic energy of the unreacted particles increases.
 - D The value of E_a decreases, moving the vertical dotted line to the right on the diagram.
- 16 Which statement is correct?
- A Aluminium chloride has a giant ionic lattice of Al^{3+} and Cl^- ions.
 - B Sodium chloride dissolves in water, forming hydrogen chloride and sodium hydroxide.
 - C The strong covalent bonds in silicon chloride prevent it from reacting with water.
 - D When phosphorus(V) chloride is added to water, the resulting solution conducts electricity.
- 17 A mixture of calcium carbonate, calcium nitrate, strontium carbonate and strontium nitrate is thermally decomposed. The decomposition reaction of each substance goes to completion. Each substance is anhydrous.
- How many different products are formed?
- A 4
 - B 5
 - C 7
 - D 8

- 18 W is a solid that reacts with water to produce an alkaline solution.

The addition of two drops of dilute H_2SO_4 to this alkaline solution produces a white precipitate.

What could be the identity of solid W?

- A magnesium hydroxide
 - B magnesium oxide
 - C barium oxide
 - D phosphorus oxide
- 19 Chlorine gas is reacted with cold aqueous sodium hydroxide.

Which statement is correct for this reaction?

- A Chlorine is both oxidised and reduced.
 - B Chlorine is neither oxidised nor reduced.
 - C Chlorine is oxidised but not reduced.
 - D Chlorine is reduced but not oxidised.
- 20 Sodium is added to water to form solution Y. The pH of solution Y is measured.

When powdered substance X is added to solution Y, the pH falls.

Which **two** compounds could each be substance X?

- A MgCl_2 and $\text{Al}(\text{OH})_3$
- B MgCl_2 and K_2O
- C NaCl and $\text{Al}(\text{OH})_3$
- D NaCl and K_2O

- 21** The table shows statements about some of the properties of halogens and their compounds and explanations for these properties.

Which row shows a correct statement about the property and a correct explanation for the statement?

	statement	explanation
A	iodine is a solid at room temperature	the I–I bond strength is high
B	the decomposition of hydrogen iodide is more endothermic than the decomposition of hydrogen chloride	chlorine is more reactive than iodine
C	when chlorine is bubbled into aqueous potassium iodide, a purple solution is seen	chlorine is a stronger oxidising agent than iodine
D	when concentrated sulfuric acid is added to solid potassium iodide, a purple vapour is seen	iodide ions are being oxidised to iodine by the sulfuric acid

- 22** Which statement describes a property of an ammonium ion?

- A** An aqueous ammonium ion is a weak Brønsted–Lowry base.
- B** Aqueous ammonium sulfate reacts with dilute hydrochloric acid to make ammonia gas.
- C** An ammonium ion has a pyramidal shape with an H–N–H bond angle of 107° .
- D** The four N–H covalent bonds in an ammonium ion are identical to each other.

- 23** Catalytic converters are fitted in the exhaust systems of many cars.

Gas X:

- causes acid rain if it is released into the air
- is removed from car exhaust fumes by a catalytic converter.

What is gas X?

- A** carbon dioxide
- B** carbon monoxide
- C** hydrocarbon vapour
- D** nitrogen dioxide

24 In the general formula of which class of compound is the ratio of hydrogen atoms to carbon atoms the highest?

- A alcohols
- B aldehydes
- C carboxylic acids
- D halogenoalkanes

25 Which statement is correct?

- A Adding sodium oxide to water gives a lower pH solution than adding silicon oxide to water.
- B The oxidation state of sodium in its chloride is higher than the oxidation state of silicon in its chloride.
- C The atomic radius of sodium is larger than that of silicon.
- D The melting point of the chloride of sodium is lower than the melting point of the chloride of silicon.

26 Z is a gaseous hydrocarbon which has a density of $3.50 \times 10^{-3} \text{ g cm}^{-3}$ under room conditions.

Z reacts with an excess of hot concentrated acidified KMnO_4 . Only **one** type of carboxylic acid is formed in this reaction.

What is Z?

- A but-2-ene
- B 2,3-dimethylbut-2-ene
- C hex-2-ene
- D hex-3-ene

27 Compound X can be oxidised to compound Y.

Compound Y gives a yellow precipitate with alkaline $\text{I}_2(\text{aq})$.

What is compound X?

- A butan-1-ol
- B butan-2-ol
- C methylpropan-1-ol
- D methylpropan-2-ol

28 Aqueous NaOH reacts with 1-bromopropane to give propan-1-ol.

What should be included in a diagram of the first step in the mechanism?

