



Cambridge International AS & A Level

CHEMISTRY

9701/11

Paper 1 Multiple Choice

October/November 2021

1 hour

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)
Data booklet

INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.

This document has **16** pages. Any blank pages are indicated.

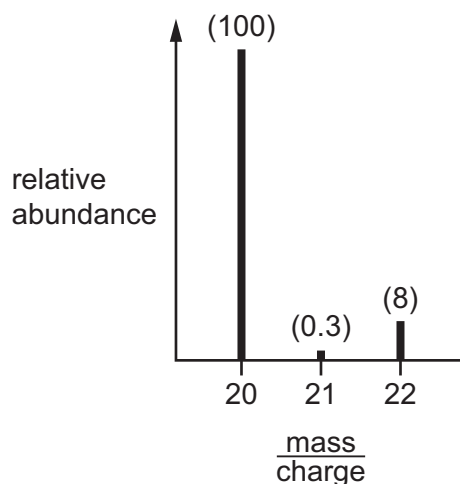


Section A

For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

Use of the Data Booklet may be appropriate for some questions.

- 1 The mass spectrum of a sample of neon is shown. The relative abundance of each peak is written in brackets above it.



What is the relative atomic mass, A_r , of this sample of neon?

- A** 20.15 **B** 20.20 **C** 21.00 **D** 21.82
- 2 2.0 g of ammonium nitrate, NH_4NO_3 , decomposes to give 0.90 g of water and a single gas.

What is the identity of the gas?

- A** NO **B** NO_2 **C** N_2O **D** N_2
- 3 Which of these elements has the highest fifth ionisation energy?

- A** C **B** N **C** P **D** Si

- 4 The ion X^{2+} has the same electronic configuration as the atom Kr.

What is the electronic configuration of an atom of X?

- A** $[\text{Ar}]4s^23d^{10}4p^6$
B $[\text{Ar}]4s^23d^{10}4p^65s^2$
C $[\text{Ar}]4s^24d^{10}4p^6$
D $[\text{Ar}]4s^24d^{10}4p^65s^2$

- 5 Which type of interaction exists between water molecules and metal cations in aqueous solution?
- A dipole-dipole interactions
B hydrogen bonds
C ion-dipole interactions
D ionic bonds

- 6 Which substance shows the greatest deviation from the properties of an ideal gas under room conditions?

A $\text{CO}_2(\text{g})$ B $\text{H}_2(\text{g})$ C $\text{Ne}(\text{g})$ D $\text{NH}_3(\text{g})$

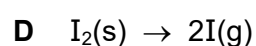
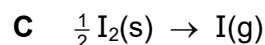
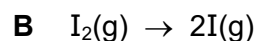
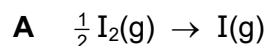
- 7 In order to determine the enthalpy of neutralisation of a strong acid and a strong alkali, 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid. The increase in temperature is 12°C .

In a second experiment, the same method is used, but 50.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 50.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

What is the increase in temperature in the second experiment?

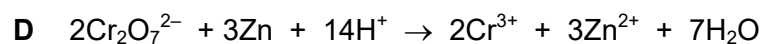
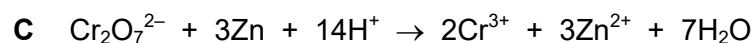
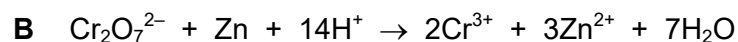
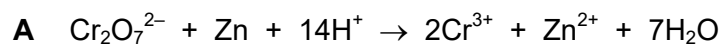
A 6°C B 12°C C 24°C D 48°C

- 8 Which equation represents the enthalpy change of atomisation of iodine?

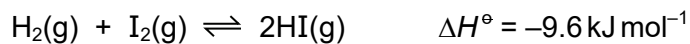


- 9 Zinc atoms can be oxidised to Zn^{2+} ions by dichromate(VI) ions in acid solution. Chromium is reduced to Cr^{3+} in this reaction.

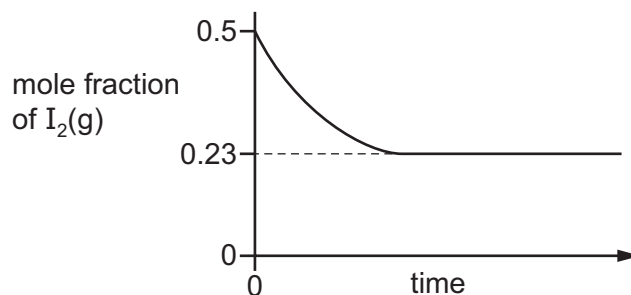
Which equation is correct?



10 The equation shows that $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ react to form an equilibrium mixture.



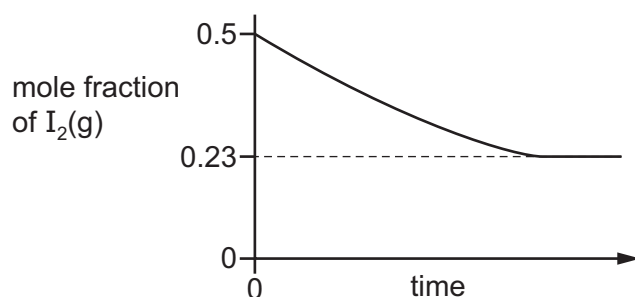
A mixture containing equal amounts of $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ is made at temperature T_1 and the composition of the mixture is monitored. A graph of the results is shown.



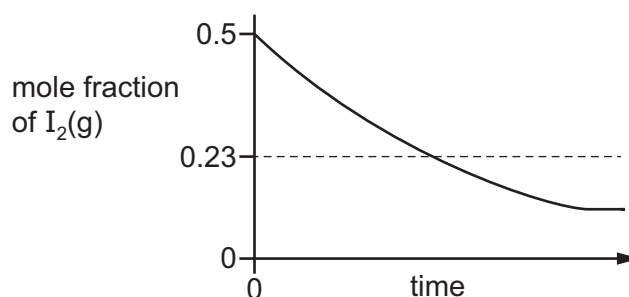
The experiment is repeated at a lower temperature, T_2 .

Which new graph would be obtained?

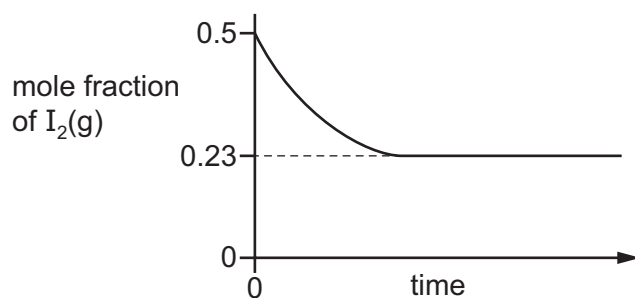
A



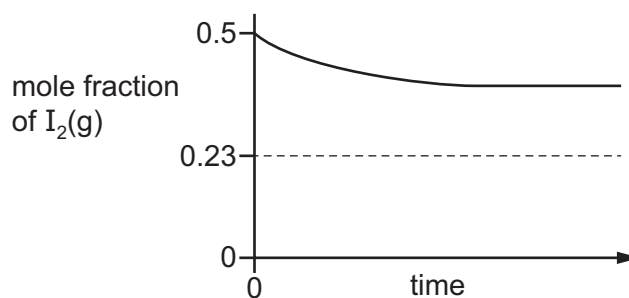
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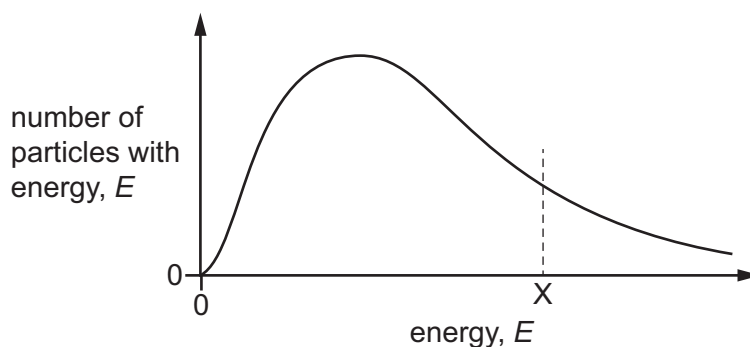
C



D

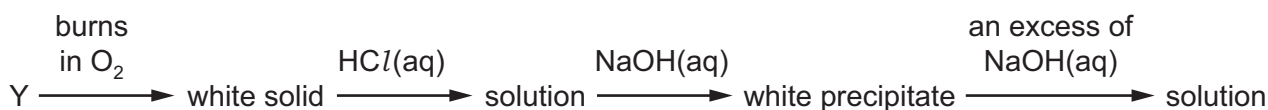


- 11 The diagram shows the Boltzmann distribution of energies for a reactant gas. For a particular reaction, the activation energy is X .



Which change to the diagram occurs if an effective catalyst is added at the same temperature?

- A** More particles will possess higher values of E .
B The peak will move to the left.
C The peak will move to the right.
D The value of the activation energy decreases.
- 12 Which element requires the least number of moles of oxygen for the complete combustion of 1 mol of its atoms?
- A** aluminium
B magnesium
C phosphorus
D sodium
- 13 An element, Y , reacts according to the following sequence.



What could be element Y ?

