Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/11**

Paper 1 Multiple Choice **October/November 2022**

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.

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1 Which sample contains the same number of the named species as the number of molecules in 35.5 g of chlorine?

A atoms in 16 g of sulfur

B atoms in 23 g of sodium

C ions in 74.5 g of potassium chloride

D molecules in 88 g of carbon dioxide

2 Mixture R consists of one mole of C_3H_6 and one mole of C_4H_6.

What is the minimum number of moles of oxygen molecules needed for complete combustion of mixture R?

A 6.5 **B** 7 **C** 10 **D** 20

3 Which statement about the electrons in a ground state carbon atom is correct?

A Electrons are present in four different energy levels.

B There are more electrons in p orbitals than there are in s orbitals.

C The occupied orbital of highest energy is spherical.

D The occupied orbital of lowest energy is spherical.

4 For the element sulfur, which pair of ionisation energies has the largest difference between them?

A third and fourth ionisation energies

B fourth and fifth ionisation energies

C fifth and sixth ionisation energies

D sixth and seventh ionisation energies

5 How many σ bonds are present in one $H–C{\equiv}C–C(CH_3)=CH(CH_3)$ molecule?

A 5 **B** 11 **C** 13 **D** 16

6 Which molecule has an equal number of bonding electrons and lone-pair electrons?

A BH_3 **B** CO_2 **C** F_2O **D** SO_2

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7 The table shows properties of four solids held together by different types of bonding.

Which row correctly describes the properties of a solid with a giant covalent structure?

	melting point	solubility in polar solvents
A	high	insoluble
B	high	soluble
C	low	insoluble
D	low	soluble

8 The carbonate of an s-block element is reacted with an excess of hydrochloric acid.

0.833 g of the carbonate releases 200 cm^3 of gas, measured under room conditions.

What is the identity of the metal carbonate?

A Na_2CO_3 **B** K_2CO_3 **C** $MgCO_3$ **D** $CaCO_3$

9 The enthalpy changes of formation, $\Delta H_f^{\ominus}$, of both PCl_3 and PCl_5 are exothermic.

PCl_3 reacts with chlorine.

$$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s) \qquad \Delta H^{\ominus}_{reaction} = -124\ kJ\ mol^{-1}$$

Which pair of statements is correct?

	statement 1	statement 2
A	$\Delta H^{\ominus}_{reaction}$ is less negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.
B	$\Delta H^{\ominus}_{reaction}$ is more negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.
C	$\Delta H^{\ominus}_{reaction}$ is less negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is not needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.
D	$\Delta H^{\ominus}_{reaction}$ is more negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is not needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.

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10 A student mixes 25.0 cm^3 of 0.350 mol dm^{-3} sodium hydroxide solution with 25.0 cm^3 of 0.350 mol dm^{-3} hydrochloric acid. The temperature increases by 2.5 °C. No heat is lost to the surroundings.

The final mixture has a specific heat capacity of 4.2 J cm^{-3} K^{-1}.

What is the molar enthalpy change for the reaction?

A –150 kJ mol^{-1}

B –60 kJ mol^{-1}

C –30 kJ mol^{-1}

D –0.15 kJ mol^{-1}

11 Ammonium ions are converted into nitrate ions by bacteria.

What is the change in the oxidation number of nitrogen?

A –6 **B** +6 **C** +8 **D** +9

12 Sodium dichromate(VI), $Na_2Cr_2O_7$, reacts with hydrogen peroxide, H_2O_2, producing Cr^{3+} ions, water and oxygen.

What is the correctly balanced ionic equation for this reaction?

A $Cr_2O_7^{2-} + 2H^+ + H_2O_2 \rightarrow 2Cr^{3+} + 2H_2O + 4O_2$

B $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

C $Cr_2O_7^{2-} + 8H^+ + 6H_2O_2 \rightarrow 2Cr^{3+} + 10H_2O + 6O_2$

D $Cr_2O_7^{2-} + 14H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

13 In which equilibrium reaction is the position of equilibrium moved to the right-hand side by increasing the temperature and also by decreasing the pressure?

A $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $\Delta H = 40$ kJ mol^{-1}

B $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = 58$ kJ mol^{-1}

C $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197$ kJ mol^{-1}

D $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $\Delta H = -10$ kJ mol^{-1}

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14 Ethanol is produced industrially by reacting ethene and steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

K_p has a value of 1.8×10^{-5} and the partial pressures of the reactants at equilibrium are shown.

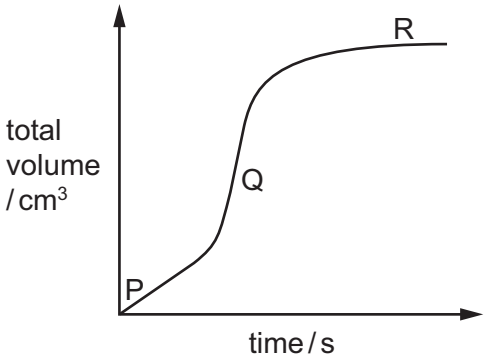
reactant	partial pressure / kPa
ethene	4.8×10^3
steam	2.8×10^3

Which row is correct?

	partial pressure of ethanol at equilibrium / kPa	units of K_p
A	2.42×10^2	kPa^{-1}
B	2.42×10^2	kPa
C	7.47×10^{11}	kPa^{-1}
D	7.47×10^{11}	kPa

15 A large excess of magnesium ribbon is added to dilute hydrochloric acid and the volume of hydrogen gas produced is measured as the reaction proceeds. The reaction is exothermic.

The results are shown.



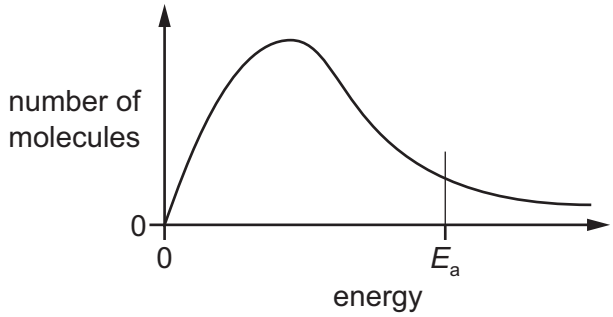
Which row explains the changes in the rate of reaction between points P and Q and between points Q and R?

	between points P and Q	between points Q and R
A	the reaction temperature is increasing	the acid concentration is falling
B	the reaction temperature is increasing	the magnesium has been used up
C	magnesium's surface area is decreasing	the acid concentration is falling
D	magnesium's surface area is decreasing	the magnesium has been used up

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16 Measurements are made to determine the activation energy, E_a, of a reaction.

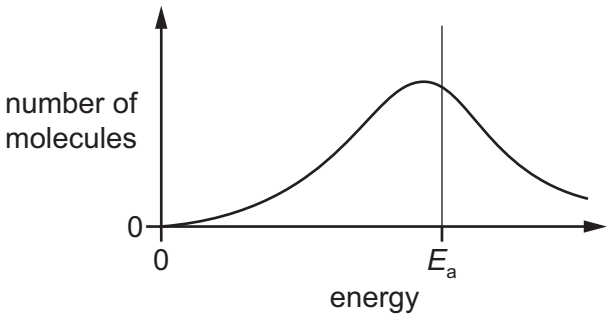
The diagram shows E_a on the Boltzmann distribution at temperature T_1.



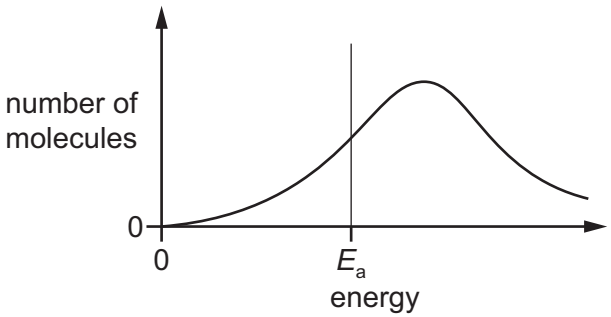
Measurements are then made at a higher temperature, T_2.