- A a curly arrow from a lone pair on the OH^- ion to the $\text{C}^{\delta+}$ atom of 1-bromopropane
- B a curly arrow from the $\text{C}^{\delta+}$ atom of 1-bromopropane to the OH^- ion
- C a curly arrow from the $\text{C}-\text{Br}$ bond to the C atom
- D the homolytic fission of the $\text{C}-\text{Br}$ bond

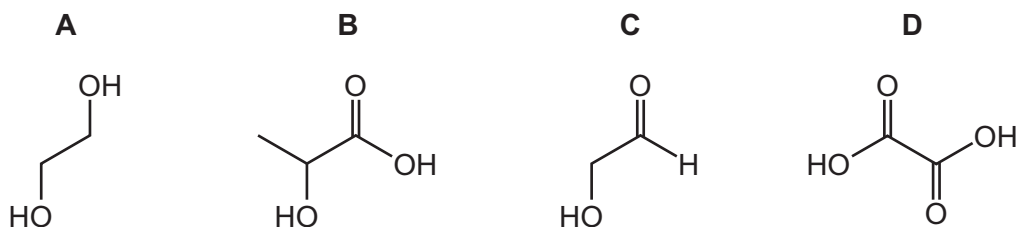
29 In which reaction is the organic compound oxidised?

- A $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{Tollens' reagent}$
- B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{LiAlH}_4$
- C $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{concentrated H}_3\text{PO}_4$
- D $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5 + \text{dilute H}_2\text{SO}_4$

30 1 mole of each of the following four compounds is reacted separately with:

- an excess of sodium
- an excess of sodium carbonate.

Which compound produces the same volume of gas with each of the **two** reagents?

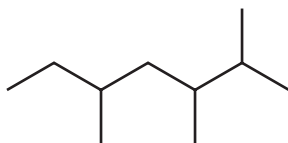


31 Which reaction will distinguish between propan-1-ol and propan-2-ol?

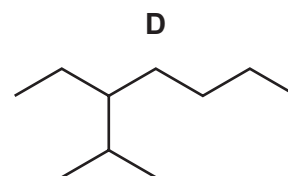
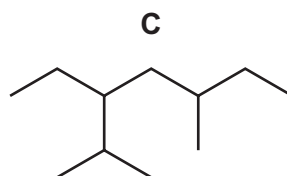
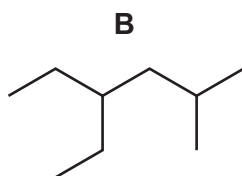
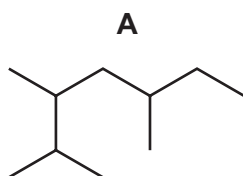
- A warming with acidified KMnO_4
- B warming with acidified $\text{K}_2\text{Cr}_2\text{O}_7$
- C dehydration, followed by reaction with $\text{Br}_2(\text{aq})$
- D mild oxidation, followed by reaction with Fehling's reagent

32 Compound T has the skeletal formula shown.

compound T

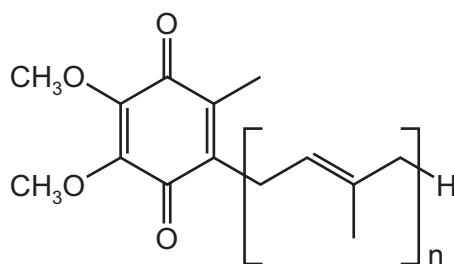


Which structure is a structural isomer of compound T?



33 The diagram shows a simplified structure of coenzyme Q₁₀.

coenzyme Q₁₀



Which row describes the structure of coenzyme Q₁₀ correctly?

	the coenzyme is	number of π bonds in one molecule
A	an aldehyde	$n + 2$
B	an aldehyde	$n + 4$
C	a ketone	$n + 2$
D	a ketone	$n + 4$

34 The molecule of limonene, C₁₀H₁₆, contains a 6-membered ring. This is the only cyclic component in its structure.

Which volume of hydrogen, at room conditions, is required to react completely with the C=C double bonds in **one** mole of limonene?

- A** 12 dm³ **B** 24 dm³ **C** 48 dm³ **D** 72 dm³

35 1-bromopropane reacts with hot ethanolic NaOH.

What is the molecular formula of the product in this reaction?

- A C_3H_6 B C_3H_8 C C_3H_7O D C_3H_8O

36 A sample of pent-2-en-4-ol, $C_5H_{10}O$, contains all the possible stereoisomers of this compound.

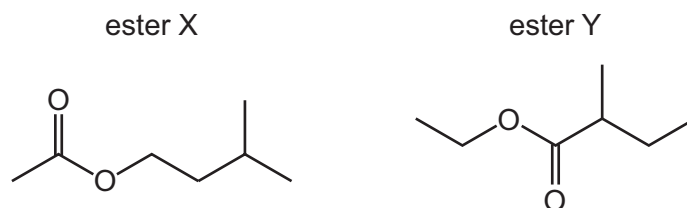
How many stereoisomers are there in the sample?

