Cambridge Assessment International Education

Cambridge Pre-U

CHEMISTRY **9791/01**

Paper 1 Multiple Choice **May/June 2023**

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.

1 W and X are two different particles. W and X contain the same number of electrons as each other but differ in their number of neutrons.

It is suggested that W and X could be:

1 ions of the same element with different charges

2 two atoms of the same element

3 ions of two different elements.

Which statements could be correct?

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

2 Which statement about electrons is correct for all elements?

A Electrons in the same orbital are spin-paired.

B Excited electrons are in the orbital with the lowest energy.

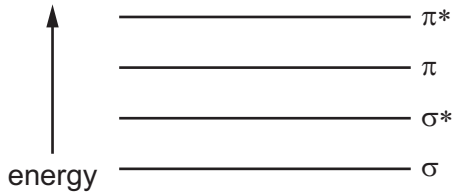
C Orbitals in subshells with the same energy are only occupied by single electrons.

D The maximum number of electrons in the fourth electron shell is 18.

3 The carbon atoms in ethene are bonded through σ and π bonds. When atomic orbitals overlap they form bonding (σ and π) and antibonding ($\sigma*$ and $\pi*$) orbitals.

What is the correct order of energies of the σ and π orbitals in an ethene molecule?

A



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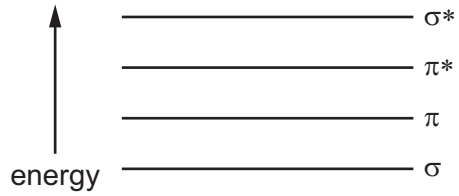

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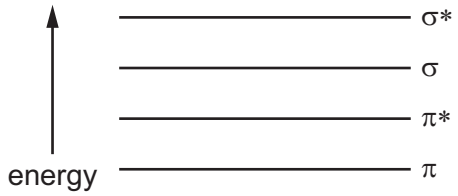

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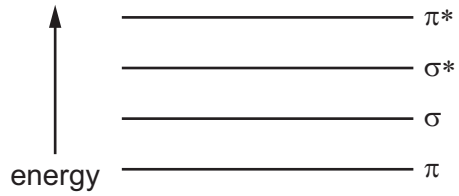


4 An excess of zinc powder is added to 50.0 cm^3 of 1.0 mol dm^{-3} copper(II) sulfate solution. The temperature of the solution rises from 21 °C to 27 °C.

What is the enthalpy change of reaction for this displacement process in kJ mol^{-1}?
(Assume density of solution = 1.0 g cm^{-3}; specific heat capacity of solution = 4.2 J g^{-1} K^{-1}.)

A –25 kJ mol^{-1} **B** –1.3 kJ mol^{-1} **C** +1.3 kJ mol^{-1} **D** +25 kJ mol^{-1}

5 Dinitrogen tetroxide exists in equilibrium with nitrogen dioxide.

$$N_2O_4 \rightleftharpoons 2NO_2$$

At 82 °C, $\Delta G^{\ominus}$ for the forward reaction is $-4.38\,kJ\,mol^{-1}$.

What is the equilibrium constant for this reaction?

A 1.00 **B** 1.48 **C** 4.41 **D** 619

6 An equilibrium is shown.

$$CH_3CH_2OH + CH_3COOH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

6 moles of ethanol, 8 moles of ethanoic acid, 4 moles of water and $1\,cm^3$ of concentrated sulfuric acid were mixed together and allowed to equilibrate at 25 °C. Analysis of the equilibrium mixture showed it to contain 4 moles of ethyl ethanoate.

What is the value of K_c for the reaction?

A $\frac{1}{4}$ **B** 2 **C** 4 **D** 12

7 $K_{sp}(AgCl)$ is the solubility product for $AgCl$.

Which statement is correct?

A $AgCl(s)$ is **not** included in the $K_{sp}(AgCl)$ expression because its concentration varies.

B If $[Ag^+][Cl^-]$ is less than $K_{sp}(AgCl)$, no precipitate forms.

C The concentration of water is left out of the $K_{sp}(AgCl)$ expression because it is $1\,mol\,dm^{-3}$.

D The $K_{sp}(AgCl)$ expression describes an unsaturated solution of $AgCl$.

8 The value for the ionic product for water, K_w, varies with temperature.

temperature / °C	value of K_w
25	1.00×10^{-14}
30	1.47×10^{-14}

Which is correct for pure water at 30 °C?