Which diagram correctly shows the Boltzmann distribution and E_a at T_2?

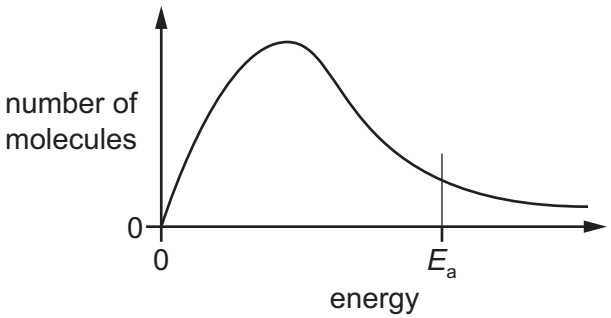
A



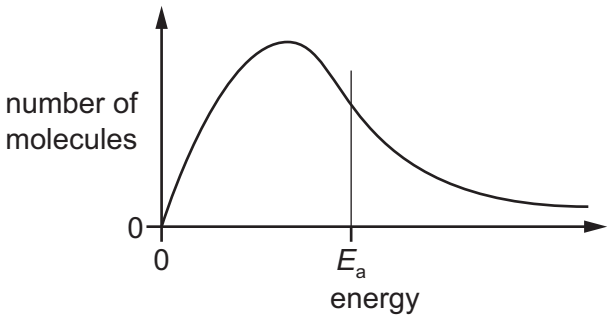
B



C



D



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17 The electrical conductivities of two compounds, Y and Z, are shown.

	for Y	for Z
conductivity of the compound in the liquid state	good	does not conduct
conductivity of the mixture obtained by adding the compound to water	good	good

What are compounds Y and Z?

	Y	Z
A	Al_2O_3	$SiCl_4$
B	$NaCl$	Al_2O_3
C	$NaCl$	$SiCl_4$
D	$SiCl_4$	Al_2O_3

18 Which row describes the relative sizes of the ionic radii of Na^+, Mg^{2+} and S^{2-}?

	smallest ⟶		largest
A	Na^+	Mg^{2+}	S^{2-}
B	Mg^{2+}	Na^+	S^{2-}
C	S^{2-}	Na^+	Mg^{2+}
D	S^{2-}	Mg^{2+}	Na^+

19 The oxides BaO, CaO, MgO and SrO all produce alkaline solutions when added to water.

Which oxide produces the saturated solution with the highest pH?

A BaO **B** CaO **C** MgO **D** SrO

20 Which row is correct?

	the temperature needed to decompose Group 2 metal nitrates	the solubility of Group 2 sulfates
A	decreases down the group	decreases down the group
B	decreases down the group	increases down the group
C	increases down the group	increases down the group
D	increases down the group	decreases down the group

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21 Which statement about Group 17 elements and compounds is correct?

A Sodium chloride produces chlorine when reacted with concentrated sulfuric acid.

B Sodium chloride produces chlorine when reacted with bromine.

C Sodium bromide produces bromine when reacted with concentrated sulfuric acid.

D Sodium bromide produces bromine when reacted with iodine in aqueous potassium iodide.

22 Chlorine is bubbled through $100\,cm^3$ of hot $4.0\,mol\,dm^{-3}$ sodium hydroxide until the reaction is complete.

$$6NaOH(aq) + xCl_2(aq) \rightarrow yNaCl(aq) + zNaClO_3(aq) + 3H_2O(l)$$

Which row is correct?

	x	$[Na^+](aq)$ after reaction / $mol\,dm^{-3}$
A	3	4.0
B	3	less than 4.0
C	6	4.0
D	6	less than 4.0

23 Which statement about ammonia or the ammonium ion is correct?

A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.

B Silver iodide is soluble in a concentrated aqueous solution of ammonia.

C The ammonium ion has the same number of electrons as a methane molecule.

D The square planar ammonium ion contains a dative covalent bond.

24 Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.

Which reaction shows how the catalyst is reformed?

A $N_2 + 2O_2 \rightleftharpoons 2NO_2$

B $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

C $N_2 + O_2 \rightarrow 2NO$

D $NO + \frac{1}{2}O_2 \rightarrow NO_2$

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25 Separate 1.0 g samples of Na_2O, MgO, Al_2O_3, SiO_2, NaCl, $MgCl_2$, Al_2Cl_6 and $SiCl_4$ are added to separate beakers containing water and stirred.

The number of beakers containing a white solid is Q.

An excess of NaOH(aq) is then added to each beaker and stirred.

The number of beakers now containing a white solid is R.

Which row is correct?

	Q	R
A	3	2
B	3	3
C	4	3
D	4	4

26 Which pair of alcohols are isomers of each other?

A butan-1-ol and 2,2-dimethylpropan-1-ol

B butan-2-ol and 2-methylpropan-2-ol

C pentan-1-ol and 2-methylpropan-2-ol

D propan-2-ol and 2-methylpropan-2-ol

27 How many chiral carbon atoms are there in one molecule of 2,2,4,5-tetramethylhexan-3-ol?

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

28 Which pair of reagents react together in a redox reaction?

A CH_3CHCH_2 + Br_2

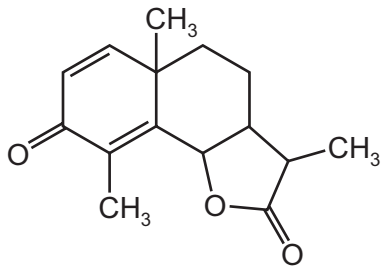
B $CH_3CH_2CH_2OH$ + concentrated H_3PO_4

C CH_3COCH_3 + HCN

D $HCO_2C_2H_5$ + dilute H_2SO_4

29 The structure of santonin is shown.

santonin



Santonin is first treated with warm dilute H_2SO_4. The product of this reaction is treated with cold dilute acidified $KMnO_4$. A final product, Q, is obtained.

How many atoms of hydrogen in each molecule of product Q will react with sodium metal?

A 2 **B** 4 **C** 5 **D** 6

30 Compound R can be formed from 1-bromopropane using a nucleophilic substitution reaction followed by an oxidation reaction.

What is the identity of R?

A propanoic acid

B propanone

C propylamine

D propyl ethanoate

31 Three colourless liquids with the following formulae are contained in separate unlabelled bottles.

$CH_3CH_2CO_2H$ $CH_3CH(OH)CO_2H$ CH_3COCO_2H

Which two tests, carried out on separate samples of each liquid, will successfully identify each liquid?

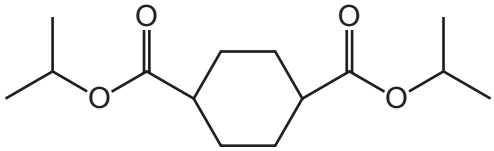
	test 1	test 2
A	$NaHCO_3$	2,4-DNPH reagent
B	$NaHCO_3$	Tollens' reagent
C	warm acidified dichromate	2,4-DNPH reagent
D	warm acidified dichromate	Tollens' reagent

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32 An alcohol, X, reacts with a dicarboxylic acid, Y, to form a double ester, Z.

The diagram shows the structure of the ester.