- A** Na **B** Mg **C** Al **D** P
- 14 In which list are all three compounds soluble in water?
- A** barium chloride, calcium carbonate, magnesium hydroxide
B barium hydroxide, calcium hydroxide, strontium carbonate
C barium chloride, barium hydroxide, magnesium sulfate
D barium sulfate, calcium sulfate, magnesium hydroxide

- 15 Anhydrous magnesium nitrate, $\text{Mg}(\text{NO}_3)_2$, decomposes when heated, giving a white solid and a mixture of two gases, X and Y.

Y is oxygen.

What is the ratio $\frac{\text{mass of X released}}{\text{mass of Y released}}$?

- A $\frac{1}{0.174}$ B $\frac{1}{0.267}$ C $\frac{1}{0.348}$ D $\frac{1}{3.43}$

- 16 In a series of nine experiments, to test the reactivity of the halogens, an aqueous solution of each halogen is added to an equal volume of an aqueous solution containing halide ions, as shown in the table.

halogen solution	halide solution		
	sodium chloride (aq)	sodium bromide (aq)	sodium iodide (aq)
chlorine (aq)	experiment 1	experiment 2	experiment 3
bromine (aq)	experiment 4	experiment 5	experiment 6
iodine (aq)	experiment 7	experiment 8	experiment 9

The nine resulting mixtures are then shaken separately with an equal volume of hexane. The nine tubes are left to stand so that the aqueous and organic solvents separate into layers.

How many test-tubes contain a purple upper hexane layer?

- A 1 B 2 C 3 D 5

- 17 Z is a compound of sodium, chlorine and oxygen.

It contains 45.1% by mass of oxygen.

Z is prepared by reacting sodium hydroxide with chlorine.

Which row shows the conditions used for the reaction and the oxidation state of chlorine in Z?

	reaction conditions	oxidation state of Cl in Z
A	cold dilute NaOH	+1
B	cold dilute NaOH	+5
C	hot concentrated NaOH	+1
D	hot concentrated NaOH	+5

18 Which row is correct?

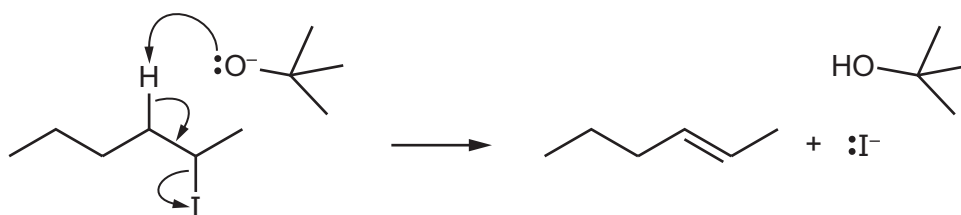
	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal	regular tetrahedral	σ	σ
B	pyramidal	regular tetrahedral	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ

19 The table describes two possible environmental consequences of adding too much ammonium nitrate fertiliser to the soil.

Which row is correct?

	increased plant growth in rivers	photochemical smog
A	x	x
B	✓	x
C	x	✓
D	✓	✓

20 Hex-2-ene can be made by the reaction shown.



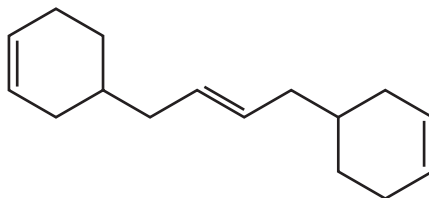
Which statement about this reaction is correct?

- A** $(\text{CH}_3)_3\text{CO}^-$ is behaving as a Brønsted-Lowry base.
- B** $(\text{CH}_3)_3\text{CO}^-$ is behaving as an oxidising agent.
- C** The C–I bond breaks via homolytic fission.
- D** This is a hydrolysis reaction.

- 21 Structural isomerism **only** should be considered when answering this question.

Molecule X contains three C=C double bonds. One mole of X is reacted with three moles of HBr. The carbon skeleton is unchanged.

molecule X



How many different products are formed?

- A 3 B 4 C 6 D 8
- 22 Structural isomerism **and** stereoisomerism should be considered when answering this question.

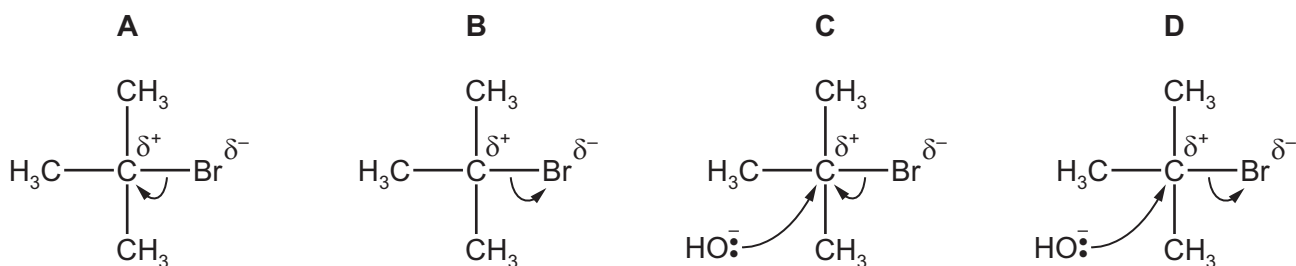
A colourless liquid, $C_5H_{11}Cl$, exists as a mixture of two optical isomers.

When heated with sodium hydroxide in ethanol, a mixture of **only two** alkenes is formed.

What could the colourless liquid be?

- A $(CH_3CH_2)_2CHCl$
 B $CH_3CH_2CH_2CHClCH_3$
 C $CH_3CH_2CCl(CH_3)_2$
 D $(CH_3)_2CHCHClCH_3$
- 23 When 2-bromo-2-methylpropane reacts with aqueous sodium hydroxide, an alcohol is formed.

Which diagram describes the first step in the reaction mechanism?



- 24 When an organic compound, Q, is treated with phosphorus pentachloride, fumes of hydrogen chloride are evolved. When Q is warmed with acidified aqueous potassium dichromate(VI), the solution turns green.

What is Q?

- A $\text{CH}_3\text{CH}_2\text{CHO}$
- B $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$
- C $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
- D $(\text{CH}_3)_3\text{COH}$

- 25 Alcohol Y gives a yellow precipitate with alkaline aqueous iodine. It can be oxidised to give a mixture of products including substance Z. Substance Z gives a red-brown precipitate with Fehling's solution.

Which alcohol could be Y?

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

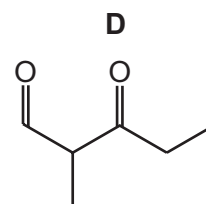
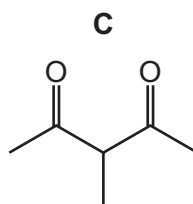
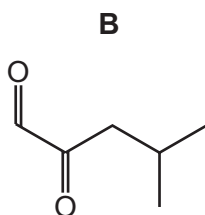
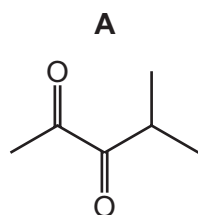
- 26 $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ reacts with hydrogen cyanide to form an organic product called a cyanohydrin.

Which statement is correct?

- A The cyanohydrin product has one chiral centre.
- B The cyanohydrin product is formed by electrophilic addition.
- C The cyanohydrin product is formed via an intermediate which contains a C–OH group.
- D The formation of the cyanohydrin product requires the use of cyanide ions as a catalyst.

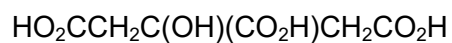
- 27 Reduction of compound R with LiAlH_4 gives the compound 4-methylpentane-2,3-diol.

What could be the identity of compound R?



- 28 Citric acid is found in lemon juice.

citric acid



Which volume of 0.40 mol dm^{-3} sodium hydroxide solution is required to neutralise a solution containing 0.0050 mol of citric acid?