A $[H^+] > [OH^-]$

B $[H^+] = 1.47 \times 10^{-14}\,mol\,dm^{-3}$

C pH < 7

D pH = 7

9 Which aqueous mixture acts as a buffer solution?

A CH_3COOH and $NaCl$

B HCl and $NaCl$

C NaBr and NaOH

D NaH_2PO_4 and Na_2HPO_4

10 Which row represents a species that can be produced at the cathode during the electrolysis of a suitable molten salt?

	atomic number	electronic configuration
A	3	$[He]2s^1$
B	11	[Ne]
C	17	[Ar]
D	17	$[Ne]3s^2\,3p^5$

11 The lattice energy of silver chloride has been measured experimentally and found to be $-905\,kJ\,mol^{-1}$. However, using the ionic model, its calculated value is $-833\,kJ\,mol^{-1}$.

Which statement explains this discrepancy?

A Silver chloride is insoluble in water and so the lattice does not fully break down.

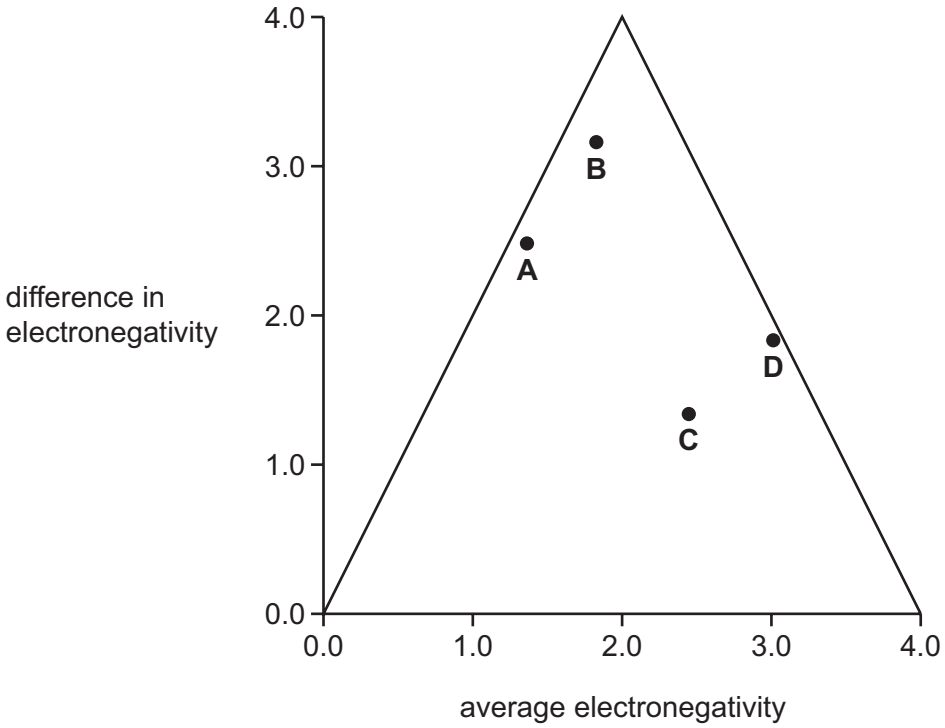
B The calculation for the ionic model ignores any repulsion between ions.

C The experimental value was **not** obtained under standard conditions.

D The ionic model cannot account for any covalent character in a compound.

12 The electronegativity values for iron and chlorine are 1.83 and 3.16 respectively.

Which letter shows the correct plot on the van Arkel diagram for iron(II) chloride?



13 X is an element in Period 3. X forms an oxide and a chloride.

Two test-tubes are half-filled with water containing a little universal indicator. A small amount of the oxide of X is added to the first test-tube. A small amount of the chloride of X is added to the second test-tube.

The final colour in both test-tubes is the same.

What could element X be?

A aluminium

B magnesium

C phosphorus

D sodium

14 Which statement explains why $MgCO_3$ decomposes at a lower temperature than $CaCO_3$?

A Magnesium has greater first and second ionisation energies than calcium.

B $MgCO_3$ has a lower relative formula mass than $CaCO_3$.

C $MgCO_3$ has a more exothermic lattice enthalpy than $CaCO_3$.

D The Mg^{2+} ion has a higher charge density than the Ca^{2+} ion.