- A 2 B 3 C 4 D 5

37 Which pair of reagents reacts to form a product with a chiral carbon atom?

- A $CH_3CH=CH_2 + HBr$
 B $(CH_3)_2C=O + NaBH_4$
 C $CH_3CH_2CHO + HCN$
 D $CH_3COOH + CH_3CH_2OH$

38 The diagrams show the structures of two esters, X and Y, that are formed in ripening apples.

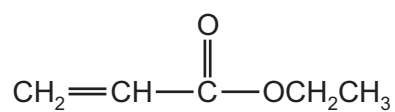


Which carboxylic acids are formed when these esters are hydrolysed by $H_2SO_4(aq)$?

	ester X	ester Y
A	CH_3COOH	CH_3CH_2COOH
B	CH_3COOH	$CH_3CH_2CH(CH_3)COOH$
C	$CH_3CH(CH_3)CH_2COOH$	CH_3CH_2COOH
D	$CH_3CH(CH_3)CH_2COOH$	$CH_3CH_2CH(CH_3)COOH$

- 39 An addition polymer is made from monomer Z.

monomer Z

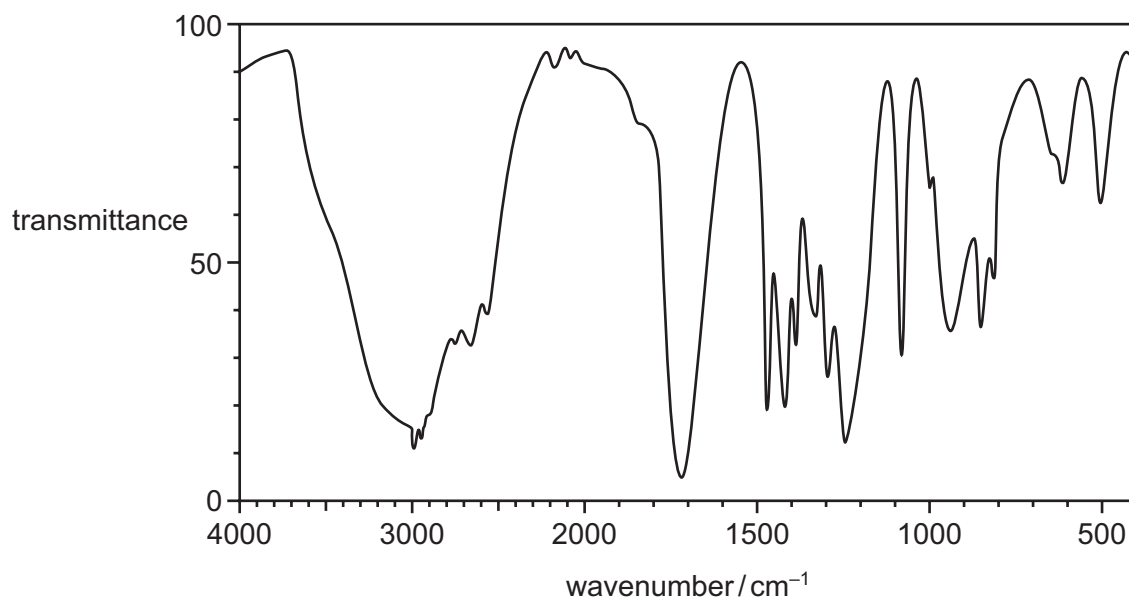


What is the structure of the polymer made from this monomer?

- A $\left[\text{CH}=\text{CH}-\overset{\text{O}}{\parallel}\text{C} \right]_n$
- B $\left[\text{CH}=\text{CH}-\overset{\text{O}}{\parallel}\text{C}-\text{O} \right]_n$
- C $\left[\text{CH}_2-\text{CH}=\underset{\text{OCH}_2\text{CH}_3}{\underset{|}{\text{C}}}-\text{O} \right]_n$
- D $\left[\text{CH}_2-\underset{\underset{\text{O}}{\parallel}}{\underset{|}{\text{C}}}-\text{OCH}_2\text{CH}_3 \right]_n$

40 Compound X reacts with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ to form compound Y.

The infrared spectrum of compound Y is shown.



bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

What is the identity of compound X?

- A** propan-1-ol
- B** propan-2-ol
- C** propanone
- D** propanoic acid

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	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ($4.18 \text{ J g}^{-1} \text{ K}^{-1}$)

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The Periodic Table of Elements

Group																			
1	2													13	14	15	16	17	18



Cambridge International AS & A Level

CHEMISTRY

9701/13

Paper 1 Multiple Choice

May/June 2024

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.