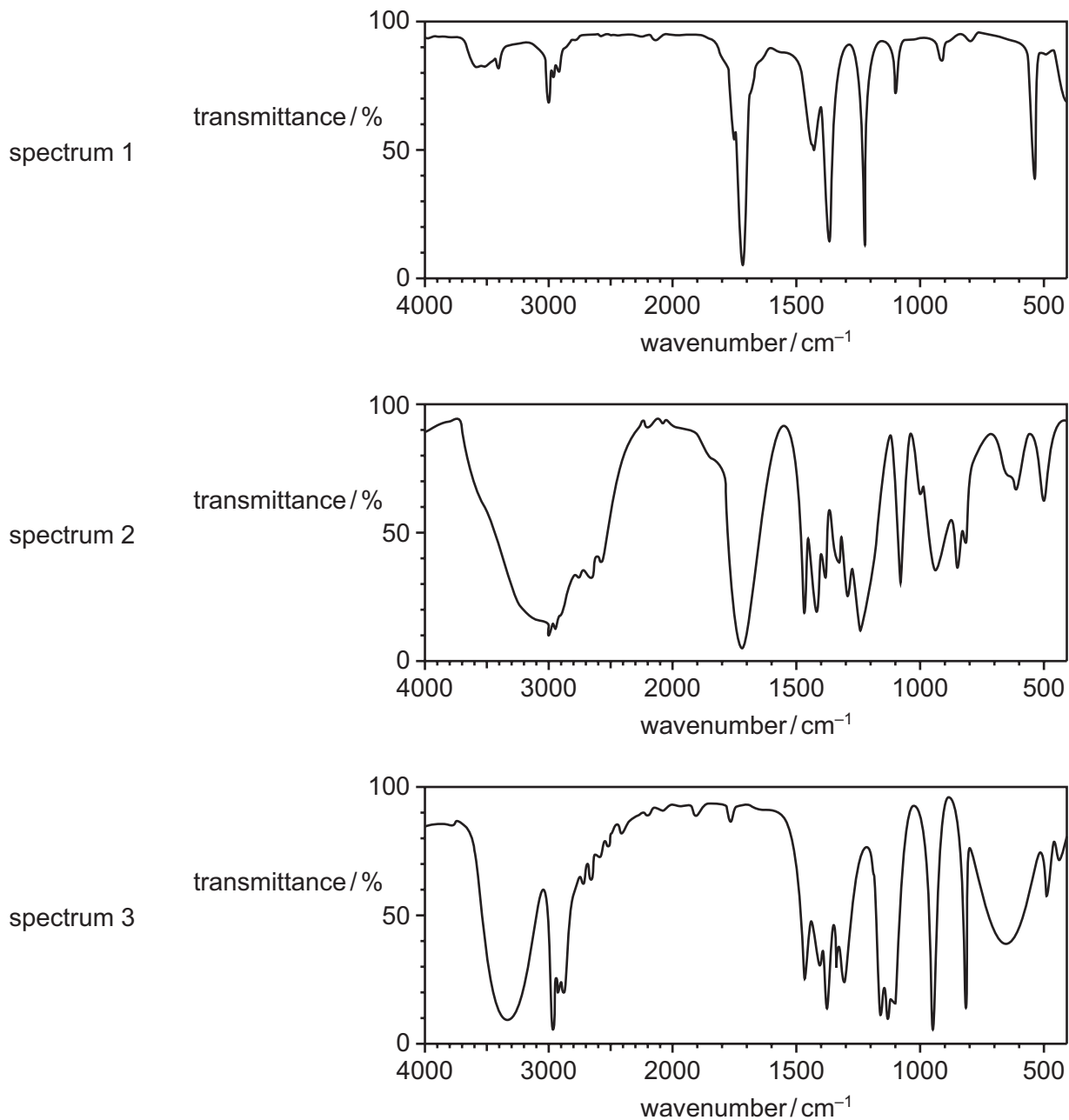
- A 12.5 cm^3 B 25.0 cm^3 C 37.5 cm^3 D 50.0 cm^3
- 29 The structural formula of an ester is $(\text{CH}_3)_2\text{CHOCO}(\text{CH}_2)_2\text{CH}_3$.

This ester is boiled with aqueous hydrochloric acid.

Which two products are formed?

- A propan-1-ol and butanoic acid
B propan-2-ol and butanoic acid
C propan-1-ol and propanoic acid
D propan-2-ol and propanoic acid

30 The infra-red spectra of three organic compounds are shown.



What could the three compounds be?

	spectrum 1	spectrum 2	spectrum 3
A	propanoic acid	propanone	propan-2-ol
B	propanone	propanoic acid	propan-2-ol
C	propanone	propan-2-ol	propanoic acid
D	propan-2-ol	propanoic acid	propanone

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

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

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

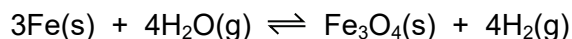
No other combination of statements is used as a correct response.

Use of the Data Booklet may be appropriate for some questions.

31 Which changes can be used to measure the rates of chemical reactions?

- 1** the decrease in concentration of a reactant per unit time
- 2** the rate of appearance of a product
- 3** the increase in total volume of gas per unit time at constant pressure

32 Iron reacts with steam to produce hydrogen and an oxide of iron.



A system containing all four substances is at equilibrium.

Which changes will decrease the mass of Fe present at equilibrium?

- 1** addition of steam at constant pressure
- 2** increase in overall pressure
- 3** addition of an effective catalyst

33 Ethylene glycol, $\text{HOCH}_2\text{CH}_2\text{OH}$, is used as a de-icer. It allows ice to melt at temperatures below 0°C .

Which statements are correct?

- 1** Ethylene glycol disrupts the extensive network of hydrogen bonds in ice.
- 2** Ethylene glycol molecules form hydrogen bonds with other ethylene glycol molecules.
- 3** Ethylene glycol molecules will dissolve in the water formed from the ice.

34 Which molecules contain at least one unpaired electron?

- 1 NO
- 2 NO₂
- 3 NH₃

35 Which elements form a chloride in which both covalent bonding and coordinate (dative covalent) bonding are present?

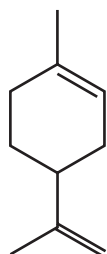
- 1 Al
- 2 Si
- 3 Mg

36 Which statements about calcium oxide are correct?

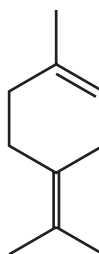
- 1 It can be reduced by heating with magnesium.
- 2 It is produced when calcium nitrate is heated.
- 3 It reacts with cold water.

37 A diketo acid is a compound with two ketone groups and one carboxylic acid group.

limonene



terpinolene



Which statements about the reactions of limonene and terpinolene are correct?

- 1 When reacted with an excess of hydrogen and a nickel catalyst, limonene and terpinolene produce the same compound.
- 2 An excess of hot concentrated acidified KMnO₄ reacts with limonene and with terpinolene to form different diketo acids.
- 3 The reactions of limonene and terpinolene with an excess of Br₂ produce positional isomers with the same number of chiral carbon atoms.

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

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

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

38 One molecule of dodecane, $C_{12}H_{26}$, is cracked, producing three product molecules, X, Y and Z.

X is a straight chain alkane. Y and Z are straight chain alkenes with different M_r values.

Which statements about X, Y and Z are correct?

- 1** If Y and Z are but-1-ene and ethene respectively, X will be hexane.
- 2** If X is butane, then Y and Z could both show *cis-trans* isomerism.
- 3** X could be octane.

39 Which statements about chlorofluoroalkanes are correct?

- 1** Both the C–Cl and C–F bonds are readily dissociated by ultra-violet light.
- 2** They have caused ozone depletion.
- 3** They are relatively chemically inert.

40 Which reactions of propan-1-ol have water as one of the products?

- 1** passing propan-1-ol vapour over hot Al_2O_3
- 2** mixing propan-1-ol with warm ethanoic acid and a few drops of concentrated sulfuric acid
- 3** warming propan-1-ol with HBr

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CHEMISTRY

9701/12

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October/November 2021

1 hour

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Section A

For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

Use of the Data Booklet may be appropriate for some questions.

- 1 Compound X consists of 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

What is the empirical formula of compound X?

- A** CH₂O **B** C₂H₂O **C** C₂H₄O **D** CHO

- 2 Which statement is correct?

- A** 1.0 g of hydrogen gas contains 3.0×10^{23} atoms.
B 4.0 g of helium gas contains 1.2×10^{24} atoms.
C 16 g of methane gas contains 3.0×10^{24} atoms.
D 44 g of carbon dioxide gas contains 6.0×10^{23} atoms.

- 3 Technetium (Tc) is a second row transition element that does not occur naturally on Earth. One of its isotopes has 56 neutrons.

What is the nucleon number of this isotope?

- A** 43 **B** 56 **C** 99 **D** 112

- 4 Which atom has more unpaired electrons than paired electrons in orbitals of principal quantum number 2?

- A** carbon
B nitrogen
C oxygen
D fluorine

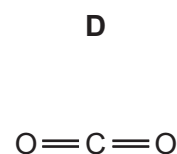
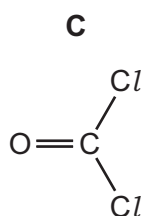
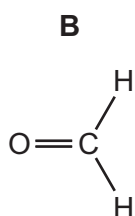
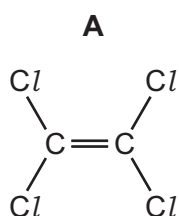
- 5 Atom X is the central atom in a molecule.

In this molecule, atom X has four pairs of valence electrons in its outer shell.

The four pairs of valence electrons include at least one bond pair and at least one lone pair.

What could be a possible shape for the molecule?

- A** linear
B non-linear
C trigonal bipyramidal
D trigonal planar
- 6 Which molecule has the largest overall dipole?



- 7 The strength of hydrogen bonding increases as the electronegativity of the element bonded to hydrogen increases.

Some information for a range of hydrides is given.

hydride	boiling point /K
PH ₃	185
HCl	188
HF	293
H ₂ O	373

Which statement and reason about these hydrides is correct?

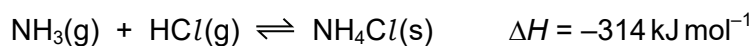
- A** The boiling point of PH₃ is much lower than the boiling point of H₂O because PH₃ does not form hydrogen bonds or instantaneous dipole-induced dipole forces between its molecules.
- B** The boiling point of HF is higher than the boiling point of HCl because the bond energy of H-F is greater than the bond energy of H-Cl.
- C** The boiling point of H₂O is higher than the boiling point of HF because each hydrogen bond between the H₂O molecules is stronger than each hydrogen bond between HF molecules.
- D** The boiling points of PH₃ and HCl are similar because the molecules of PH₃ and HCl have the same number of electrons and similar intermolecular forces.