15 Sulfuric acid, one of the most important industrial chemicals, can carry out several functions in chemical reactions.

Three examples of industrial reactions in which sulfuric acid is used are shown.

reaction 1 $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

reaction 2 $Cu + H_2SO_4 \rightarrow CuO + SO_2 + H_2O$

reaction 3 $(CH_3)_3COH + H_2SO_4 \rightarrow (CH_3)_2C{=}CH_2 + H_2SO_4 + H_2O$

What is the role of sulfuric acid in each reaction?

	reaction 1	reaction 2	reaction 3
A	acid	oxidising agent	dehydrating agent
B	acid	acid	dehydrating agent
C	dehydrating agent	oxidising agent	catalyst
D	dehydrating agent	acid	catalyst

16 Chlorine undergoes a disproportionation reaction with cold aqueous sodium hydroxide.

$$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$$

If the resulting solution is warmed, the sodium chlorate(I) undergoes further disproportionation.

$$3NaOCl \rightarrow NaClO_3 + 2NaCl$$

Assuming 100% disproportionation at each stage, how many moles of $NaCl$ would be produced from an initial three moles of Cl_2?

A 1 **B** 2 **C** 3 **D** 5

17 Which descriptions of germanium and tin are correct?

	germanium	tin
A	electrical conductor	electrical conductor
B	electrical conductor	electrical semiconductor
C	electrical semiconductor	electrical conductor
D	electrical semiconductor	electrical semiconductor

18 Which statement about lead chemistry is correct?

A Lead(IV) oxide decomposes on heating to give lead(II) oxide and oxygen.

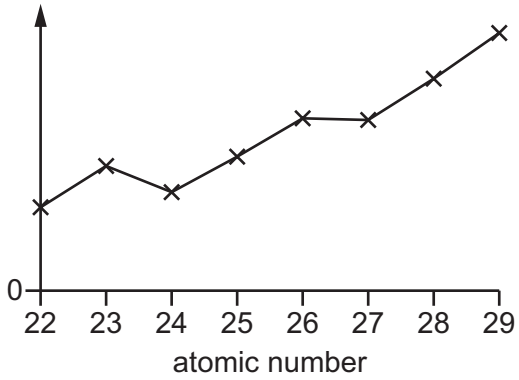
B Lead(II) oxide shows more covalent character than lead(IV) oxide.

C Lead is more likely than tin to involve the s electrons in the outer shell in bonding.

D The +4 oxidation state is less easily reduced in lead than in tin.

19 Which graph shows the variation in atomic radius across the first row of transition elements from titanium to copper?

A



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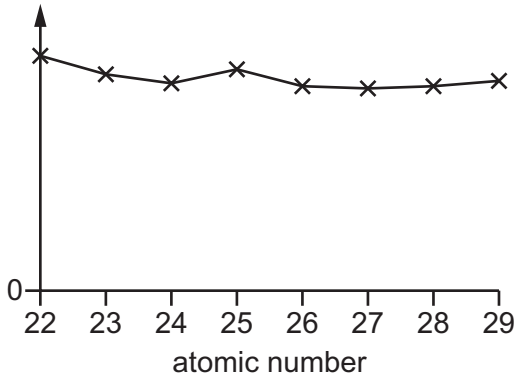

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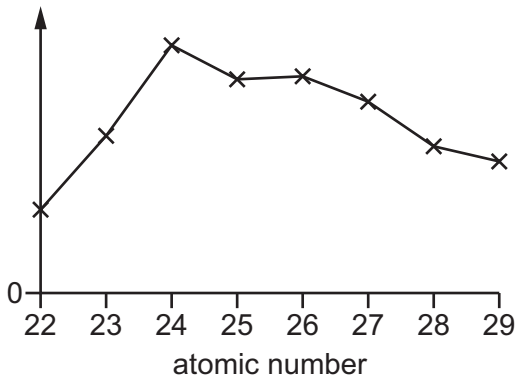

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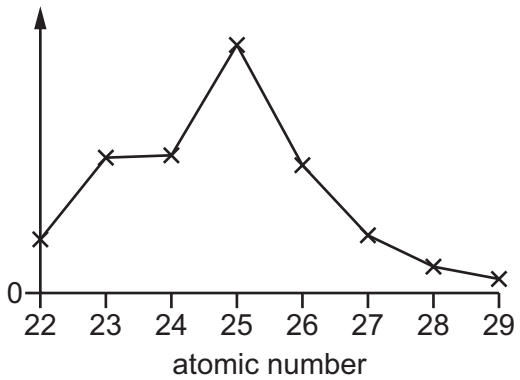


20 Why are aqueous solutions of titanium(III) chloride purple in colour?

A The d-electrons in $Ti^{3+}(aq)$ compounds are degenerate.

B $Ti^{3+}(aq)$ compounds absorb red and blue light.

C $Ti^{3+}(aq)$ compounds absorb yellow-green light.

D $Ti^{3+}(aq)$ compounds undergo redox reactions with water.

21 A conical flask contains acidified $Fe^{2+}(aq)$. $KMnO_4(aq)$ is added with stirring until present in large excess.

Which colour changes are seen in the conical flask?