Z



Which row about the reactants forming ester Z is correct?

	the class of alcohol X	the shape of the ring in Y
A	secondary	non-planar
B	secondary	planar
C	tertiary	non-planar
D	tertiary	planar

33 W reacts with alkaline I_2(aq) to form a yellow precipitate and $CH_3CH_2CO_2^-$ ions.

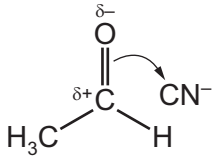
Which row identifies W and the yellow precipitate?

	identity of W	identity of yellow precipitate
A	butanone	CHI_3
B	butanone	CH_3I
C	propanone	CHI_3
D	propanone	CH_3I

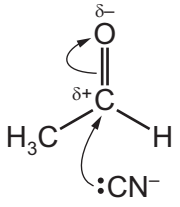
34 Ethanal reacts with hydrogen cyanide in the presence of KCN to produce a hydroxynitrile.

What is the first step in the mechanism of this reaction?

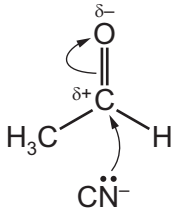
A



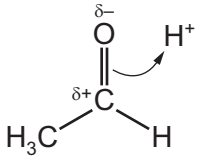
B



C



D

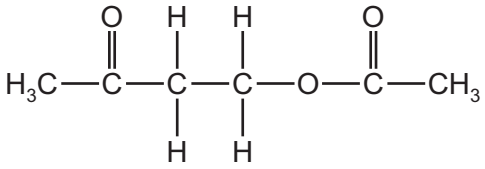


35 Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomeric compounds with molecular formula $C_5H_6O_4$ contain two $–CO_2H$ groups and one C=C double bond?

A 5 **B** 6 **C** 7 **D** 8

36 Compound X reacts with ethanoic acid in the presence of an H^+ catalyst to produce the compound shown.



What is the molecular formula of compound X?

A C_2H_4O **B** $C_2H_6O_2$ **C** C_4H_8O **D** $C_4H_8O_2$

37 2-bromopropane reacts with hot ethanolic sodium hydroxide.

Which substance is the major product of this reaction?

A propan-1-ol

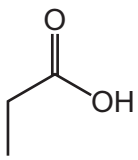
B propan-2-ol

C 2-hydroxypropene

D propene

38 Which compounds can be used to make Y in a single-step reaction?

Y



1 propanenitrile

2 ethanenitrile

3 propyl ethanoate

4 ethyl propanoate

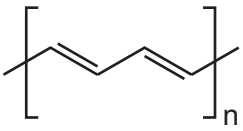
A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

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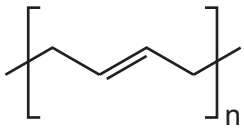
39 The monomer buta-1,3-diene can undergo addition polymerisation in various ways. Two of the polymers that can be made are called *cis*-poly(buta-1,3-diene) and *trans*-poly(buta-1,3-diene). In these names *cis* and *trans* have their usual meanings.

What is the structure of the repeat unit of *cis*-poly(buta-1,3-diene)?

A



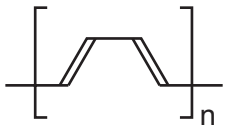
B



C



D



40 In the mass spectrum of a compound, Z, the relative abundances of the M and M+1 peaks are in the ratio 13 : 1.

What is compound Z?

A butyl butanoate

B hexan-3-one

C 2,2,3-trimethylhexane

D 3,3-dimethylpentan-1-ol

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

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The Periodic Table of Elements

Group																		
1	2											13	14	15	16	17	18
								1 H hydrogen 1.0									2 He helium 4.0
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 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 oganesson –

Key

atomic number
atomic symbol
name
relative atomic mass

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 –

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Cambridge International AS & A Level

CHEMISTRY **9701/12**

Paper 1 Multiple Choice **October/November 2022**

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

0575101073

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 Why is the first ionisation energy of phosphorus greater than the first ionisation energy of silicon?

A A phosphorus atom has one more proton in its nucleus.

B The atomic radius of a phosphorus atom is greater.

C The outer electron in a phosphorus atom is more shielded.

D The outer electron in a phosphorus atom is paired.

2 Sodium peroxide, Na_2O_2, is used to absorb carbon dioxide from the atmosphere and release oxygen in closed environments such as space capsules and submarines.

$$2Na_2O_2 + 2CO_2 \rightarrow 2Na_2CO_3 + O_2$$

Which mass of sodium peroxide would be required to remove 2.4 dm^3 of carbon dioxide from the atmosphere at room temperature and pressure?

A 2.4 g **B** 3.9 g **C** 7.8 g **D** 15.6 g

3 In which species are the numbers of protons, neutrons and electrons all different?

A $^{27}_{13}Al$ **B** $^{35}_{17}Cl^-$ **C** $^{32}_{16}S^{2-}$ **D** $^{39}_{19}K^+$

4 Calcium oxide and magnesium sulfide each react with acid.

$$CaO(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l)$$

$$MgS(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2S(g)$$

A mixture of these two compounds, X, reacts with exactly 0.125 mol of dilute hydrochloric acid.

The amount of hydrogen sulfide formed is 0.0250 mol.

What was the mass of calcium oxide in mixture X?

A 1.4 g **B** 2.1 g **C** 2.8 g **D** 4.2 g

5 Two moles of VO_2^+ ions react with one mole of zinc atoms in the presence of dilute acid. The products include Zn^{2+} ions and an ion, Y. Ion Y contains vanadium. Only zinc and vanadium change oxidation state in the reaction.

What is ion Y?

A VO_3^- **B** VO^+ **C** VO^{2+} **D** VO_2^{2+}

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6 The compound potassium bismuthate(V), $KBiO_3$, is a powerful oxidising agent.

What is the significance of the (V) in potassium bismuthate(V)?

A It is the oxidation number of the bismuth atom.

B It is the charge of the bismuthate ion.

C It is the oxidation number of the bismuthate ion.

D It is the sum of the charges of the two ions present.

7 Hydrogen peroxide decomposes slowly at 20 °C to form water and oxygen.

$$2H_2O_2 \rightleftharpoons 2H_2O + O_2 \qquad \text{equilibrium constant} = K_c$$

The reaction is faster when a catalyst is present.

Which statement is correct?

A The catalyst alters the Boltzmann distribution so that the reactant molecules have more energy.

B The catalyst has no effect on the value of K_c.

C The catalyst increases the value of K_c.

D The catalyst provides a different reaction mechanism with a higher activation energy.

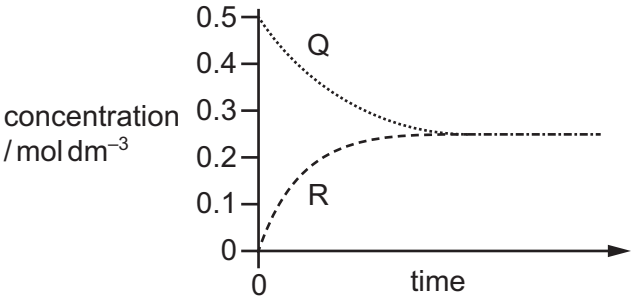
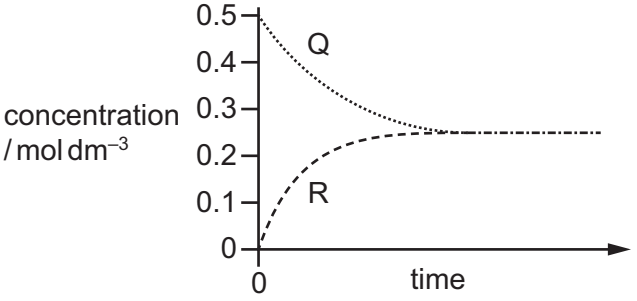
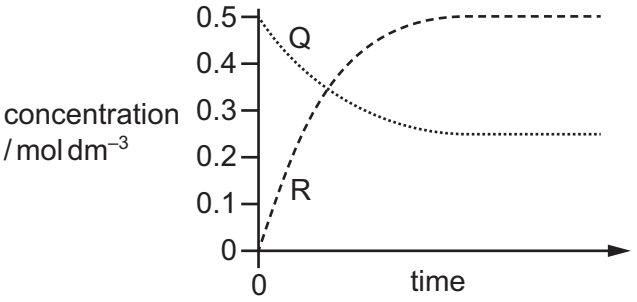
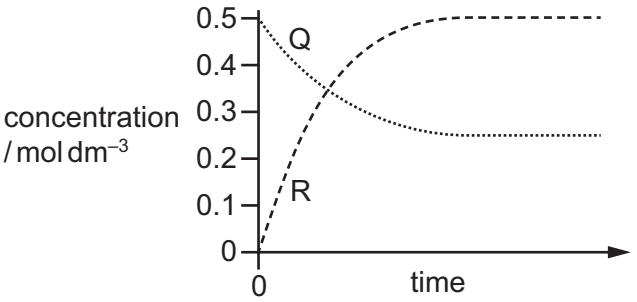
8 A dimer, Q, is stable when solid but a dynamic equilibrium is set up in solution.