- 8 The general gas equation can be used to calculate the value of the M_r of a gas.

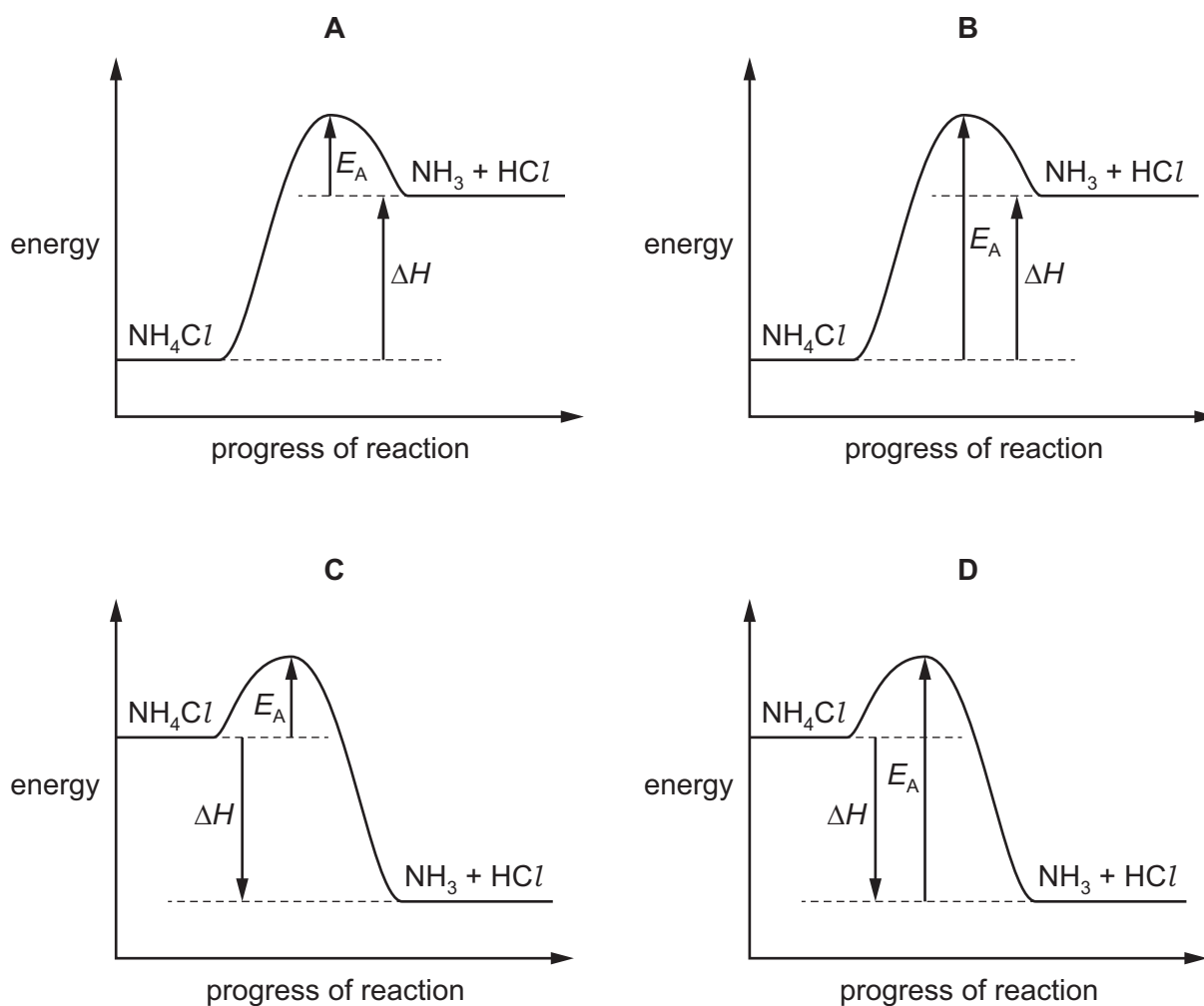
For a sample of a gas of mass m grams, which expression will give the value of M_r ?

A $M_r = \frac{mRT}{pV}$
 B $M_r = \frac{pVRT}{m}$
 C $M_r = \frac{mpV}{RT}$
 D $M_r = \frac{pV}{mRT}$

- 9 The equation for the formation of ammonium chloride is shown.



Which diagram shows the correctly labelled reaction pathway diagram for the decomposition of ammonium chloride?



- 10** In a catalytic converter in the exhaust system of a car, carbon monoxide is oxidised to carbon dioxide, and nitrogen monoxide is reduced to nitrogen.

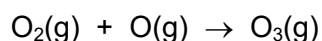
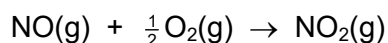
What are the changes in oxidation number of carbon and nitrogen in these two processes?

	carbon	nitrogen
A	−2	+2
B	−1	+1
C	+1	−1
D	+2	−2

- 11** NO and NO₂ are both present in the lower atmosphere as pollutants.

The reaction sequence shows the production of ozone from oxygen in the lower atmosphere.

This sequence repeats many times.



Which statement about this reaction sequence is correct?

- A** NO is acting as a catalyst, but NO₂ is not acting as a catalyst.
 - B** NO₂ is acting as a catalyst, but NO is not acting as a catalyst.
 - C** Neither NO nor NO₂ are acting as catalysts.
 - D** Both NO and NO₂ are acting as catalysts.
- 12** A mixture of two Period 3 oxides are added to water. A solution forms with a pH of just below 7.

What could be the constituents of the mixture?

- A** Al₂O₃ and MgO
- B** Na₂O and MgO
- C** Na₂O and P₄O₁₀
- D** SO₃ and P₄O₁₀

13 Which statement about the compounds of the Group 2 metals is correct?

- A Barium carbonate is less thermally stable than strontium carbonate.
- B Barium sulfate is less soluble than magnesium sulfate.
- C Calcium hydroxide is less soluble than magnesium hydroxide.
- D Calcium nitrate is more thermally stable than strontium nitrate.

14 A 0.005 mol sample of anhydrous calcium carbonate is completely thermally decomposed to give 100 cm³ of gas.

In a separate experiment carried out under the same conditions, a 0.005 mol sample of anhydrous calcium nitrate is completely thermally decomposed. The volume of gaseous products is measured.

What total volume of gaseous products is produced from the calcium nitrate?

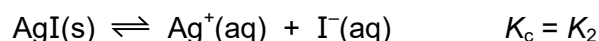
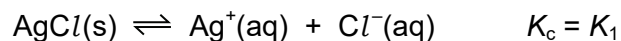
- A 50 cm³ B 100 cm³ C 200 cm³ D 250 cm³

15 Redox reactions are common in the chemistry of Group 17 elements.

Which statement is correct?

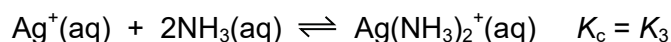
- A Br⁻ ions will reduce Cl₂ but not I₂.
- B Cl₂ will oxidise Br⁻ ions but not I⁻ ions.
- C F₂ is the weakest oxidising agent out of F₂, Cl₂, Br₂ and I₂.
- D I⁻ ions are the weakest reducing agent out of F⁻, Cl⁻, Br⁻ and I⁻.

- 16 Silver chloride and silver iodide form equilibria when added to water.



Each equilibrium position lies well to the **left**.

Silver iodide will not dissolve in aqueous ammonia. Silver chloride will dissolve in aqueous ammonia. Another equilibrium is formed.



The position of this equilibrium lies to the **right**.

What is the order of magnitude for these three equilibrium constants?

	smallest	→	largest
A	K_3	K_2	K_1
B	K_3	K_1	K_2
C	K_2	K_1	K_3
D	K_1	K_2	K_3

- 17 X is the ion of a metal which burns with a red flame.

Y is an ion that reacts with concentrated H_2SO_4 to produce H_2S .

What could be the formula of a compound containing X and Y?

- A** BaBr_2 **B** BaI_2 **C** SrBr_2 **D** SrI_2

- 18 Oxides of nitrogen are present in the environment due to natural and man-made sources.

Which row is correct?

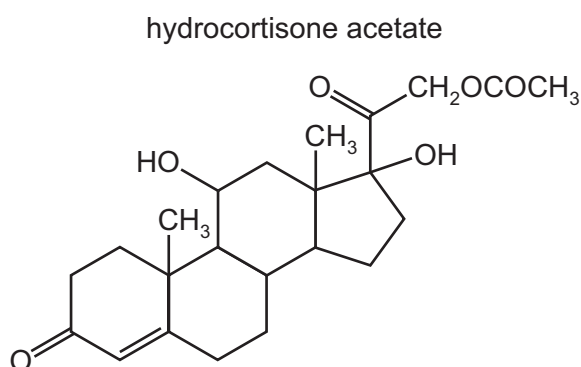
	natural source of nitrogen oxides	man-made source of nitrogen oxides
A	electrical discharges in the atmosphere	internal combustion engines
B	electrical discharges in the atmosphere	as a by-product of the Haber process
C	decomposition of dead plants in rivers	internal combustion engines
D	decomposition of dead plants in rivers	as a by-product of the Haber process

- 19 Magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride.