A pale green → yellow → pink → purple

B purple → pink → colourless

C purple → pink → yellow → green

D yellow → pale green → pink → purple

22 The compound MX_2 is an ionic compound in which X^{2-} ions form a cubic close-packed (CCP) structure.

What is a possible arrangement of M^{4+} ions in the crystal structure of MX_2?

A M^{4+} ions occupy all octahedral holes in the CCP structure.

B M^{4+} ions occupy all tetrahedral holes in the CCP structure.

C M^{4+} ions occupy 50% of the octahedral holes in the CCP structure.

D M^{4+} ions occupy 50% of the tetrahedral holes in the CCP structure.

23 The compound of molecular formula $C_3H_4Br_2$ has structural isomers.

How many of these **structural** isomers contain C=C and how many do **not** contain C=C?

	structural isomers with C=C	structural isomers without C=C
A	4	0
B	4	2
C	5	0
D	5	2

24 Allophanic acid has the structural formula $H_2NCONHCO_2H$.

Which row correctly describes the functional group levels of the two carbon atoms in allophanic acid?

	carbonyl level	carboxylic acid level	carbon dioxide level
A	0	0	2
B	0	1	1
C	1	0	1
D	1	1	0

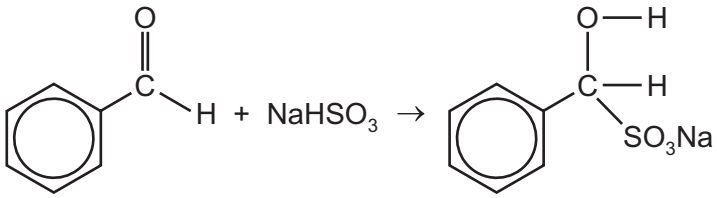
25 Which conditions and reagent are needed for reactions 1 and 2?

$$C_2H_5Cl \xrightarrow{1} C_2H_5OH$$

$$C_2H_5OH \xrightarrow{2} C_2H_5Cl$$

	1	2
A	warm NaOH(aq)	Cl_2(g)
B	warm NaOH(aq)	PCl_5(s)
C	boiling NaOH(ethanolic)	Cl_2(g)
D	boiling NaOH(ethanolic)	PCl_5(s)

26 Which type of reaction is shown?



A addition

B oxidation

C reduction

D substitution

27 In the Krebs cycle, fumaric acid is converted to oxaloacetic acid by a two-step process involving an intermediate compound X.

$$HO_2CCH{=}CHCO_2H \xrightarrow{\text{step 1}} X \xrightarrow{\text{step 2}} HO_2CCOCH_2CO_2H$$

fumaric acid — oxaloacetic acid

What is the identity of X?

A $HO_2CCH_2CH_2CO_2H$

B $HO_2CCHBrCH_2CO_2H$

C $HO_2CCH(OH)CH_2CO_2H$

D $HO_2CCH(OH)CH(OH)CO_2H$

28 Which reactions have a 100% atom economy when the organic compound is the only utilised product?

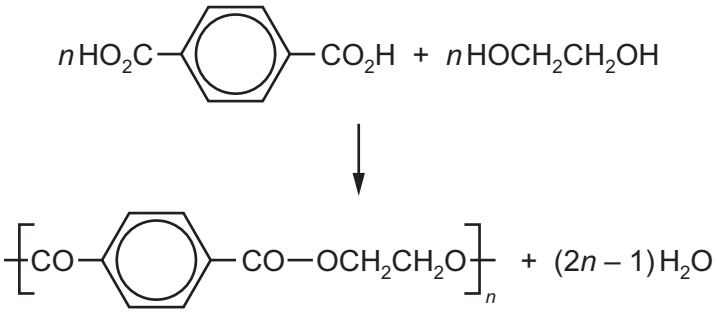
reaction 1 $C_2H_4 + H_2O \rightarrow C_2H_5OH$

reaction 2 $C_2H_5OH + [O] \rightarrow CH_3CHO + H_2O$

reaction 3 $C_2H_4 + HBr \rightarrow C_2H_5Br$

	reaction 1	reaction 2	reaction 3
A	✓	✓	✓
B	✓	✗	✓
C	✓	✗	✗
D	✗	✗	✓

29 The diagram represents the formation of a polymer.



Which pair of terms describes this process?