$$Q(aq) \rightleftharpoons 2R(aq)$$

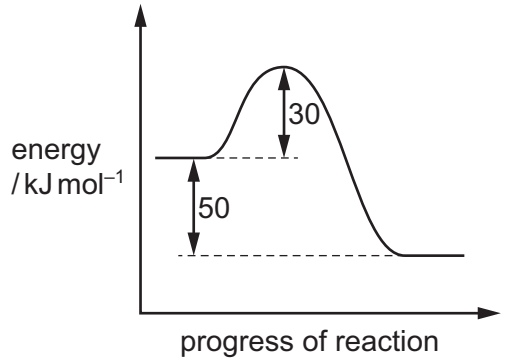
A solution of Q has an initial concentration of $0.50\,mol\,dm^{-3}$. When equilibrium has been reached, [Q(aq)] has fallen to $0.25\,mol\,dm^{-3}$.

The changes in [Q(aq)] and [R(aq)] are plotted against time until equilibrium is reached. The value of K_c is then calculated.

Which graph and value for K_c are correct?

	graph	K_c / mol dm^{-3}
A		1
B		0.25
C		1
D		2

9 The reaction pathway for the forward reaction of a reversible reaction is shown.



Which statement is correct?

A The activation energy of the reverse reaction is +80 kJ mol^{-1}.

B The enthalpy change for the forward reaction is +30 kJ mol^{-1}.

C The enthalpy change for the forward reaction is +50 kJ mol^{-1}.

D The enthalpy change for the reverse reaction is +30 kJ mol^{-1}.

10 The enthalpy changes for the possible reactions W, X, Y and Z are given.

W $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ $\Delta H^{\ominus} = -56\ kJ\ mol^{-1}$

X $NaCl(aq) + H_2O(l) \rightarrow NaOH(aq) + HCl(aq)$ $\Delta H^{\ominus} = +56\ kJ\ mol^{-1}$

Y $2HI(g) \rightarrow H_2(g) + I_2(g)$ $\Delta H^{\ominus} = +11\ kJ\ mol^{-1}$

Z $H_2(g) + I_2(g) \rightarrow 2HI(g)$ $\Delta H^{\ominus} = -11\ kJ\ mol^{-1}$

Which statement about the activation energies of these reactions is correct?

A X is greater than W; Z is greater than Y.

B X is greater than W; Y is greater than Z.

C W is greater than X; Z is greater than Y.

D W is greater than X; Y is greater than Z.

11 The Haber process is carried out with a nitrogen partial pressure of 50 kPa, a hydrogen partial pressure of 150 kPa, a temperature of 400 °C and an iron catalyst.

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

If all other conditions are kept the same, which change will result in a raised activation energy?

A Both the nitrogen and hydrogen partial pressures are changed to 100 kPa.

B The iron is removed.

C The nitrogen partial pressure is increased to 150 kPa.

D The temperature is increased to 500 °C.

12 The compound $(CH_3)_3NAlCl_3$ has a simple molecular structure.

Which statement about $(CH_3)_3NAlCl_3$ is correct?

A $(CH_3)_3NAlCl_3$ molecules attract each other by hydrogen bonds.

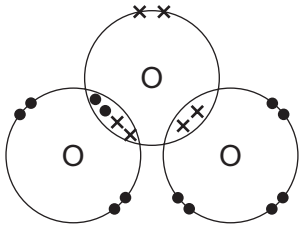
B The Al atom in $(CH_3)_3NAlCl_3$ has an incomplete valence shell of electrons.

C The bonds around the Al atom are planar.

D The molecules contain coordinate bonding.

13 VSEPR theory should be used in answering this question.

The dot-and-cross diagram for an ozone, O_3, molecule is shown.



What is the predicted bond angle in this molecule?

A 107° **B** 109.5° **C** 117° **D** 120°

14 Each of the substances shown is gaseous.

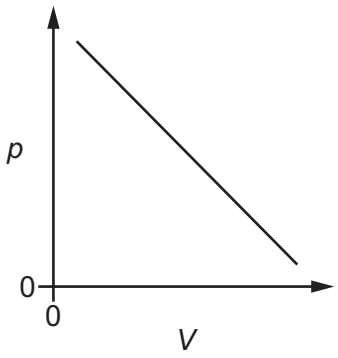
Which substance is most likely to show ideal behaviour in the conditions shown?

	substance	temperature / K	pressure / Pa
A	carbon dioxide	250	1.00×10^5
B	hydrogen chloride	1000	1.00×10^6
C	nitrogen	1000	1.00×10^5
D	oxygen	250	1.00×10^6

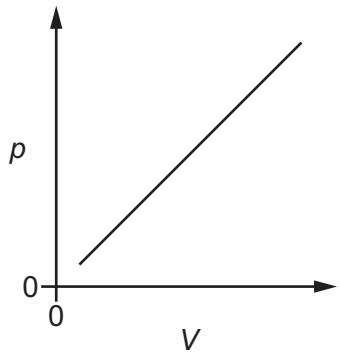
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15 Which graph represents the variation of pressure p and volume V of a sample of an ideal gas at constant temperature?

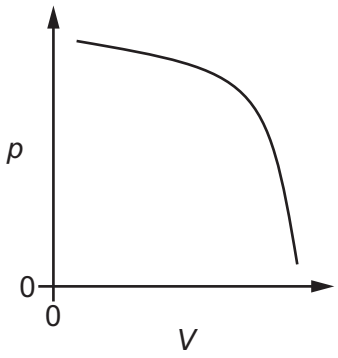
A



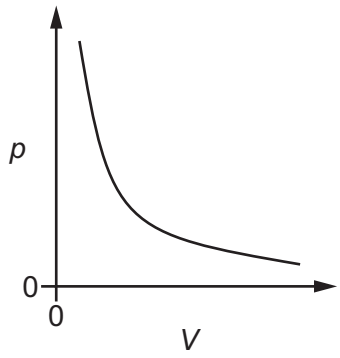
B



C



D



16 Use relevant enthalpy changes from the tables to answer this question.

reaction	ΔH / kJ mol^{-1}
$C(s) + 2H_2(g) \rightarrow CH_4(g)$	–76
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	–890
$CH_4(g) \rightarrow C(g) + 4H(g)$	1648
$3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$	–105

bond	bond enthalpy / kJ mol^{-1}
H–H	436
C–C	350
C=C	610
C=O	805

Which value can be calculated for the enthalpy change for the following reaction?

$$2C(g) + 6H(g) \rightarrow C_2H_6(g)$$

A –2822 kJ mol^{-1}

B –2122 kJ mol^{-1}

C –1998 kJ mol^{-1}

D –1772 kJ mol^{-1}

17 Element X requires strong heating to react with oxygen.

Element X reacts with chlorine to give a covalently-bonded chloride.

What could be the identity of element X?