Which statement explains this observation?

- A** The ionic radius of the NH_4^+ ion is similar to that of Mg^{2+} but not that of Na^+ .
B NH_4Cl dissociates less fully than NaCl .
C The Na^+ and Mg^{2+} ions have the same number of electrons.
D The NH_4^+ ion can donate a proton.

- 20 The formula of hydrocortisone acetate is shown.



Which row is correct?

	number of C atoms in one molecule	number of chiral atoms in one molecule
A	22	7
B	22	8
C	23	7
D	23	8

- 21 Bromomethane, CH_3Br , decomposes in the stratosphere forming methyl free radicals and bromine free radicals.

Which row correctly describes this decomposition?

	type of bond fission	number of electrons in a bromine free radical
A	homolytic	35
B	heterolytic	35
C	homolytic	36
D	heterolytic	36

- 22 Structural and stereoisomerism should be taken into account when answering this question.

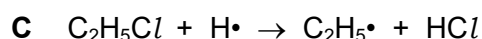
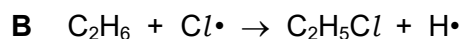
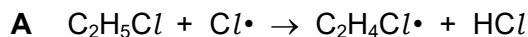
Y is a gaseous hydrocarbon which decolourises aqueous bromine. It contains no rings.

10.0 g of Y occupies a volume of 3.43 dm³ under room conditions.

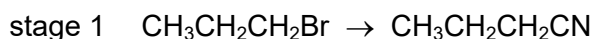
How many isomeric structures are possible for Y?

- A 4 B 5 C 6 D 7

- 23 Which equation represents a valid propagation step in the chlorination of ethane?



- 24 Butanoic acid can be made from 1-bromopropane in two stages.



Which types of reaction are stage 1 and stage 2?

	stage 1	stage 2
A	electrophilic addition	hydrolysis
B	electrophilic addition	oxidation
C	nucleophilic substitution	hydrolysis
D	nucleophilic substitution	oxidation

- 25 A halogenoalkane has the molecular formula C₅H₁₁Br. The halogenoalkane does **not** form an alkene when treated with ethanolic sodium hydroxide.

What could be the halogenoalkane?

A 1-bromo-2-methylbutane

B 2-bromo-2-methylbutane

C 3-bromopentane

D 1-bromo-2,2-dimethylpropane

- 26** Compound P is heated under reflux with an excess of acidified potassium dichromate(VI) to form compound Q.

Compound Q has a **lower** boiling point than compound P.

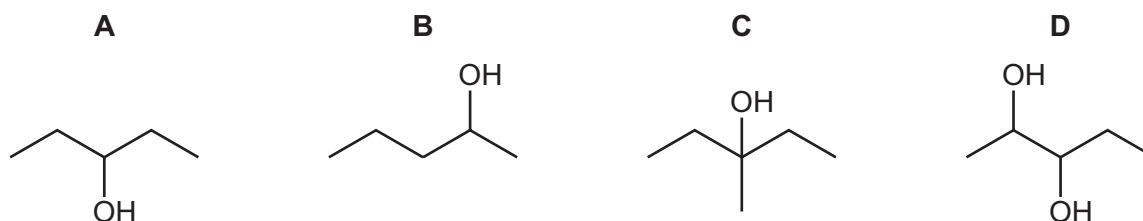
What could be compound P?

- A** 2-methylbutan-1-ol
 - B** 2-methylbutan-2-ol
 - C** pentan-1-ol
 - D** pentan-2-ol
- 27** Structural and stereoisomerism should be taken into account when answering this question.

An organic compound, X, is dehydrated by heating with concentrated phosphoric(V) acid.

Only **two** organic products are formed.

What could be X?



- 28** Which compound produces a precipitate with 2,4-dinitrophenylhydrazine reagent **and** also with alkaline aqueous iodine?

- A** butan-2-ol
- B** butanal
- C** butanone
- D** pentan-3-one

- 29 Organic compound Z has an alcohol group and a carboxylic acid group.

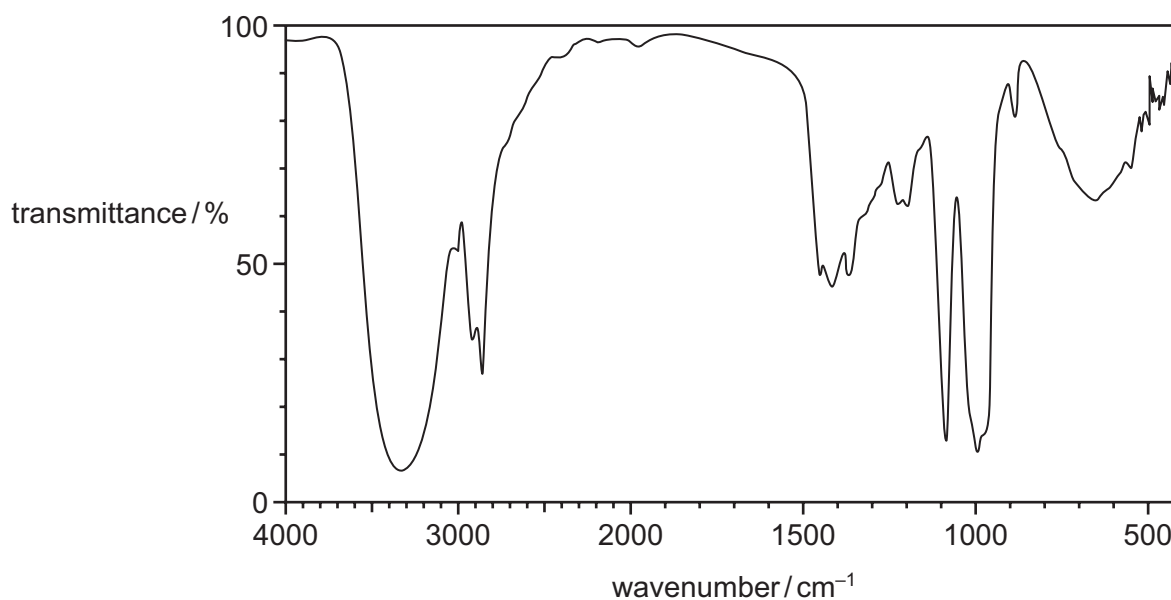
Compound Z reacts with magnesium carbonate to make a salt with a relative formula mass of 230.3.

Compound Z does **not** react with acidified potassium manganate(VII).

What could be the identity of compound Z?

- A 2-hydroxy-2-methylbutanoic acid
- B 2-hydroxy-2-methylpropanoic acid
- C 3-hydroxy-2-methylbutanoic acid
- D 3-hydroxy-2-methylpropanoic acid

- 30 The infra-red spectrum of Y is shown.



What could Y be?

- A $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$
- B $\text{CH}_2(\text{OH})\text{CH}=\text{CHCH}_2\text{OH}$
- C $\text{CH}_3(\text{CH}_2)_2\text{CO}_2\text{H}$
- D $\text{CH}_2(\text{OH})(\text{CH}_2)_2\text{CHO}$

Section B

For each of the questions in this section, one or more of the three numbered statements 1 to 3 may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

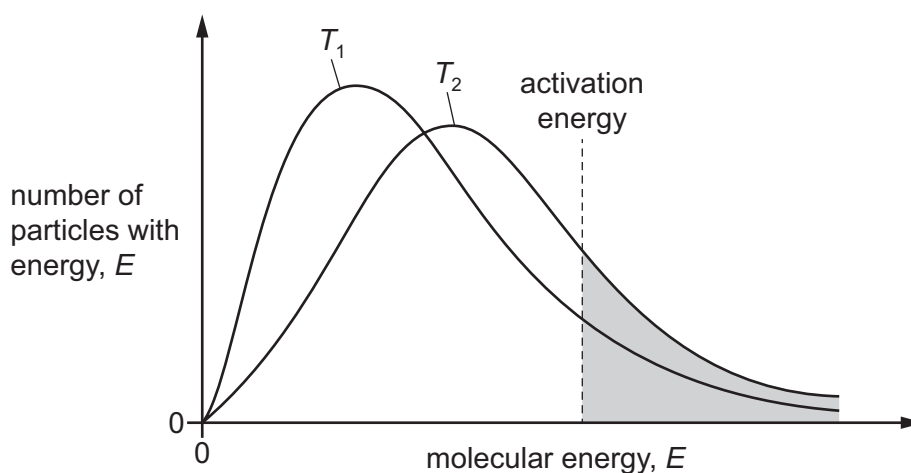
The responses **A** to **D** should be selected on the basis of

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

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

Use of the Data Booklet may be appropriate for some questions.

- 31** The Boltzmann distribution diagram shows a fixed amount of a gas at two different temperatures, T_1 and T_2 .



Which statements correctly describe the features of this diagram?

- 1** Temperature T_1 is lower than temperature T_2 .
- 2** The shaded area indicates the particles that have sufficient energy to react at T_2 .
- 3** The total area under each curve is the same for both temperatures.