- 1 X is an impure sample of a Group 2 metal carbonate, MCO_3 . X contains 57% by mass of MCO_3 . The impurities in X do **not** react with hydrochloric acid.

7.4 g of X is reacted with an excess of dilute hydrochloric acid.

0.050 mol of the Group 2 metal chloride is produced.

What is the identity of the Group 2 metal?

- A** Mg **B** Ca **C** Sr **D** Ba

- 2 Which of these samples of gas contains the same number of atoms as 1 g of hydrogen gas?

A 22 g of carbon dioxide (M_r : CO_2 , 44)

B 8 g of methane (M_r : CH_4 , 16)

C 20 g of neon (M_r : Ne, 20)

D 8 g of ozone (M_r : O_3 , 48)

- 3 What is the total number of protons, neutrons and electrons present in an ammonium ion with a relative formula mass of 21?

	number of protons	number of neutrons	number of electrons
A	11	10	10
B	10	11	11
C	10	11	10
D	11	10	11

- 4 This question is about the first ionisation energies of magnesium and neon.

Which row is correct?

	first ionisation energy	type of electron removed	
		from Mg	from Ne
A	Mg > Ne	p	s
B	Mg > Ne	s	p
C	Ne > Mg	p	s
D	Ne > Mg	s	p

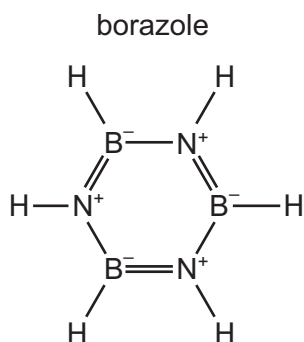
- 5 Arsenic forms a compound with fluorine. In this compound, the arsenic atom has no lone pair of electrons and there are no dative bonds.

Selenium also forms a compound with fluorine. In this compound, the selenium atom has no lone pair of electrons and there are no dative bonds.

In which compounds are there two different bond angles?

(In this question, 180° bond angles should be ignored.)

- A** both arsenic fluoride and selenium fluoride
B arsenic fluoride only
C selenium fluoride only
D neither arsenic fluoride nor selenium fluoride
- 6 A structure for borazole, $\text{N}_3\text{B}_3\text{H}_6$, is shown.



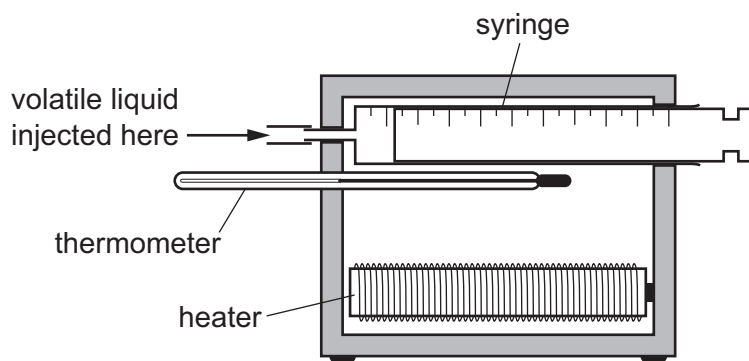
Which shape is borazole and how many π electrons are there in the structure?

	shape	number of π electrons
A	non-planar	3
B	non-planar	6
C	planar	3
D	planar	6

- 7 The diagram shows the apparatus used to find the relative molecular mass of a volatile liquid.

When 0.10 g of a volatile liquid is injected into the syringe, all of the volatile liquid evaporates and the volume increases by 85 cm³.

The heater maintains a temperature of 400 K and the experiment is carried out at a pressure of 101 300 Pa.



If the vapour of the volatile liquid behaves as an ideal gas, which expression can be used to calculate the relative molecular mass of the liquid?

- A** $M_r = (85 \times 101\,300) \div (0.10 \times 8.31 \times 400)$
B $M_r = (85 \times 101.3) \div (0.10 \times 8.31 \times 400)$
C $M_r = (0.10 \times 8.31 \times 400) \div (85 \times 10^{-6} \times 101\,300)$
D $M_r = (0.10 \times 8.31 \times 400) \div (85 \times 10^{-6} \times 101.3)$