A magnesium

B phosphorus

C sodium

D silicon

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18 The melting points of the Period 3 elements sodium to aluminium are shown in the table.

element	Na	Mg	A*l*
melting point / K	371	923	932

Which factor explains the **increase** in melting points from sodium to aluminium?

A the change in first ionisation energy from sodium to aluminium

B the increase in electronegativity from sodium to aluminium

C the increase in the A_r of the elements from sodium to aluminium

D the increase in the number of outer electrons in each atom from sodium to aluminium

19 The nitrates of beryllium, calcium, magnesium and strontium all decompose in the same way when heated. When 2.00 g of one of these anhydrous nitrates is decomposed, 1.32 g of gas is produced.

What is the nitrate?

A beryllium nitrate

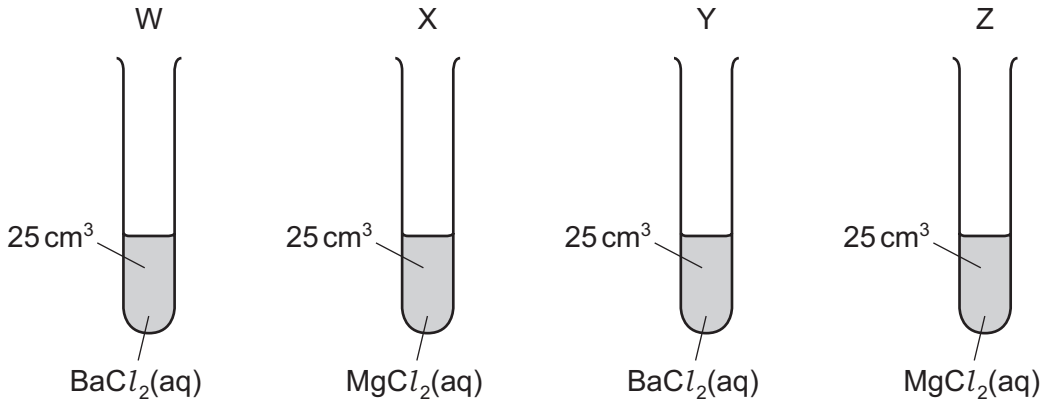
B calcium nitrate

C magnesium nitrate

D strontium nitrate

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20 In the diagram, each test-tube W, X, Y and Z contains 25 cm^3 of a 0.1 mol dm^{-3} solution of a salt.



To test-tubes W and X, 25 cm^3 of 0.1 mol dm^{-3} NaOH(aq) is added.

To test-tubes Y and Z, 25 cm^3 of 0.1 mol dm^{-3} H_2SO_4(aq) is added.

In which of test-tubes W and X does the liquid have the higher pH and which of test-tubes Y and Z has the greater mass of precipitate?

	higher pH	greater mass of precipitate
A	W	Y
B	W	Z
C	X	Y
D	X	Z

21 What is the oxidation state of the chlorine-containing species that kills bacteria in drinking water?

A –1 **B** +1 **C** +3 **D** +5

22 Compound Q is a white crystalline solid which dissolves easily in water.

When concentrated sulfuric acid is added to a dry sample of Q, steamy white fumes are formed.

When these white fumes are passed into aqueous silver nitrate solution, a white precipitate forms.

This precipitate is soluble in dilute ammonia solution.

What is compound Q?

A AgCl **B** NaBr **C** NaCl **D** $PbBr_2$

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23 R is a solid. R fizzes when hydrochloric acid is added.

R reacts with hot aqueous sodium hydroxide, giving off a gas which turns red litmus blue.

What is the formula of R?

A NH_4CO_3 **B** $(NH_4)_2CO_3$ **C** $(NH_4)_2HCO_3$ **D** $(NH_4)_2SO_4$

24 Photochemical smog is a type of air pollution produced in urban areas by the effect of sunlight on substances released from vehicle exhausts.

Which mixture of primary pollutants leads to the formation of photochemical smog?

A carbon dioxide and water vapour

B carbon monoxide and unburnt hydrocarbons

C nitrogen oxide and unburnt hydrocarbons

D sulfur dioxide and water vapour

25 T is an element in Period 3.

The first ionisation energy of T is lower than that of the element with one less proton.

The oxide of T does not react with water.

What is the identity of T?

A aluminium

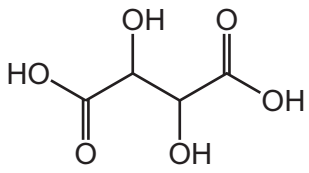
B silicon

C sodium

D sulfur

26 The structure of tartaric acid is shown.

tartaric acid



Which statements about tartaric acid are correct?

1 A molecule of tartaric acid has more than one chiral centre.

2 The molecular formula of tartaric acid is $C_4H_4O_6$.

3 One molecule of tartaric acid produces four hydrogen ions in aqueous solution.

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

27 A carboxylic acid, P, has no chain isomers. It reacts with an alcohol, Q, that has only one positional isomer.

What could be the ester formed from a reaction between P and Q?

A butyl propanoate

B ethyl butanoate

C pentyl ethanoate

D propyl pentanoate

28 Which pair includes a hydrocarbon without a chiral centre?

A $CH_3CH_2CH_2CH(CH_3)CH_2CH_3$ $CH_3CH(CH_3)CH(CH_3)CH_2CH_3$

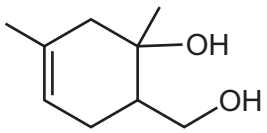
B $CH_3CH_2CH_2CH(CH_2CH_3)CH_3$ $CH_3CH_2CH_2CH(CH_3)CH_2CH_3$

C $CH_3CH_2CH_2CH(CH_3)CH_2CH_3$ $CH_3CH_2CH(CH_3)CH(CH_3)_2$

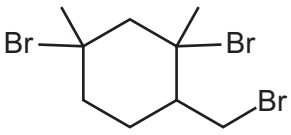
D $CH_3CH(CH_2CH_3)CH(CH_3)CH_3$ $CH_3CH(CH_3)CH_2CH(CH_3)_2$

29 What is the major product formed when compound R is warmed with an excess of HBr?

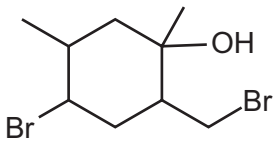
R



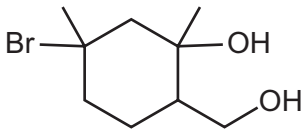
A



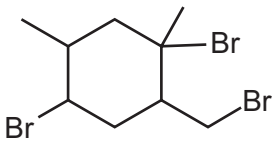
B



C



D



30 *cis*-but-2-ene reacts with cold dilute acidified potassium manganate(VII) solution to give product X.

cis-but-2-ene reacts with hot concentrated acidified potassium manganate(VII) solution to give product Y.

Which row describing the reactions of X and Y is correct?

	when sodium metal is added to separate samples of X and Y	when sodium hydroxide solution is added to separate samples of X and Y
A	both X and Y will react	neither X nor Y will react
B	both X and Y will react	only one of X and Y will react
C	only one of X and Y will react	neither X nor Y will react
D	only one of X and Y will react	only one of X and Y will react

31 For which reaction will the major organic product have the lowest relative molecular mass?

A Bromoethane is heated under reflux with an aqueous solution of sodium hydroxide.

B Bromoethane is heated under reflux with a solution of sodium cyanide in ethanol.

C 2-bromopropane is heated under reflux with an aqueous solution of sodium hydroxide.

D 2-bromopropane is heated under reflux with concentrated ethanolic sodium hydroxide.

32 C_4H_9Cl reacts with warm dilute aqueous sodium hydroxide solution.

Which isomer of C_4H_9Cl will form the most stable cation intermediate?

A 1-chlorobutane

B 2-chlorobutane

C 1-chloro-2-methylpropane

D 2-chloro-2-methylpropane

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33 1.0 mol of an organic compound, J, requires 6.0 mol of oxygen for complete combustion.