- 32 Four solutions, each of concentration 0.1 mol dm^{-3} , were tested with a pH meter. The results are shown.

solution	formula of acid or base	pH
acid 1	$\text{CH}_3\text{CO}_2\text{H}$	4
acid 2	HNO_3	1
base 1	CH_3NH_2	11
base 2	NaOH	14

Which statements explain these results?

- 1 Acid 2 has a lower pH than acid 1 because it is more soluble.
- 2 Base 2 has a higher concentration of hydroxide ions in solution than base 1.
- 3 Acid 1 dissociates less than acid 2.

- 33 Which reactions are redox reactions?

- 1 $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
- 2 $2\text{K}_2\text{CrO}_4 + 2\text{H}^+ \rightarrow \text{K}_2\text{Cr}_2\text{O}_7 + 2\text{K}^+ + \text{H}_2\text{O}$
- 3 $\text{CuCO}_3 + 2\text{HCl} \rightarrow \text{CuCl}_2 + \text{H}_2\text{O} + \text{CO}_2$

- 34 When the liquid N_2F_4 is heated, it decomposes into a **single** product, X.

Which statements are correct?

- 1 N–F bonds are broken during this decomposition.
- 2 The enthalpy change when N_2F_4 decomposes into X is approximately $+160 \text{ kJ mol}^{-1}$.
- 3 Molecules of X are non-linear.

- 35 The following statements compare some properties of the oxides and chlorides of sodium and silicon.

Which statements are correct?

- 1 The melting point of SiCl_4 is higher than the melting point of SiO_2 .
- 2 SiCl_4 reacts with water, NaCl does not.
- 3 The melting point of SiCl_4 is lower than the melting point of NaCl .

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

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

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

36 Which statements about ammonium chloride are correct?

- 1** It reacts with hot aqueous sodium hydroxide to produce an alkaline gas.
- 2** In solution, it reacts with aqueous silver nitrate to produce a white precipitate.
- 3** When solid, it reacts with concentrated sulfuric acid to produce chlorine.

37 What is the same for a pair of optical isomers?

- 1** their empirical formula
- 2** their functional groups
- 3** their structural formula

38 Which of the molecular formulae represent at least one compound that can undergo addition polymerisation?

- 1** C_4H_8
- 2** C_2H_3Cl
- 3** C_3H_6O

39 Which of the reactions give products containing a chiral centre?

- 1** $CH_2(OH)COCO_2H$ + an excess of HCN
- 2** $CH_2(OH)COCO_2H$ + an excess of $NaBH_4$
- 3** $CH_2(OH)COCO_2H$ + an excess of $LiAlH_4$

40 Ethyl butanoate is heated with a dilute aqueous solution of sodium hydroxide.

Which substances are products of this reaction?

- 1** sodium butanoate
- 2** water
- 3** sodium ethanoate

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Cambridge International AS & A Level

CHEMISTRY

9701/13

Paper 1 Multiple Choice

October/November 2021

1 hour

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)
Data booklet

INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.

This document has **16** pages. Any blank pages are indicated.

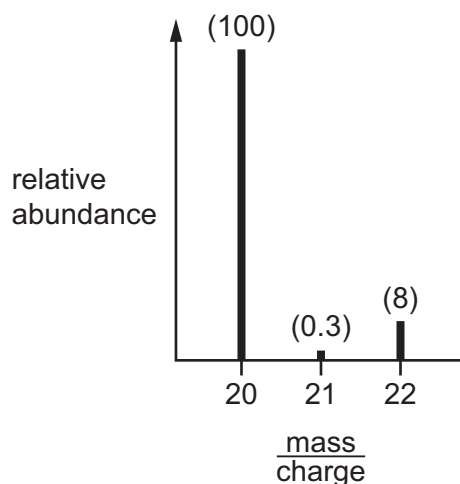


Section A

For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

Use of the Data Booklet may be appropriate for some questions.

- 1 The mass spectrum of a sample of neon is shown. The relative abundance of each peak is written in brackets above it.



What is the relative atomic mass, A_r , of this sample of neon?

- A** 20.15 **B** 20.20 **C** 21.00 **D** 21.82
- 2 2.0 g of ammonium nitrate, NH_4NO_3 , decomposes to give 0.90 g of water and a single gas.

What is the identity of the gas?

- A** NO **B** NO_2 **C** N_2O **D** N_2
- 3 Which of these elements has the highest fifth ionisation energy?

- A** C **B** N **C** P **D** Si

- 4 The ion X^{2+} has the same electronic configuration as the atom Kr.

What is the electronic configuration of an atom of X?

- A** $[\text{Ar}]4s^23d^{10}4p^6$
B $[\text{Ar}]4s^23d^{10}4p^65s^2$
C $[\text{Ar}]4s^24d^{10}4p^6$
D $[\text{Ar}]4s^24d^{10}4p^65s^2$

- 5 Which type of interaction exists between water molecules and metal cations in aqueous solution?
- A dipole-dipole interactions
B hydrogen bonds
C ion-dipole interactions
D ionic bonds

- 6 Which substance shows the greatest deviation from the properties of an ideal gas under room conditions?

A $\text{CO}_2(\text{g})$ B $\text{H}_2(\text{g})$ C $\text{Ne}(\text{g})$ D $\text{NH}_3(\text{g})$

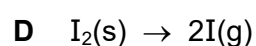
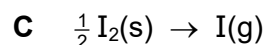
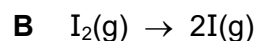
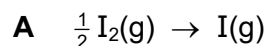
- 7 In order to determine the enthalpy of neutralisation of a strong acid and a strong alkali, 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid. The increase in temperature is 12°C .

In a second experiment, the same method is used, but 50.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide is added to 50.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

What is the increase in temperature in the second experiment?

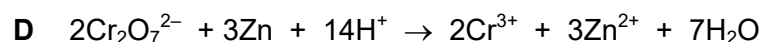
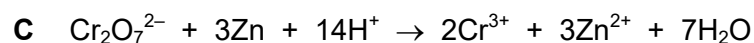
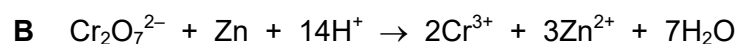
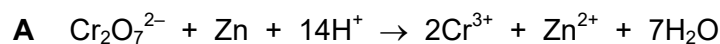
A 6°C B 12°C C 24°C D 48°C

- 8 Which equation represents the enthalpy change of atomisation of iodine?

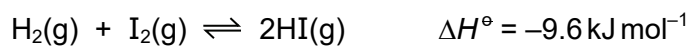


- 9 Zinc atoms can be oxidised to Zn^{2+} ions by dichromate(VI) ions in acid solution. Chromium is reduced to Cr^{3+} in this reaction.

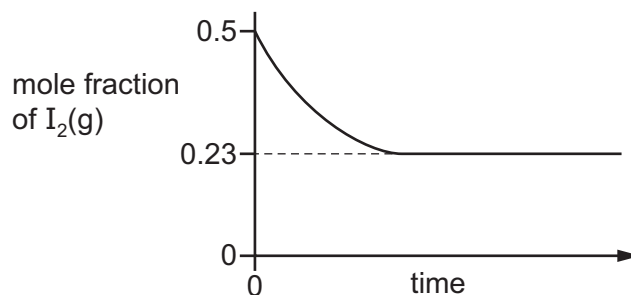
Which equation is correct?



10 The equation shows that $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ react to form an equilibrium mixture.



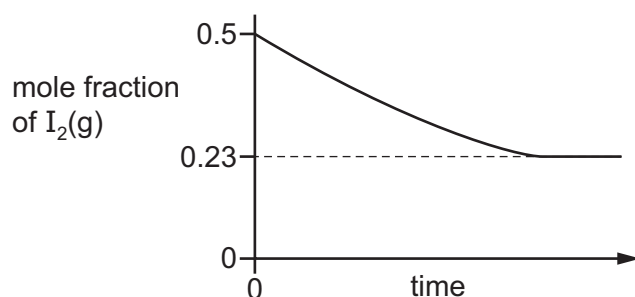
A mixture containing equal amounts of $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ is made at temperature T_1 and the composition of the mixture is monitored. A graph of the results is shown.



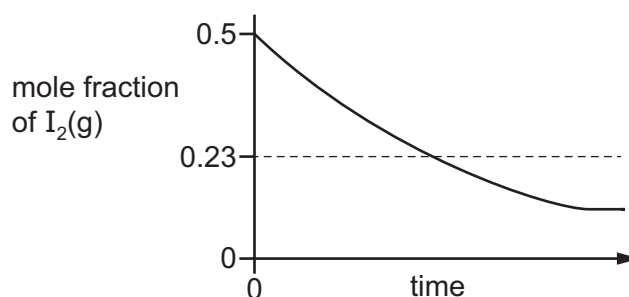
The experiment is repeated at a lower temperature, T_2 .

Which new graph would be obtained?