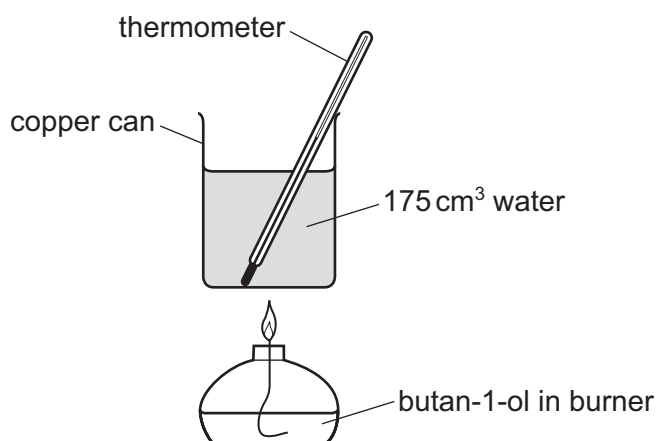
- 8 The table shows physical properties of four substances, W, X, Y and Z.

	melting point / °C	boiling point / °C	electrical conductivity of solid	electrical conductivity of liquid	electrical conductivity in water
W	993	1695	poor	good	good
X	-119	39	poor	poor	insoluble
Y	1535	2750	good	good	insoluble
Z	1610	2230	poor	poor	insoluble

What are the identities of W, X, Y and Z?

	W	X	Y	Z
A	MgO	C ₂ H ₅ Br	Fe	Al ₂ O ₃
B	MgO	HCl	K	Al ₂ O ₃
C	NaF	C ₂ H ₅ Br	Fe	SiO ₂
D	NaF	HCl	K	SiO ₂

- 9 The apparatus used to determine a value for the enthalpy of combustion of butan-1-ol is shown. The mass of 1.00 cm^3 of water is 1.00 g .



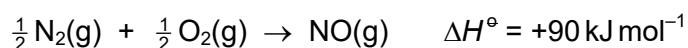
initial mass of burner + butan-1-ol	58.34 g
initial temperature of water	$17.6\text{ }^{\circ}\text{C}$
final mass of burner + butan-1-ol	57.85 g
final temperature of water	$41.1\text{ }^{\circ}\text{C}$

butan-1-ol $M_r = 74$

Which value, to three significant figures, for the enthalpy of combustion of butan-1-ol can be calculated from these data?

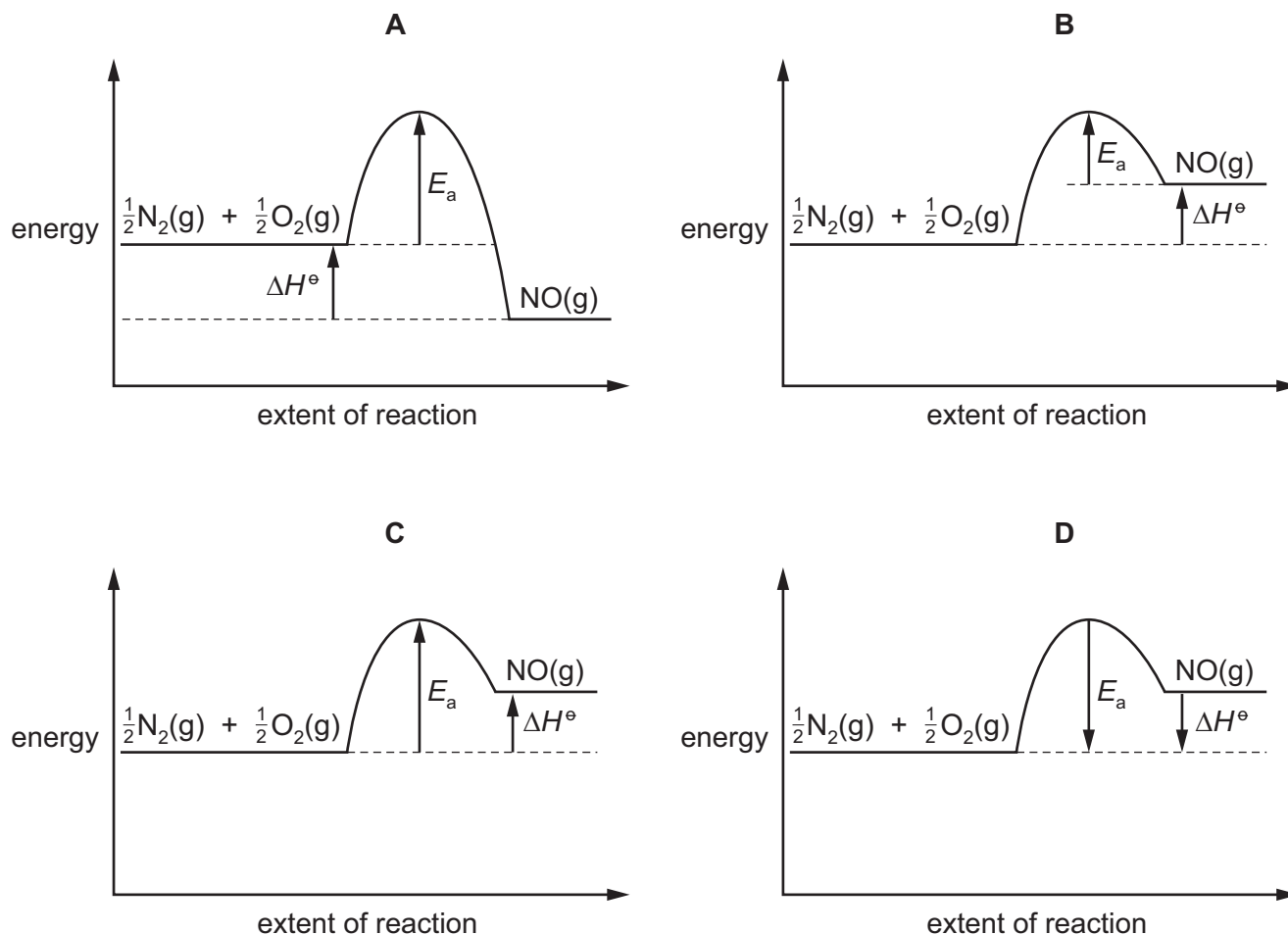
- A -114 J mol^{-1}
- B -17.2 kJ mol^{-1}
- C -2600 kJ mol^{-1}
- D -4540 kJ mol^{-1}