1.0 mol of J reacts with sodium, producing 0.50 mol of a gas that gives a 'pop' with a lighted splint.

J reacts with an excess of hot acidified potassium manganate(VII) to produce an organic compound which gives an orange-red precipitate with 2,4-DNPH reagent.

Which compound is J?

A but-1-ene

B butan-2-ol

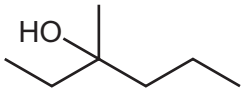
C propan-2-ol

D 2-methylpropan-2-ol

34 Structural isomerism and stereoisomerism should be considered when answering this question.

3-methylhexan-3-ol reacts with hot concentrated sulfuric acid to form several isomeric compounds with the molecular formula C_7H_{14}.

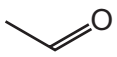
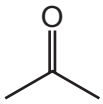
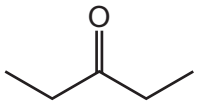
3-methylhexan-3-ol



How many isomeric compounds could be formed in this reaction?

A 3 **B** 4 **C** 5 **D** 6

35 The table shows a student's predictions for the reactions of three compounds.

	compound	alkaline I_2(aq)	Fehling's reagent	Tollens' reagent
1		✓	✓	✓
2		✓	✗	✗
3		✗	✗	✗

key
✓ = reaction occurs
✗ = no reaction

Which rows show the correct predictions?

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

36 Which mechanism describes the reaction of aldehydes and ketones with HCN + NaCN?

A electrophilic addition

B electrophilic substitution

C nucleophilic addition

D nucleophilic substitution

37 Propyl propanoate can be synthesised in three steps using propanenitrile as the only organic starting material.

In step 1, the nitrile is converted into compound X.

In step 2, compound X is converted into compound Y.

In step 3, compound Y is reacted with more of compound X to give propyl propanoate.

$$CH_3CH_2CN \xrightarrow{\text{step 1}} X \xrightarrow{\text{step 2}} Y \xrightarrow{\text{step 3}} CH_3CH_2CO_2CH_2CH_2CH_3$$

Which reagents are suitable for carrying out step 1 and step 2?

	step 1	step 2
A	HCl(aq)	conc. H_2SO_4
B	HCl(aq)	LiA$l$$H_4$
C	NaOH(aq)	conc. H_2SO_4
D	NaOH(aq)	$NaBH_4$

38 The ester $CH_3CH_2CO_2CH_3$ is hydrolysed by boiling with aqueous sodium hydroxide.

Which compound is one of the products?

A ethanol

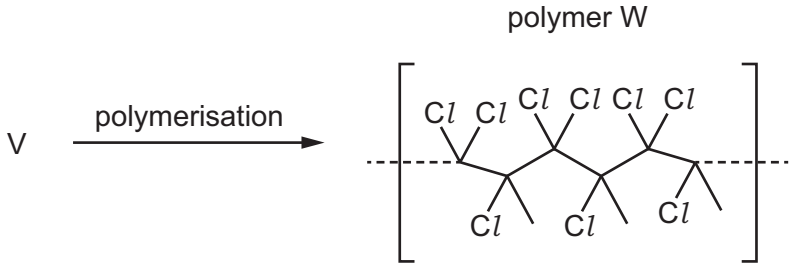
B propan-1-ol

C sodium methanoate

D sodium propanoate

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39 Compound V polymerises to form polymer W. A section of polymer W is shown.



What is the correct name of compound V?

A 1,1,2-trichlorobutene

B 1,1,2-trichloroethene

C 1,1,2-trichloropropene

D 1,1,2-trichloro-2-methylethene

40 A molecule of an organic compound, P, contains three carbon atoms and shows a strong absorption at 1720 cm^{-1} in its infrared spectrum.

P is reacted with an excess of hot acidified potassium dichromate(VI) forming organic product Q.

Q shows a strong absorption at 1700 cm^{-1} and a strong, broad absorption centred at 2800 cm^{-1} in its infrared spectrum.

bond	functional group 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 P?

A propanal

B propanone

C propan-1-ol

D propan-2-ol

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

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The Periodic Table of Elements

Group																		
1	2											13	14	15	16	17	18
								1 H hydrogen 1.0									2 He helium 4.0
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 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 oganesson –

Key

atomic number
atomic symbol
name
relative atomic mass

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 –

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CHEMISTRY **9701/13**

Paper 1 Multiple Choice **October/November 2022**

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.

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1 Which sample contains the same number of the named species as the number of molecules in 35.5 g of chlorine?

A atoms in 16 g of sulfur

B atoms in 23 g of sodium

C ions in 74.5 g of potassium chloride

D molecules in 88 g of carbon dioxide

2 Mixture R consists of one mole of C_3H_6 and one mole of C_4H_6.

What is the minimum number of moles of oxygen molecules needed for complete combustion of mixture R?

A 6.5 **B** 7 **C** 10 **D** 20

3 Which statement about the electrons in a ground state carbon atom is correct?

A Electrons are present in four different energy levels.

B There are more electrons in p orbitals than there are in s orbitals.

C The occupied orbital of highest energy is spherical.

D The occupied orbital of lowest energy is spherical.

4 For the element sulfur, which pair of ionisation energies has the largest difference between them?

A third and fourth ionisation energies

B fourth and fifth ionisation energies

C fifth and sixth ionisation energies

D sixth and seventh ionisation energies

5 How many σ bonds are present in one $H–C{\equiv}C–C(CH_3)=CH(CH_3)$ molecule?

A 5 **B** 11 **C** 13 **D** 16

6 Which molecule has an equal number of bonding electrons and lone-pair electrons?

A BH_3 **B** CO_2 **C** F_2O **D** SO_2

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7 The table shows properties of four solids held together by different types of bonding.

Which row correctly describes the properties of a solid with a giant covalent structure?

	melting point	solubility in polar solvents
A	high	insoluble
B	high	soluble
C	low	insoluble
D	low	soluble

8 The carbonate of an s-block element is reacted with an excess of hydrochloric acid.

0.833 g of the carbonate releases 200 cm^3 of gas, measured under room conditions.

What is the identity of the metal carbonate?

A Na_2CO_3 **B** K_2CO_3 **C** $MgCO_3$ **D** $CaCO_3$

9 The enthalpy changes of formation, $\Delta H_f^{\ominus}$, of both PCl_3 and PCl_5 are exothermic.

PCl_3 reacts with chlorine.

$$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s) \qquad \Delta H^{\ominus}_{reaction} = -124\ kJ\ mol^{-1}$$

Which pair of statements is correct?

	statement 1	statement 2
A	$\Delta H^{\ominus}_{reaction}$ is less negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.
B	$\Delta H^{\ominus}_{reaction}$ is more negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.
C	$\Delta H^{\ominus}_{reaction}$ is less negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is not needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.
D	$\Delta H^{\ominus}_{reaction}$ is more negative than $\Delta H_f^{\ominus}$ (PCl_5).	The Cl_2 bond energy is not needed in calculating $\Delta H^{\ominus}_{reaction}$ from enthalpies of formation.

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10 A student mixes 25.0 cm^3 of 0.350 mol dm^{-3} sodium hydroxide solution with 25.0 cm^3 of 0.350 mol dm^{-3} hydrochloric acid. The temperature increases by 2.5 °C. No heat is lost to the surroundings.

The final mixture has a specific heat capacity of 4.2 J cm^{-3} K^{-1}.

What is the molar enthalpy change for the reaction?

A –150 kJ mol^{-1}

B –60 kJ mol^{-1}

C –30 kJ mol^{-1}

D –0.15 kJ mol^{-1}

11 Ammonium ions are converted into nitrate ions by bacteria.

What is the change in the oxidation number of nitrogen?

A –6 **B** +6 **C** +8 **D** +9

12 Sodium dichromate(VI), $Na_2Cr_2O_7$, reacts with hydrogen peroxide, H_2O_2, producing Cr^{3+} ions, water and oxygen.