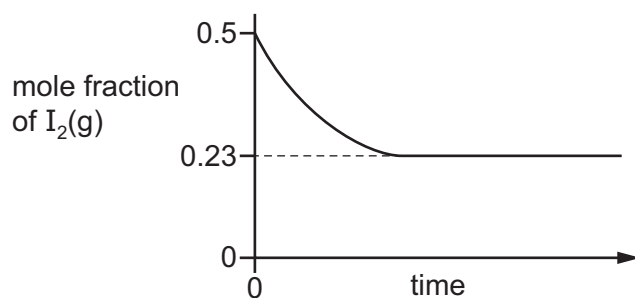
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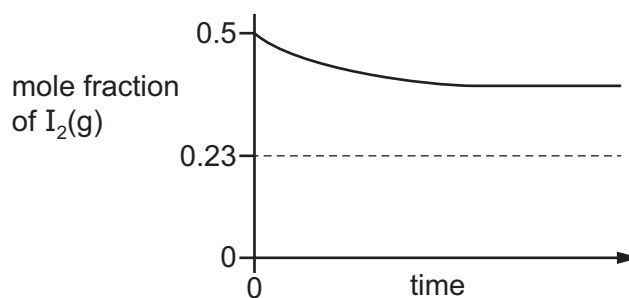
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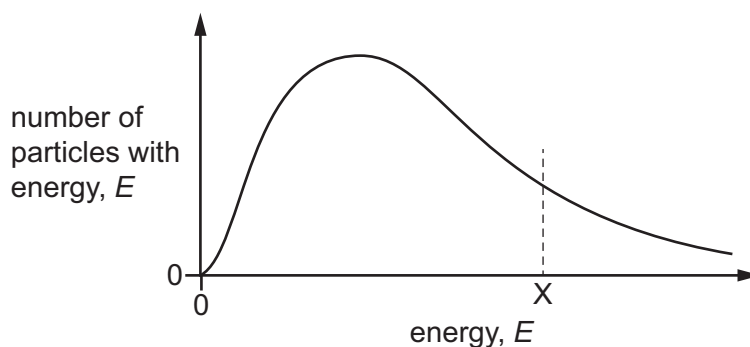
C



D

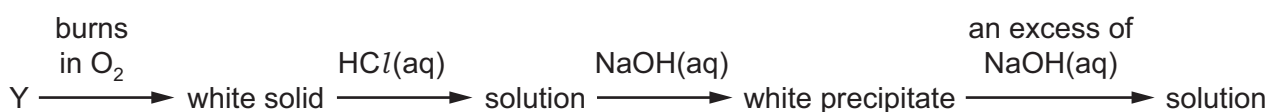


- 11 The diagram shows the Boltzmann distribution of energies for a reactant gas. For a particular reaction, the activation energy is X .



Which change to the diagram occurs if an effective catalyst is added at the same temperature?

- A** More particles will possess higher values of E .
B The peak will move to the left.
C The peak will move to the right.
D The value of the activation energy decreases.
- 12 Which element requires the least number of moles of oxygen for the complete combustion of 1 mol of its atoms?
- A** aluminium
B magnesium
C phosphorus
D sodium
- 13 An element, Y , reacts according to the following sequence.



What could be element Y ?

- A** Na **B** Mg **C** Al **D** P
- 14 In which list are all three compounds soluble in water?
- A** barium chloride, calcium carbonate, magnesium hydroxide
B barium hydroxide, calcium hydroxide, strontium carbonate
C barium chloride, barium hydroxide, magnesium sulfate
D barium sulfate, calcium sulfate, magnesium hydroxide

- 15 Anhydrous magnesium nitrate, $\text{Mg}(\text{NO}_3)_2$, decomposes when heated, giving a white solid and a mixture of two gases, X and Y.

Y is oxygen.

What is the ratio $\frac{\text{mass of X released}}{\text{mass of Y released}}$?

- A $\frac{1}{0.174}$ B $\frac{1}{0.267}$ C $\frac{1}{0.348}$ D $\frac{1}{3.43}$

- 16 In a series of nine experiments, to test the reactivity of the halogens, an aqueous solution of each halogen is added to an equal volume of an aqueous solution containing halide ions, as shown in the table.

halogen solution	halide solution		
	sodium chloride (aq)	sodium bromide (aq)	sodium iodide (aq)
chlorine (aq)	experiment 1	experiment 2	experiment 3
bromine (aq)	experiment 4	experiment 5	experiment 6
iodine (aq)	experiment 7	experiment 8	experiment 9

The nine resulting mixtures are then shaken separately with an equal volume of hexane. The nine tubes are left to stand so that the aqueous and organic solvents separate into layers.

How many test-tubes contain a purple upper hexane layer?

- A 1 B 2 C 3 D 5

- 17 Z is a compound of sodium, chlorine and oxygen.

It contains 45.1% by mass of oxygen.

Z is prepared by reacting sodium hydroxide with chlorine.

Which row shows the conditions used for the reaction and the oxidation state of chlorine in Z?

	reaction conditions	oxidation state of Cl in Z
A	cold dilute NaOH	+1
B	cold dilute NaOH	+5
C	hot concentrated NaOH	+1
D	hot concentrated NaOH	+5

18 Which row is correct?

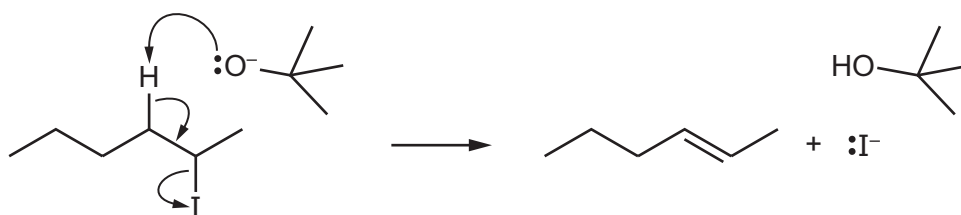
	shape		bonds present	
	ammonia molecule	ammonium ion	ammonia molecule	ammonium ion
A	pyramidal	regular tetrahedral	σ	σ
B	pyramidal	regular tetrahedral	σ	π
C	regular tetrahedral	pyramidal	σ	σ
D	regular tetrahedral	pyramidal	π	σ

19 The table describes two possible environmental consequences of adding too much ammonium nitrate fertiliser to the soil.

Which row is correct?

	increased plant growth in rivers	photochemical smog
A	x	x
B	✓	x
C	x	✓
D	✓	✓

20 Hex-2-ene can be made by the reaction shown.



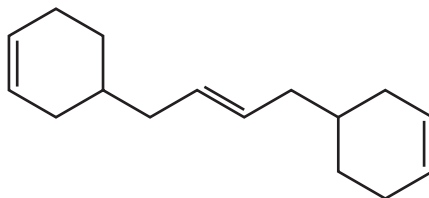
Which statement about this reaction is correct?

- A** $(\text{CH}_3)_3\text{CO}^-$ is behaving as a Brønsted-Lowry base.
- B** $(\text{CH}_3)_3\text{CO}^-$ is behaving as an oxidising agent.
- C** The C–I bond breaks via homolytic fission.
- D** This is a hydrolysis reaction.

21 Structural isomerism **only** should be considered when answering this question.

Molecule X contains three C=C double bonds. One mole of X is reacted with three moles of HBr. The carbon skeleton is unchanged.

molecule X



How many different products are formed?

- A** 3 **B** 4 **C** 6 **D** 8

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

A colourless liquid, $C_5H_{11}Cl$, exists as a mixture of two optical isomers.

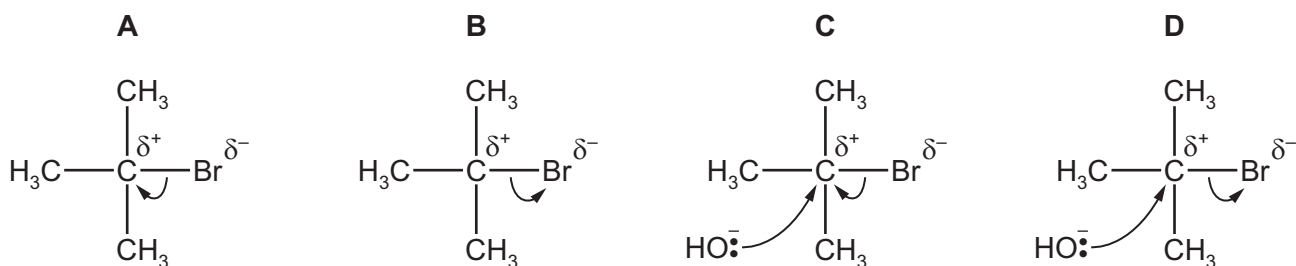
When heated with sodium hydroxide in ethanol, a mixture of **only two** alkenes is formed.

What could the colourless liquid be?

- A** $(CH_3CH_2)_2CHCl$
B $CH_3CH_2CH_2CHClCH_3$
C $CH_3CH_2CCl(CH_3)_2$
D $(CH_3)_2CHCHClCH_3$

23 When 2-bromo-2-methylpropane reacts with aqueous sodium hydroxide, an alcohol is formed.

Which diagram describes the first step in the reaction mechanism?



- 24 When an organic compound, Q, is treated with phosphorus pentachloride, fumes of hydrogen chloride are evolved. When Q is warmed with acidified aqueous potassium dichromate(VI), the solution turns green.

What is Q?

- A $\text{CH}_3\text{CH}_2\text{CHO}$
- B $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$
- C $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
- D $(\text{CH}_3)_3\text{COH}$

- 25 Alcohol Y gives a yellow precipitate with alkaline aqueous iodine. It can be oxidised to give a mixture of products including substance Z. Substance Z gives a red-brown precipitate with Fehling's solution.

Which alcohol could be Y?