A addition polymerisation and elimination

B addition polymerisation and esterification

C condensation polymerisation and elimination

D condensation polymerisation and esterification

30 What are the products of the hydrolysis of urea (NH_2CONH_2)?

A $HCHO + NH_2NHOH$

B $CO_2 + 2NH_3$

C $HCONH_2 + NH_2OH$

D $HCOOH + N_2H_4$

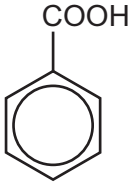
31 2-chloromethylpropane, $(CH_3)_3CCl$, undergoes a substitution reaction with OH^- ions.

Which row correctly describes the reaction?

	type of reaction	bond angle in intermediate
A	S_N1	109.5°
B	S_N1	120°
C	S_N2	120°
D	S_N2	109.5°

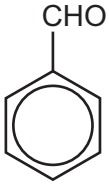
32 Which molecule will undergo aromatic electrophilic substitution to give primarily 1,2-disubstituted and 1,4-disubstituted products?

A



B

C



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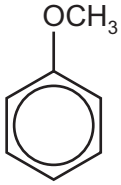


33 Ammonia (NH_3), ethylamine ($C_2H_5NH_2$) and phenylamine ($C_6H_5NH_2$) are all bases.

What is the correct order of basicity of these compounds, from least basic to most basic?

A $C_2H_5NH_2 < NH_3 < C_6H_5NH_2$

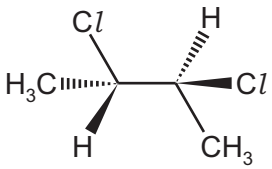
B $C_6H_5NH_2 < C_2H_5NH_2 < NH_3$

C $C_6H_5NH_2 < NH_3 < C_2H_5NH_2$

D $NH_3 < C_6H_5NH_2 < C_2H_5NH_2$

34 Which structure represents a *meso* compound?

A



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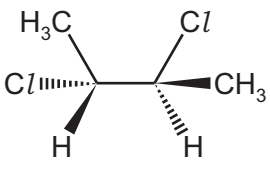

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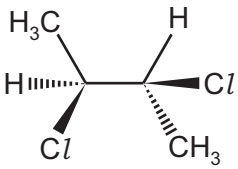

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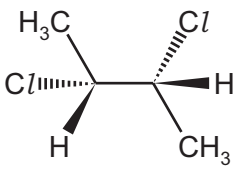


35 A 30 cm^3 sample of butane, C_4H_{10}, was completely reacted in a limited supply of oxygen to produce 60 cm^3 of carbon dioxide and 60 cm^3 of carbon monoxide.

All volumes were measured at room temperature and pressure.

Which volume of oxygen was used?

A 90 cm^3 **B** 120 cm^3 **C** 150 cm^3 **D** 165 cm^3

36 What is the best description of the fragmentation of a positive free-radical in the mass spectrometer?

A One positive free-radical and one neutral free-radical are formed.

B One positive ion and one neutral free-radical are formed.

C Two positive free-radicals are formed.

D Two positive ions are formed.

37 In hydrogen atoms, the four electron transitions below result in the emission of photons of different frequencies.

Which transition results in the emission of a photon of the highest frequency?

A 3s $\rightarrow$ 2p **B** 4p $\rightarrow$ 3s **C** 5p $\rightarrow$ 4d **D** 6d $\rightarrow$ 5p

38 Infrared spectroscopy is used to detect specific functional groups in organic molecules.

Which two factors will increase the frequency of absorption of a chemical bond between two atoms?

A a decrease in mass of both atoms and a decrease in bond strength between the atoms

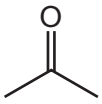
B a decrease in mass of both atoms and an increase in bond strength between the atoms

C an increase in mass of both atoms and a decrease in bond strength between the atoms

D an increase in mass of both atoms and an increase in bond strength between the atoms

39 Which molecule has an odd number of peaks in its carbon-13 NMR spectrum?

A



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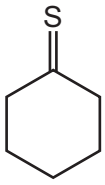

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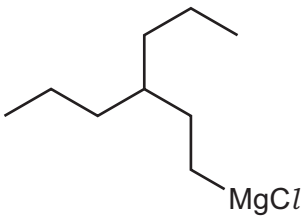

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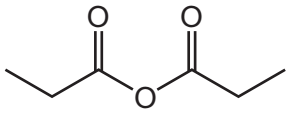

40 A sample of propan-2-ol was shaken with D_2O and its proton NMR spectrum obtained.

What would be seen in the spectrum?

A a doublet with a signal integration of six and a septet with a signal integration of one

B a doublet with a signal integration of six and a singlet with a signal integration of one

C two doublets each with a signal integration of three and two singlets each with a signal integration of one

D two doublets each with a signal integration of three and a singlet with a signal integration of one

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