What is the correctly balanced ionic equation for this reaction?

A $Cr_2O_7^{2-} + 2H^+ + H_2O_2 \rightarrow 2Cr^{3+} + 2H_2O + 4O_2$

B $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

C $Cr_2O_7^{2-} + 8H^+ + 6H_2O_2 \rightarrow 2Cr^{3+} + 10H_2O + 6O_2$

D $Cr_2O_7^{2-} + 14H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

13 In which equilibrium reaction is the position of equilibrium moved to the right-hand side by increasing the temperature and also by decreasing the pressure?

A $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $\Delta H = 40$ kJ mol^{-1}

B $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = 58$ kJ mol^{-1}

C $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197$ kJ mol^{-1}

D $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $\Delta H = -10$ kJ mol^{-1}

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14 Ethanol is produced industrially by reacting ethene and steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

K_p has a value of 1.8×10^{-5} and the partial pressures of the reactants at equilibrium are shown.

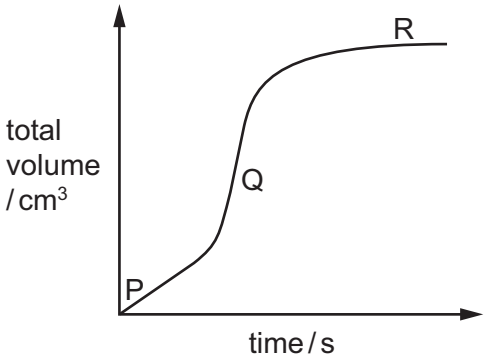
reactant	partial pressure / kPa
ethene	4.8×10^3
steam	2.8×10^3

Which row is correct?

	partial pressure of ethanol at equilibrium / kPa	units of K_p
A	2.42×10^2	kPa^{-1}
B	2.42×10^2	kPa
C	7.47×10^{11}	kPa^{-1}
D	7.47×10^{11}	kPa

15 A large excess of magnesium ribbon is added to dilute hydrochloric acid and the volume of hydrogen gas produced is measured as the reaction proceeds. The reaction is exothermic.

The results are shown.



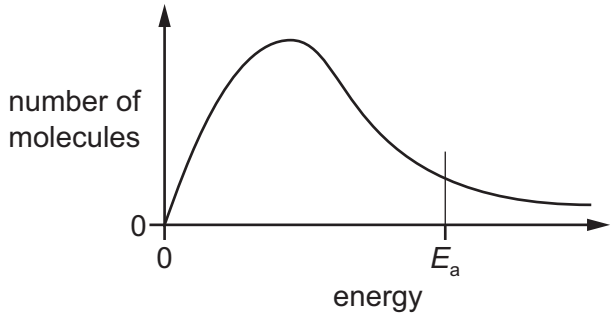
Which row explains the changes in the rate of reaction between points P and Q and between points Q and R?

	between points P and Q	between points Q and R
A	the reaction temperature is increasing	the acid concentration is falling
B	the reaction temperature is increasing	the magnesium has been used up
C	magnesium's surface area is decreasing	the acid concentration is falling
D	magnesium's surface area is decreasing	the magnesium has been used up

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16 Measurements are made to determine the activation energy, E_a, of a reaction.

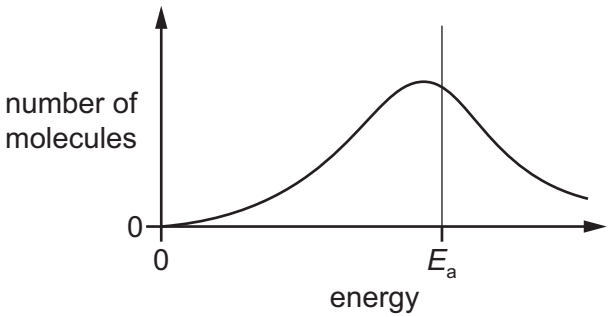
The diagram shows E_a on the Boltzmann distribution at temperature T_1.



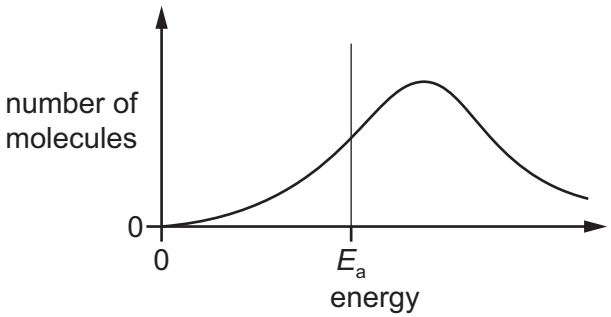
Measurements are then made at a higher temperature, T_2.

Which diagram correctly shows the Boltzmann distribution and E_a at T_2?

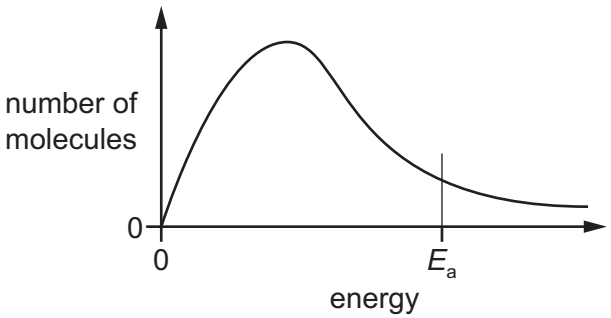
A



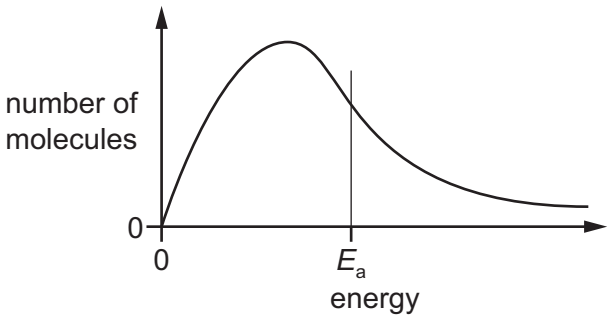
B



C



D



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17 The electrical conductivities of two compounds, Y and Z, are shown.

	for Y	for Z
conductivity of the compound in the liquid state	good	does not conduct
conductivity of the mixture obtained by adding the compound to water	good	good

What are compounds Y and Z?

	Y	Z
A	Al_2O_3	$SiCl_4$
B	$NaCl$	Al_2O_3
C	$NaCl$	$SiCl_4$
D	$SiCl_4$	Al_2O_3

18 Which row describes the relative sizes of the ionic radii of Na^+, Mg^{2+} and S^{2-}?

	smallest ⟶		largest
A	Na^+	Mg^{2+}	S^{2-}
B	Mg^{2+}	Na^+	S^{2-}
C	S^{2-}	Na^+	Mg^{2+}
D	S^{2-}	Mg^{2+}	Na^+

19 The oxides BaO, CaO, MgO and SrO all produce alkaline solutions when added to water.

Which oxide produces the saturated solution with the highest pH?

A BaO **B** CaO **C** MgO **D** SrO

20 Which row is correct?

	the temperature needed to decompose Group 2 metal nitrates	the solubility of Group 2 sulfates
A	decreases down the group	decreases down the group
B	decreases down the group	increases down the group
C	increases down the group	increases down the group
D	increases down the group	decreases down the group

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21 Which statement about Group 17 elements and compounds is correct?

A Sodium chloride produces chlorine when reacted with concentrated sulfuric acid.

B Sodium chloride produces chlorine when reacted with bromine.

C Sodium bromide produces bromine when reacted with concentrated sulfuric acid.

D Sodium bromide produces bromine when reacted with iodine in aqueous potassium iodide.