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

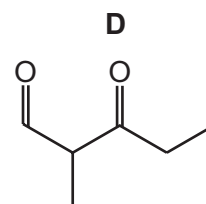
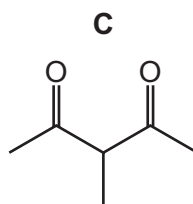
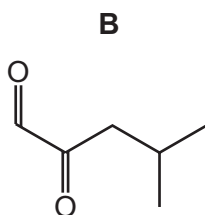
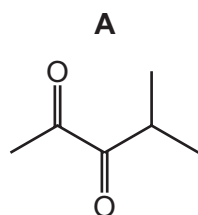
- 26 $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ reacts with hydrogen cyanide to form an organic product called a cyanohydrin.

Which statement is correct?

- A The cyanohydrin product has one chiral centre.
- B The cyanohydrin product is formed by electrophilic addition.
- C The cyanohydrin product is formed via an intermediate which contains a C–OH group.
- D The formation of the cyanohydrin product requires the use of cyanide ions as a catalyst.

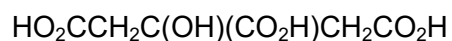
- 27 Reduction of compound R with LiAlH_4 gives the compound 4-methylpentane-2,3-diol.

What could be the identity of compound R?



- 28 Citric acid is found in lemon juice.

citric acid



Which volume of 0.40 mol dm^{-3} sodium hydroxide solution is required to neutralise a solution containing 0.0050 mol of citric acid?

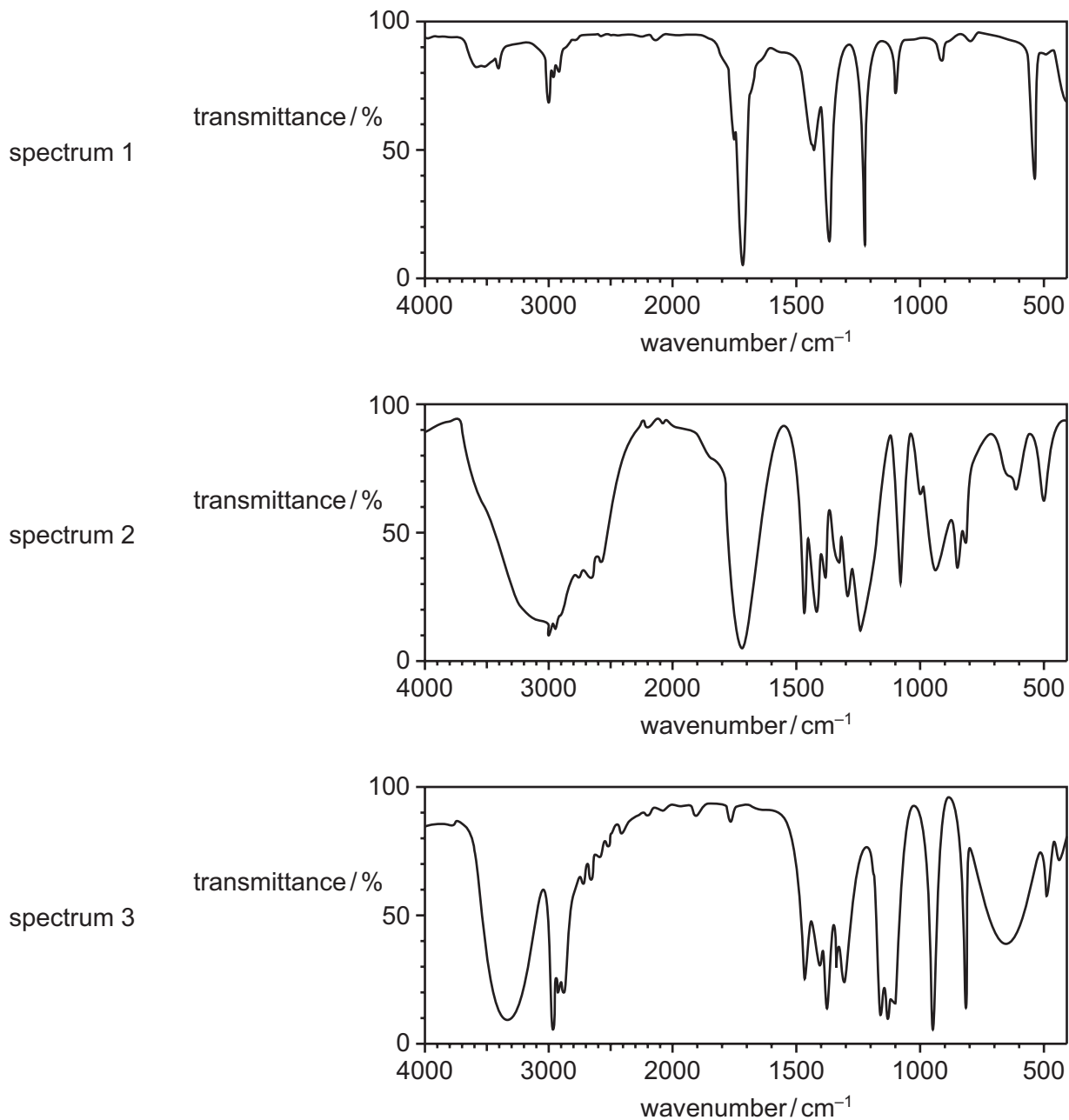
- A** 12.5 cm^3 **B** 25.0 cm^3 **C** 37.5 cm^3 **D** 50.0 cm^3
- 29 The structural formula of an ester is $(\text{CH}_3)_2\text{CHOCO}(\text{CH}_2)_2\text{CH}_3$.

This ester is boiled with aqueous hydrochloric acid.

Which two products are formed?

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

30 The infra-red spectra of three organic compounds are shown.



What could the three compounds be?

	spectrum 1	spectrum 2	spectrum 3
A	propanoic acid	propanone	propan-2-ol
B	propanone	propanoic acid	propan-2-ol
C	propanone	propan-2-ol	propanoic acid
D	propan-2-ol	propanoic acid	propanone

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

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

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

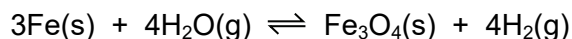
No other combination of statements is used as a correct response.

Use of the Data Booklet may be appropriate for some questions.

31 Which changes can be used to measure the rates of chemical reactions?

- 1** the decrease in concentration of a reactant per unit time
- 2** the rate of appearance of a product
- 3** the increase in total volume of gas per unit time at constant pressure

32 Iron reacts with steam to produce hydrogen and an oxide of iron.



A system containing all four substances is at equilibrium.

Which changes will decrease the mass of Fe present at equilibrium?

- 1** addition of steam at constant pressure
- 2** increase in overall pressure
- 3** addition of an effective catalyst

33 Ethylene glycol, $\text{HOCH}_2\text{CH}_2\text{OH}$, is used as a de-icer. It allows ice to melt at temperatures below 0°C .

Which statements are correct?

- 1** Ethylene glycol disrupts the extensive network of hydrogen bonds in ice.
- 2** Ethylene glycol molecules form hydrogen bonds with other ethylene glycol molecules.
- 3** Ethylene glycol molecules will dissolve in the water formed from the ice.

34 Which molecules contain at least one unpaired electron?

- 1 NO
- 2 NO₂
- 3 NH₃

35 Which elements form a chloride in which both covalent bonding and coordinate (dative covalent) bonding are present?

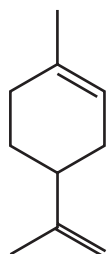
- 1 Al
- 2 Si
- 3 Mg

36 Which statements about calcium oxide are correct?

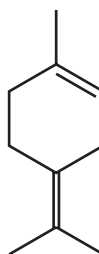
- 1 It can be reduced by heating with magnesium.
- 2 It is produced when calcium nitrate is heated.
- 3 It reacts with cold water.

37 A diketo acid is a compound with two ketone groups and one carboxylic acid group.

limonene



terpinolene



Which statements about the reactions of limonene and terpinolene are correct?

- 1 When reacted with an excess of hydrogen and a nickel catalyst, limonene and terpinolene produce the same compound.
- 2 An excess of hot concentrated acidified KMnO₄ reacts with limonene and with terpinolene to form different diketo acids.
- 3 The reactions of limonene and terpinolene with an excess of Br₂ produce positional isomers with the same number of chiral carbon atoms.

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

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

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

38 One molecule of dodecane, $C_{12}H_{26}$, is cracked, producing three product molecules, X, Y and Z.

X is a straight chain alkane. Y and Z are straight chain alkenes with different M_r values.

Which statements about X, Y and Z are correct?

- 1** If Y and Z are but-1-ene and ethene respectively, X will be hexane.
- 2** If X is butane, then Y and Z could both show *cis-trans* isomerism.
- 3** X could be octane.

39 Which statements about chlorofluoroalkanes are correct?

- 1** Both the C–Cl and C–F bonds are readily dissociated by ultra-violet light.
- 2** They have caused ozone depletion.
- 3** They are relatively chemically inert.

40 Which reactions of propan-1-ol have water as one of the products?

- 1** passing propan-1-ol vapour over hot Al_2O_3
- 2** mixing propan-1-ol with warm ethanoic acid and a few drops of concentrated sulfuric acid
- 3** warming propan-1-ol with HBr

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