- 10 In the high temperatures of car engines, nitrogen reacts with oxygen to produce nitrogen monoxide.



This reaction has activation energy E_a .

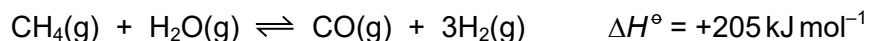
Which reaction pathway diagram correctly represents this reaction?



- 11 In which reaction does the oxidation number of chlorine change by the largest amount?

- A $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$
- B $2\text{ClO}^- \rightarrow \text{Cl}^- + \text{ClO}_2^-$
- C $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$
- D $2\text{NaClO}_2 + \text{Cl}_2 \rightarrow 2\text{NaCl} + 2\text{ClO}_2$

12 Hydrogen is produced industrially from methane as shown in the equation.



Which conditions give the highest yield of hydrogen at equilibrium?

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

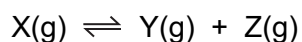
13 W moles of HNO_2 undergoes a disproportionation reaction to produce U moles of HNO_3 and V moles of NO.

- No other nitrogen containing product is produced.
- Nitrogen is the only element oxidised or reduced.

What are the values of W, U and V?

	W	U	V
A	2	1	1
B	3	1	2
C	5	3	2
D	5	1	4

14 Gas X dissociates on heating to set up the following equilibrium.

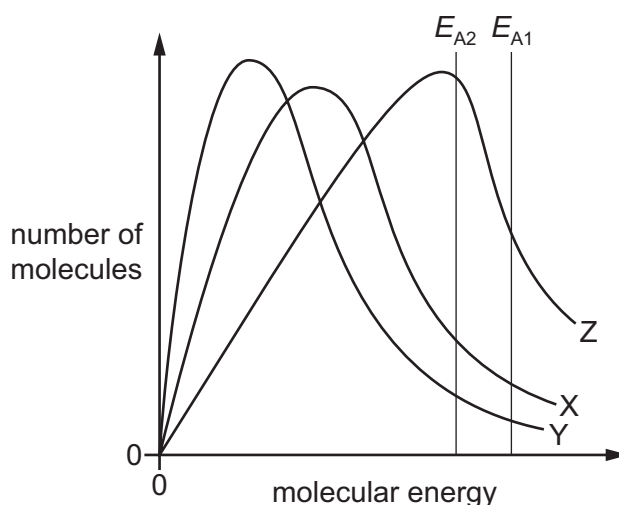


A quantity of gas X is heated at constant pressure, p , at a certain temperature. The equilibrium partial pressure of gas X is found to be $\frac{1}{7}p$.

What is the equilibrium constant, K_p , at this temperature?

- A** $\frac{6}{7}p$ **B** $\frac{9}{7}p$ **C** $\frac{36}{7}p$ **D** $9p$

- 15 In the diagram, X is the Boltzmann distribution for the energies of the particles in a reaction and E_{A1} is the activation energy for that reaction.



Which statement is correct?

- A E_{A2} is the activation energy at a higher temperature.
 B E_{A2} is the activation energy at a lower temperature.
 C Y is the Boltzmann distribution at a lower temperature.
 D Z is the Boltzmann distribution at a higher temperature.
- 16 Magnesium, aluminium and silicon are elements in the Periodic Table. Each element forms an oxide.