22 Chlorine is bubbled through $100\,cm^3$ of hot $4.0\,mol\,dm^{-3}$ sodium hydroxide until the reaction is complete.

$$6NaOH(aq) + xCl_2(aq) \rightarrow yNaCl(aq) + zNaClO_3(aq) + 3H_2O(l)$$

Which row is correct?

	x	$[Na^+](aq)$ after reaction / $mol\,dm^{-3}$
A	3	4.0
B	3	less than 4.0
C	6	4.0
D	6	less than 4.0

23 Which statement about ammonia or the ammonium ion is correct?

A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.

B Silver iodide is soluble in a concentrated aqueous solution of ammonia.

C The ammonium ion has the same number of electrons as a methane molecule.

D The square planar ammonium ion contains a dative covalent bond.

24 Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.

Which reaction shows how the catalyst is reformed?

A $N_2 + 2O_2 \rightleftharpoons 2NO_2$

B $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

C $N_2 + O_2 \rightarrow 2NO$

D $NO + \frac{1}{2}O_2 \rightarrow NO_2$

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25 Separate 1.0 g samples of Na_2O, MgO, Al_2O_3, SiO_2, NaCl, $MgCl_2$, Al_2Cl_6 and $SiCl_4$ are added to separate beakers containing water and stirred.

The number of beakers containing a white solid is Q.

An excess of NaOH(aq) is then added to each beaker and stirred.

The number of beakers now containing a white solid is R.

Which row is correct?

	Q	R
A	3	2
B	3	3
C	4	3
D	4	4

26 Which pair of alcohols are isomers of each other?

A butan-1-ol and 2,2-dimethylpropan-1-ol

B butan-2-ol and 2-methylpropan-2-ol

C pentan-1-ol and 2-methylpropan-2-ol

D propan-2-ol and 2-methylpropan-2-ol

27 How many chiral carbon atoms are there in one molecule of 2,2,4,5-tetramethylhexan-3-ol?

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

28 Which pair of reagents react together in a redox reaction?

A CH_3CHCH_2 + Br_2

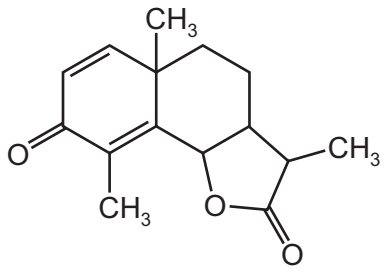
B $CH_3CH_2CH_2OH$ + concentrated H_3PO_4

C CH_3COCH_3 + HCN

D $HCO_2C_2H_5$ + dilute H_2SO_4

29 The structure of santonin is shown.

santonin



Santonin is first treated with warm dilute H_2SO_4. The product of this reaction is treated with cold dilute acidified $KMnO_4$. A final product, Q, is obtained.

How many atoms of hydrogen in each molecule of product Q will react with sodium metal?

A 2 **B** 4 **C** 5 **D** 6

30 Compound R can be formed from 1-bromopropane using a nucleophilic substitution reaction followed by an oxidation reaction.

What is the identity of R?

A propanoic acid

B propanone

C propylamine

D propyl ethanoate

31 Three colourless liquids with the following formulae are contained in separate unlabelled bottles.

$CH_3CH_2CO_2H$ $CH_3CH(OH)CO_2H$ CH_3COCO_2H

Which two tests, carried out on separate samples of each liquid, will successfully identify each liquid?

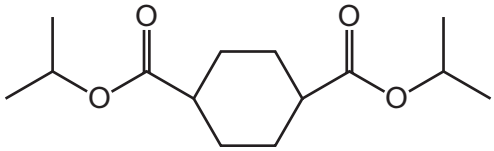
	test 1	test 2
A	$NaHCO_3$	2,4-DNPH reagent
B	$NaHCO_3$	Tollens' reagent
C	warm acidified dichromate	2,4-DNPH reagent
D	warm acidified dichromate	Tollens' reagent

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32 An alcohol, X, reacts with a dicarboxylic acid, Y, to form a double ester, Z.

The diagram shows the structure of the ester.

Z



Which row about the reactants forming ester Z is correct?

	the class of alcohol X	the shape of the ring in Y
A	secondary	non-planar
B	secondary	planar
C	tertiary	non-planar
D	tertiary	planar

33 W reacts with alkaline I_2(aq) to form a yellow precipitate and $CH_3CH_2CO_2^-$ ions.

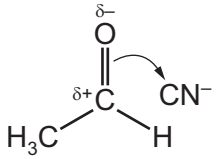
Which row identifies W and the yellow precipitate?

	identity of W	identity of yellow precipitate
A	butanone	CHI_3
B	butanone	CH_3I
C	propanone	CHI_3
D	propanone	CH_3I

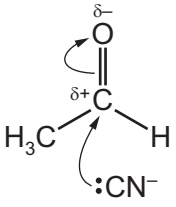
34 Ethanal reacts with hydrogen cyanide in the presence of KCN to produce a hydroxynitrile.

What is the first step in the mechanism of this reaction?

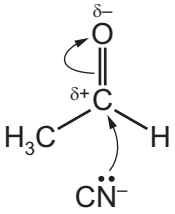
A



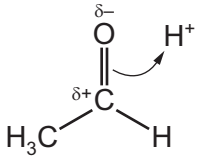
B



C



D

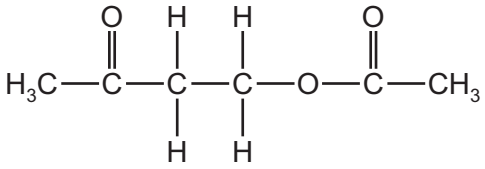


35 Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomeric compounds with molecular formula $C_5H_6O_4$ contain two $–CO_2H$ groups and one C=C double bond?

A 5 **B** 6 **C** 7 **D** 8

36 Compound X reacts with ethanoic acid in the presence of an H^+ catalyst to produce the compound shown.



What is the molecular formula of compound X?

A C_2H_4O **B** $C_2H_6O_2$ **C** C_4H_8O **D** $C_4H_8O_2$

37 2-bromopropane reacts with hot ethanolic sodium hydroxide.

Which substance is the major product of this reaction?

A propan-1-ol

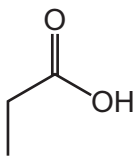
B propan-2-ol

C 2-hydroxypropene

D propene

38 Which compounds can be used to make Y in a single-step reaction?

Y



1 propanenitrile

2 ethanenitrile

3 propyl ethanoate

4 ethyl propanoate

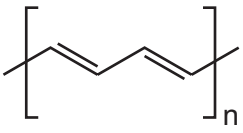
A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

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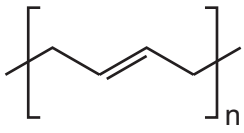
39 The monomer buta-1,3-diene can undergo addition polymerisation in various ways. Two of the polymers that can be made are called *cis*-poly(buta-1,3-diene) and *trans*-poly(buta-1,3-diene). In these names *cis* and *trans* have their usual meanings.

What is the structure of the repeat unit of *cis*-poly(buta-1,3-diene)?

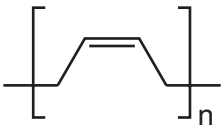
A



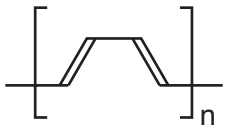
B



C



D



40 In the mass spectrum of a compound, Z, the relative abundances of the M and M+1 peaks are in the ratio 13 : 1.

What is compound Z?

A butyl butanoate

B hexan-3-one

C 2,2,3-trimethylhexane

D 3,3-dimethylpentan-1-ol

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

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The Periodic Table of Elements

Group																		
1	2											13	14	15	16	17	18
								1 H hydrogen 1.0									2 He helium 4.0
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 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 oganesson –

Key

atomic number
atomic symbol
name
relative atomic mass

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 –

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