Which row is correct?

	MgO	Al_2O_3	SiO_2
A	basic	amphoteric	amphoteric
B	giant ionic	simple molecular	giant ionic
C	high melting point	high melting point	low melting point
D	slight reaction with water	no reaction with water	no reaction with water

- 17 Which statement correctly describes what happens when silicon tetrachloride is added to water?
- A The $SiCl_4$ dissolves to give a neutral solution only.
 B The $SiCl_4$ reacts to give an acidic solution only.
 C The $SiCl_4$ reacts to give a precipitate and an acidic solution.
 D The $SiCl_4$ reacts to give a precipitate and a neutral solution.

- 18 X and Y are two elements from Period 3 of the Periodic Table.

Element X has a higher electrical conductivity than element Y. Element Y has a higher melting point than element X.

Which formula is a compound formed from element X and element Y?

- A MgS B Mg_2Si C NaCl D SiCl_4

- 19 A sample consisting of 1.0 mol of anhydrous calcium nitrate is completely decomposed by strong heating.

What is the total amount of gas produced in this reaction?

- A 1.0 mol B 2.0 mol C 2.5 mol D 3.0 mol

- 20 Steam is passed over heated magnesium to give compound J and hydrogen.

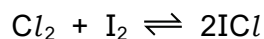
What is **not** a property of compound J?

- A It has an M_r of 40.3.
B It is basic.
C It is a white solid.
D It is very soluble in water.

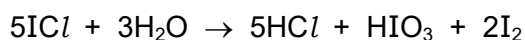
- 21 Which statement is correct?

- A Hydrogen bromide reduces concentrated sulfuric acid to form sulfur dioxide gas.
B Hydrogen bromide decomposes at a higher temperature than hydrogen chloride.
C When hydrogen bromide gas is shaken with aqueous silver nitrate a yellow precipitate is formed.
D When hydrogen bromide gas is bubbled through aqueous iodine the solution becomes colourless.

- 22 ICl is made when Cl_2 and I_2 react together.



ICl reacts with water.



Which row is correct?

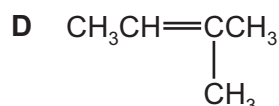
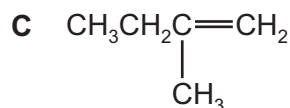
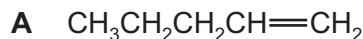
	oxidation number of I in ICl	reaction occurring when ICl reacts with H_2O
A	+1	the iodine atoms are oxidised to form I_2
B	+1	the iodine atoms are oxidised to form HIO_3
C	-1	the chlorine atoms are reduced to form HCl
D	-1	the iodine atoms are oxidised to form HIO_3

- 23 NH_4Cl reacts with NaOH in an aqueous solution.

Which statement is correct?

- A** The reaction gives rise to two different polar product molecules.
- B** The bond angle in the nitrogen-containing species remains unchanged.
- C** The ammonium ion acts as a base.
- D** The oxidation state of nitrogen increases in the reaction.
- 24 What is produced when 60 g of nitrogen monoxide reacts with an excess of carbon monoxide in a catalytic converter?
- A** 12 g of carbon and 92 g of nitrogen dioxide
- B** 24 g of carbon and 92 g of nitrogen dioxide
- C** 88 g of carbon dioxide and 28 g of nitrogen
- D** 88 g of carbon dioxide and 56 g of nitrogen

25 Which alkene shows geometric isomerism?



26 What is the correct name of the major product of the reaction of HBr with 3-ethylhex-3-ene?

A 3-bromo-3-ethylhexane

B 3-bromo-4-ethylhexane

C 4-bromo-3-ethylhexane

D 4-bromo-4-ethylhexane

27 The alkane $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)_2$ undergoes free radical substitution with chlorine. No C–C bonds are broken in this reaction.

How many isomeric products, including positional and optical isomers, of molecular formula $\text{C}_5\text{H}_{11}\text{Cl}$ can be formed?

A 4

B 5

C 6

D 7

28 What is involved in the mechanism of the reaction between aqueous NaOH and 1-bromobutane?

A attack by a nucleophile on a carbon atom with a partial positive charge

B heterolytic bond fission and attack by a nucleophile on a carbocation

C homolytic bond fission and attack by an electrophile on a carbanion

D homolytic bond fission and attack by a nucleophile on a carbocation

- 29 But-2-ene reacts with cold dilute acidified KMnO_4 to give product X.

But-2-ene reacts with an excess of hot concentrated acidified KMnO_4 to give product Y.

Which statement about X and Y is correct?

- A** Only one of X and Y reacts with 2,4-dinitrophenylhydrazine.
- B** X and Y both react with sodium hydroxide.
- C** X and Y both react with sodium metal.
- D** Y reacts with LiAlH_4 to give X.
- 30 When heated with KOH dissolved in ethanol, halogenoalkanes can undergo an elimination reaction to form alkenes.

What are the possible elimination products when 2-bromobutane is heated with KOH dissolved in ethanol?

- A** $\text{CH}_3\text{CH}=\text{CHCH}_3$ only
- B** $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$ only
- C** $\text{CH}_3\text{CH}=\text{CHCH}_3$ and $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$
- D** $\text{CH}_3\text{CH}=\text{CHCH}_3$ and $\text{CH}_2=\text{CHCH}=\text{CH}_2$
- 31 Chloroethane can be used to make sodium propanoate.



Intermediate Q is hydrolysed with boiling aqueous NaOH to give sodium propanoate.

Which reagent would produce intermediate Q from chloroethane?

- A** concentrated ammonia solution
- B** dilute sulfuric acid
- C** hydrogen cyanide in water
- D** potassium cyanide in ethanol
- 32 Four different alcohols are treated with alkaline $\text{I}_2(\text{aq})$.

Which row is correct?

	name of alcohol	formulae of products
A	butan-2-ol	CH_3COO^- and CH_3CI_3
B	propan-1-ol	CH_3COO^- and CHI_3
C	propan-2-ol	CH_3COO^- and CHI_3
D	butan-2-ol	$\text{CH}_3\text{CH}_2\text{COO}^-$ and CH_3I

- 33** The M_r of compound X is 88.

Compound X is heated under reflux with an excess of acidified potassium dichromate(VI) to produce compound Y.

Compound Y reacts with compound X under suitable conditions to produce compound Z. The M_r of compound Z is 172.

What is compound X?

- A** $\text{CH}_3\text{CH}_2\text{CHOHCH}_2\text{CH}_3$
- B** $(\text{CH}_3)_2\text{COHCH}_2\text{CH}_3$
- C** $(\text{CH}_3)_2\text{CHCHOHCH}_3$
- D** $(\text{CH}_3)_3\text{CCH}_2\text{OH}$

- 34** Butanedione, $\text{CH}_3\text{COCOCH}_3$, is a yellow liquid.

How does butanedione react with 2,4-dinitrophenylhydrazine reagent and Fehling's reagent?

	2,4-dinitrophenylhydrazine	Fehling's
A	positive	positive
B	positive	negative
C	negative	positive
D	negative	negative

- 35** Which substance reacts with ethanoic acid to give the organic product with the highest M_r ?

- A** lithium aluminium hydride
- B** magnesium
- C** potassium carbonate
- D** propan-2-ol

- 36** A sample of propyl ethanoate is hydrolysed by heating under reflux with aqueous NaOH. The two organic products of the hydrolysis are separated, purified and weighed.

Out of the total mass of products obtained, what is the percentage by mass of each product?

- A** 32.4% and 67.6%
- B** 38.3% and 61.7%
- C** 42.3% and 57.7%
- D** 50.0% and 50.0%

37 Which statement about PVC is correct?

- A Combustion products of PVC are very alkaline and harmful to breathe in.
- B The empirical formula of PVC is the same as the empirical formula of the monomer.
- C Molecules of PVC are unsaturated.
- D The repeat unit of PVC is $(\text{CH}_2\text{CCl}_2)$.

38 Compound Q reacts separately with HCN and NaBH_4 under suitable conditions.

Both reactions produce an organic product with a chiral centre.

What is compound Q?

- A butanone
- B ethanal
- C propanal
- D propanone

39 Compound X has the following properties.

- When 0.20 mol of X undergoes complete combustion, 14.4 dm^3 of carbon dioxide is produced, measured under room conditions.
- X reacts with 2,4-dinitrophenylhydrazine reagent to give an orange crystalline product.
- X does **not** give a yellow precipitate with alkaline $\text{I}_2(\text{aq})$.

What could be X?

- A hexan-3-one
- B propanal
- C propan-1-ol
- D propanone

40 A sample of but-2-enoic acid, $\text{CH}_3\text{CH}=\text{CHCOOH}$, is analysed using infrared spectroscopy.

The infrared spectrum shows a broad peak in the range $2500\text{--}3000\text{ cm}^{-1}$.

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3600

Which bond is responsible for this peak?

- A** C=C **B** C=O **C** C–O **D** O–H

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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	Key										13	14	15	16	17	18		
		atomic number atomic symbol name relative atomic mass																	
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2		
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9		
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 72.6	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8		
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3		
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —	
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —	
lanthanoids		57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium —	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0			
actinoids		89 Ac actinium —	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium —	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —			