



Cambridge International AS & A Level

CHEMISTRY

9701/11

Paper 1 Multiple Choice

May/June 2023

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

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

INSTRUCTIONS

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

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

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



- 1 Element X has six more protons than element Y.

Which statement **must** be correct?

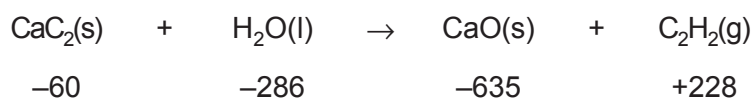
- A Atoms of element Y are smaller than atoms of element X.
 - B Element X has a full shell of electrons.
 - C Element X and element Y are in the same group.
 - D Element X and element Y are in the same period.
- 2 Which statement explains why calcium has a higher melting point than barium?
- A Calcium cations are smaller than barium cations and have a stronger attraction to the delocalised electrons.
 - B The structure of calcium is partly giant molecular.
 - C There are more delocalised electrons in calcium than in barium as it has a lower ionisation energy.
 - D There is greater repulsion between barium atoms as they have more complete electron shells than calcium atoms.
- 3 Three statements about potassium and chlorine and their ions are listed.

- 1 The atomic radius of a potassium atom is greater than the atomic radius of a chlorine atom.
- 2 The first ionisation energy of potassium is greater than the first ionisation energy of chlorine.
- 3 The ionic radius of a potassium ion is greater than the ionic radius of a chloride ion.

Which statements are correct?

- A 1 only B 2 only C 1 and 3 D 2 and 3
- 4 For which equilibrium do both of the equilibrium constants K_c and K_p have no units?
- A $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$
 - B $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
 - C $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
 - D $\text{SO}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightleftharpoons \text{SO}_3(\text{g})$

- 5 Calcium carbide, CaC_2 , reacts with water, as shown. The data below the equation show, in kJ mol^{-1} , the standard enthalpies of formation of the compounds involved.



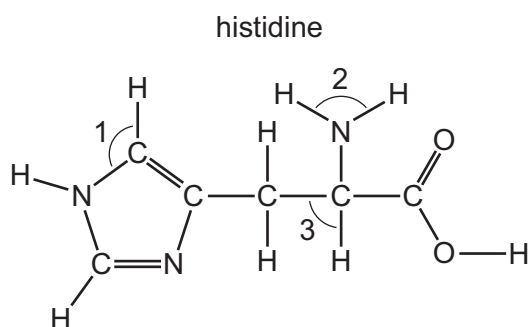
What is the standard enthalpy change of the reaction shown?

- A** -753 kJ mol^{-1}
B -61 kJ mol^{-1}
C $+61 \text{ kJ mol}^{-1}$
D $+753 \text{ kJ mol}^{-1}$
- 6 In the sodium chloride lattice the number of chloride ions that surround each sodium ion is called the coordination number of the sodium ions.

What are the coordination numbers of the sodium ions and the chloride ions in the sodium chloride lattice?

	coordination number of sodium ions	coordination number of chloride ions
A	4	6
B	6	4
C	6	6
D	8	6

- 7 Histidine is an amino acid.



What are the approximate bond angles 1, 2, and 3?

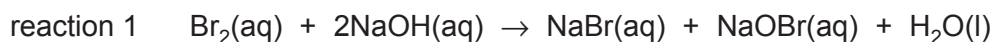
	1	2	3
A	109.5°	107°	90°
B	120°	107°	109.5°
C	120°	120°	90°
D	120°	120°	109.5°

- 8 The Contact process takes place at a pressure between 100 000 Pa and 200 000 Pa. A catalyst is used.

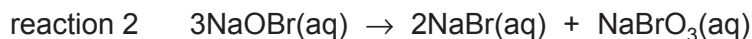
Which statement is correct?

- A** A V_2O_5 catalyst is added to increase the equilibrium yield of the reaction.
- B** Changes in pressure have no effect on the position of equilibrium.
- C** The equilibrium yield of the reaction is very high under the conditions used.
- D** An iron catalyst is added to increase the rate of reaction.

- 9 Bromine reacts with aqueous sodium hydroxide at 25 °C.

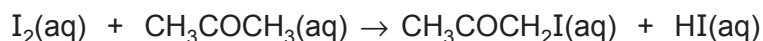


The NaOBr formed is unstable at 25 °C and reacts further.



Which reactions are disproportionations?

- A both reaction 1 and reaction 2
 - B neither reaction 1 nor reaction 2
 - C reaction 1 only
 - D reaction 2 only
- 10 Which statement is correct?
- A The relative atomic mass of a ^{35}Cl atom is 35.5.
 - B The relative formula mass of CaCO_3 is 100.1.
 - C The relative isotopic mass of a ^{24}Mg atom is 24.3.
 - D The relative molecular mass of O_2 is 16.0.
- 11 Iodine and propanone react according to the following equation.



If the concentration of propanone is increased, keeping the total reaction volume constant, the initial rate of the reaction also increases.

What could be the reason for this?

- A A greater proportion of collisions are successful at the higher concentration.
- B The particles are further apart at the higher concentration.
- C The particles have more energy at the higher concentration.
- D There are more collisions per second between particles at the higher concentration.

- 12 Four successive ionisation energies (IE) of element E are shown.

Element E is in Period 3 of the Periodic Table.

fifth IE /kJ mol ⁻¹	sixth IE /kJ mol ⁻¹	seventh IE /kJ mol ⁻¹	eighth IE /kJ mol ⁻¹
16 000	20 000	24 000	29 000

In which group of the Periodic Table is E?

- A** 14 **B** 15 **C** 16 **D** 17

- 13 In this question you should assume that the gas formed behaves as an ideal gas.

A 1.7 g sample of Mg reacts with 50.0 cm³ of 2.2 mol dm⁻³ HCl at 303 K and 110 400 Pa.

Which volume of gas is produced, measured under these conditions?

- A** 1.3 dm³ **B** 1.6 dm³ **C** 2.5 dm³ **D** 5.0 dm³

- 14 Chlorine dioxide, ClO₂, reacts with aqueous sodium hydroxide to produce water and a mixture of two sodium salts, NaClO₂ and NaClO₃.

What is the mole ratio of NaClO₂ to NaClO₃ in the product mixture?

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

- 15 The temperature of a sample of an inert gas is increased.

What effect does this have on the number of molecules with the most probable energy and on the number of molecules with higher energy?

	number of molecules with the most probable energy	number of molecules with higher energy
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

16 For which compound is there the greatest percentage loss of mass on strong heating?

- A anhydrous calcium carbonate
- B anhydrous calcium nitrate
- C anhydrous magnesium carbonate
- D anhydrous magnesium nitrate

17 The solids sodium chloride and sodium iodide both react with concentrated sulfuric acid at room temperature.

With NaCl , the products are NaHSO_4 and HCl .

With NaI , the products are NaHSO_4 , HI , I_2 , SO_2 , H_2O , S and H_2S .

What is the explanation for this difference in products?

- A Chloride ions will displace iodine from the solution.
 - B Hydrogen chloride is more volatile than hydrogen iodide.
 - C Iodide ions are better reducing agents than chloride ions.
 - D Sulfuric acid is able to act as a dehydrating agent with NaI .
- 18 SiO_2 has a melting point of 1713°C . It reacts with hot NaOH(aq) to form sodium silicate, Na_2SiO_3 , and water.

No reaction occurs when SiO_2 is added to hot $\text{H}_2\text{SO}_4\text{(aq)}$.

What can be deduced from this information?

	chemical behaviour of SiO_2	structure of SiO_2
A	amphoteric	giant
B	amphoteric	simple
C	acidic	giant
D	acidic	simple

- 19 Element X has the second largest atomic radius in its period. An atom of X has three occupied electron shells only.

The oxide of X is shaken with water.

What could be the pH of the resulting solution?

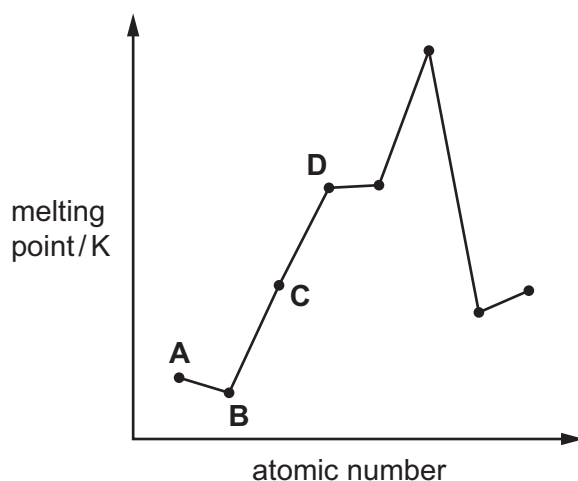
- A 5 B 7 C 9 D 14

- 20 Which emission from an internal combustion engine contributes to the erosion of marble statues?

- A carbon monoxide
B nitrogen
C nitrogen dioxide
D unburnt hydrocarbons

- 21 The diagram shows the melting points of eight elements with consecutive atomic numbers.

Which element could be sodium?



22 The boiling points of Br_2 , ICl and IBr are given in the table.

	Br_2	ICl	IBr
boiling point / $^{\circ}\text{C}$	59	97	116

Which row explains:

- why the boiling point of ICl is greater than Br_2
- why the boiling point of IBr is greater than ICl ?

	boiling point of ICl is greater than Br_2	boiling point of IBr is greater than ICl
A	ICl has stronger instantaneous dipole-induced dipoles	IBr has stronger instantaneous dipole-induced dipoles
B	ICl has permanent dipoles	IBr has stronger instantaneous dipole-induced dipoles
C	ICl has stronger instantaneous dipole-induced dipoles	IBr has stronger permanent dipoles
D	ICl has permanent dipoles	IBr has stronger permanent dipoles

23 A solution contains both $\text{Mg}^{2+}(\text{aq})$ and $\text{Sr}^{2+}(\text{aq})$ at the same concentration.

The solution is divided into two equal portions. Aqueous sodium hydroxide is added dropwise to one portion. Dilute sulfuric acid is added dropwise to the other portion.

Which row is correct?

	precipitate seen first when $\text{NaOH}(\text{aq})$ is added	precipitate seen first when $\text{H}_2\text{SO}_4(\text{aq})$ is added
A	magnesium hydroxide	magnesium sulfate
B	magnesium hydroxide	strontium sulfate
C	strontium hydroxide	magnesium sulfate
D	strontium hydroxide	strontium sulfate

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

If a molecule contains two non-identical chiral carbon atoms, four optical isomers exist.

How many isomers are there with:

- molecular formula $C_7H_{14}O$ **and**
- a five-membered ring **and**
- a tertiary alcohol group?

A 4

B 5

C 9

D 13

25 Which reagent will react with pentan-3-ol to give a mixture of stereoisomers?

- A** acidified potassium dichromate
- B** concentrated sulfuric acid
- C** ethanoic acid in the presence of a little concentrated H_2SO_4
- D** hydrogen chloride

26 An organic molecule W contains 3 carbon atoms. It requires 4.5 molecules of oxygen for complete combustion.

What could W be?

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

27 Which equation represents a reaction that proceeds through initiation, propagation and termination steps?

- A** $C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$
- B** $C_5H_{11}Br + NaOH \rightarrow C_5H_{11}OH + NaBr$
- C** $C_6H_{12} + H_2O \rightarrow C_6H_{13}OH$
- D** $C_6H_{13}CHO + HCN \rightarrow C_6H_{13}CH(OH)CN$

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

A set of isomeric hydrocarbons:

- all contain 14.3% by mass of hydrogen
- all react with bromine by addition, 0.280 g of each hydrocarbon reacting with 0.799 g of bromine.

What is the maximum number of isomeric compounds in the set?

- A 1 B 3 C 4 D 5

29 Which row describes the solvent used and type of reaction occurring when bromoethane reacts with NaOH to form ethene?

	solvent	type of reaction
A	ethanol	elimination
B	ethanol	substitution
C	water	elimination
D	water	substitution

30 Which row describes the type of reaction that occurs when propan-1-ol reacts to form the named carbon-containing product?

	carbon-containing product	type of reaction
A	1-chloropropane	addition to propan-1-ol
B	carbon monoxide	complete combustion of propan-1-ol
C	propene	dehydration of propan-1-ol
D	propanal	reduction of propan-1-ol

31 Which statement describes what happens when 2-chloro-2-methylpropane is warmed with NaOH(aq)?

- A This secondary halogenoalkane reacts by a mixture of an S_N1 and an S_N2 mechanism.
- B This secondary halogenoalkane reacts only by an S_N2 mechanism.
- C This tertiary halogenoalkane reacts mostly by an S_N1 mechanism.
- D This tertiary halogenoalkane does **not** react with hydroxide ions under these conditions.

32 How many structurally isomeric secondary alcohols are there with the molecular formula $C_5H_{12}O$?

- A 1 B 2 C 3 D 4

33 Which reagent:

- can confirm the presence of a carbonyl group in an organic compound
- does **not** distinguish between aldehydes and ketones?

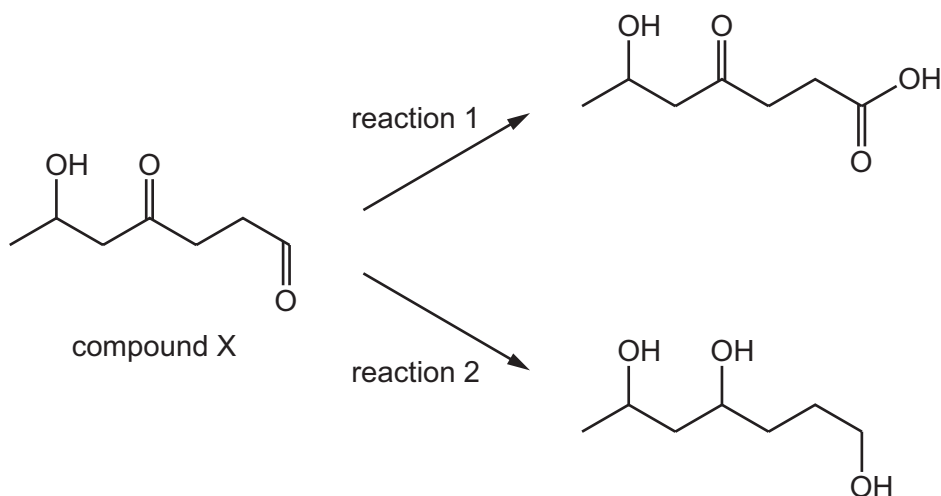
- A acidified $K_2Cr_2O_7$
B 2,4-DNPH reagent
C Fehling's reagent
D $LiAlH_4$

34 Which compound gives a positive test with alkaline aqueous iodine and does **not** show optical isomerism?

- A $CH_3COCH_2CH_2OH$
B $CH_3CH_2CH(OH)CHO$
C $CH_3COCH(OH)CH_3$
D $(CH_3)_2C(OH)CHO$

- 35** Two samples of compound X were treated separately with different reagents which were added in excess.

The products of these two reactions are shown.



Which reagents could be used for reaction 1 and reaction 2?

	reaction 1	reaction 2
A	hot acidified sodium dichromate(VI)	Na
B	hot acidified sodium dichromate(VI)	NaBH ₄
C	Tollens' reagent followed by HCl(aq)	Na
D	Tollens' reagent followed by HCl(aq)	NaBH ₄

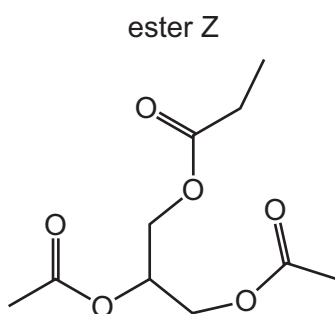
- 36** Which method could produce butanoic acid?
- A** an acid–base reaction involving CH₃CH₂CH₂CO₂Na
 - B** the hydrolysis of CH₃CH₂CH₂CH₂CN
 - C** the acidic hydrolysis of CH₃CH₂COOCH₂CH₂CH₃
 - D** the oxidation of CH₃CH₂CH₂OH

37 Which ester may be hydrolysed to produce two products, one of which may be reduced to the other?

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

38 Two compounds, X and Y, are mixed and a little concentrated H_2SO_4 is added.

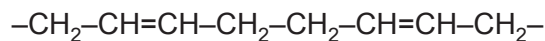
Ester Z is found in the resulting mixture of products.



Which two compounds could be X and Y?

	X	Y
A	$\text{CH}_3\text{CH}_2\text{OH}$	$\text{CH}(\text{CO}_2\text{H})_3$
B	$\text{CH}_3\text{CH}_2\text{OH}$	$\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{OCOCH}_2\text{CH}_3$
C	$\text{CH}_3\text{CO}_2\text{H}$	$\text{CH}_3\text{CH}_2\text{CO}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$
D	$\text{CH}_3\text{CO}_2\text{H}$	$\text{CH}_2(\text{OH})\text{CH}(\text{OH})\text{CH}_2(\text{OH})$

39 The diagram shows a section of a polymer molecule.



Which monomer will produce this polymer?

- A $\text{CH}_2=\text{CH}_2$
 B $\text{CH}_3\text{CH}=\text{CH}_2$
 C $\text{CH}_3\text{CH}=\text{CHCH}_3$
 D $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$

- 40 There are two naturally occurring isotopes of bromine. One isotope has 44 neutrons. The other isotope has 46 neutrons.

Ignoring fragments, how many peaks are there in the mass spectrum of tribromomethane, $^{12}\text{C}^1\text{HBr}_3$?

A 2

B 3

C 4

D 6

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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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

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The Periodic Table of Elements

Group																								
1	2													13	14	15	16	17	18					
		1 H hydrogen 1.0																						
		Key atomic number atomic symbol name relative atomic mass																						
3	4													5	6	7	8	9	10	11	12			
Li lithium 6.9	Be beryllium 9.0													B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0						
11	12													13	14	15	16	17	18					
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9					
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36							
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8							
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54							
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3							
55	56	57–71 lanthanoids		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86						
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —						
87	88	89–103 actinoids		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118						
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganeson —						

lanthanoids

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

actinoids



Cambridge International AS & A Level

CHEMISTRY

9701/12

Paper 1 Multiple Choice

May/June 2023

1 hour 15 minutes

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- 1 When chlorine gas is analysed in a mass spectrometer $^{35}\text{Cl}^+$ ions are detected.

Which row is correct?

	number of neutrons in $^{35}\text{Cl}^+$	electronic configuration of $^{35}\text{Cl}^+$
A	17	$1s^2 2s^2 2p^6 3s^2 3p^4$
B	17	$1s^2 2s^2 2p^6 3s^2 3p^6$
C	18	$1s^2 2s^2 2p^6 3s^2 3p^4$
D	18	$1s^2 2s^2 2p^6 3s^2 3p^6$

- 2 Which species is a free radical?

A He **B** Be^- **C** O^{2-} **D** Zn

- 3 Which statement is correct?

- A** The first ionisation energy of chlorine is more than the first ionisation energy of argon.
B The second ionisation energy of calcium is more than the second ionisation energy of magnesium.
C The second ionisation energy of sulfur is equal to the first ionisation energy of phosphorus.
D The eighth ionisation energy of chlorine is more than the first ionisation energy of neon.

- 4 If 1 mole of hexane combusts in an excess of oxygen, how many moles of products are formed?

A 11 **B** 12 **C** 13 **D** 14

- 5 Separate samples, each of mass 1.0 g, of the compounds listed are treated with an excess of dilute acid.

Which compound releases the largest amount of CO_2 ?

A 1.0 g CaCO_3 **B** 1.0 g Li_2CO_3 **C** 1.0 g MgCO_3 **D** 1.0 g Na_2CO_3

- 6 Which statement about the $\text{Cl}-\text{N}=\text{O}$ molecule is correct?

- A** Each molecule contains one σ and two π bonds.
B It is a non-polar molecule.
C It is a linear molecule.
D The nitrogen atom is sp^2 hybridised .

7 Which row is correct?

	molecule	shape	total number of pairs of electrons in the valence shell of the central atom
A	CO ₂	linear	two
B	BF ₃	trigonal planar	three
C	NH ₃	regular tetrahedral	four
D	PF ₅	octahedral	six

8 The volume of a vessel is $1.20 \times 10^{-3} \text{ m}^3$. It contains pure argon at a pressure of $1.00 \times 10^5 \text{ Pa}$, and at a temperature of 25.0°C . Under these conditions it can be assumed that argon behaves as an ideal gas.

Which mass of argon does it contain?

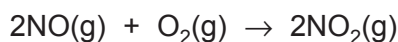
- A** 0.0485 g **B** 1.93 g **C** 10.4 g **D** 23.0 g

9 A student mixed 25.0 cm^3 of 4.00 mol dm^{-3} hydrochloric acid with an equal volume of 4.00 mol dm^{-3} sodium hydroxide. The initial temperature of both solutions was 15.0°C . The maximum temperature recorded was 30.0°C . The heat capacity of the final solution can be assumed to be $4.18 \text{ J K}^{-1} \text{ g}^{-1}$ and the density of this solution can be assumed to be 1.00 g cm^{-3} .

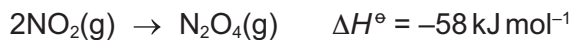
Using these results, what is the enthalpy change of neutralisation of hydrochloric acid?

- A** $-62.7 \text{ kJ mol}^{-1}$
B $-31.4 \text{ kJ mol}^{-1}$
C $-15.7 \text{ kJ mol}^{-1}$
D $-3.14 \text{ kJ mol}^{-1}$

- 10 Nitrogen monoxide is rapidly oxidised to nitrogen dioxide.

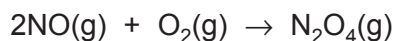


Nitrogen dioxide can then dimerise to form dinitrogen tetroxide.



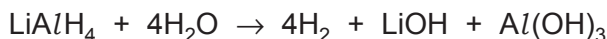
$$\Delta H_f^\circ \text{NO} = +91 \text{ kJ mol}^{-1} \text{ and } \Delta H_f^\circ \text{NO}_2 = +34 \text{ kJ mol}^{-1}$$

What is the value of the standard enthalpy change for the reaction shown?



- A** $+56 \text{ kJ mol}^{-1}$ **B** -1 kJ mol^{-1} **C** -115 kJ mol^{-1} **D** -172 kJ mol^{-1}
- 11 LiAlH_4 contains AlH_4^- ions in which aluminium has an oxidation state of +3.

LiAlH_4 reacts with water, as shown.

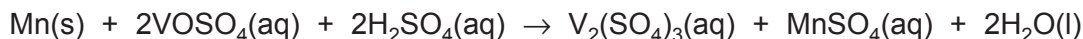


In this reaction, each of the four water molecules produces one hydroxide ion. It does this by losing one H^+ ion, which reacts with the LiAlH_4 .

Which changes in oxidation number occur in this reaction?

- A** Al increases by 1 and H decreases by 1.
B H decreases by 2 and also increases by 1.
C H increases by 1 and also decreases by 1.
D O decreases by 1 and H increases by 1.
- 12 The vanadium salt, VOSO_4 , is soluble in water and reacts readily with powdered manganese in dilute sulfuric acid.

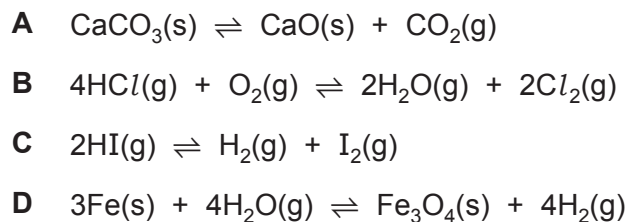
The equation for the reaction is shown.



Which statement about this reaction is correct?

- A** Hydrogen is oxidised in the reaction.
B Manganese is the reducing agent in this reaction.
C Sulfuric acid is the oxidising agent in this reaction.
D The oxidation state of the vanadium changes from +5 to +3.

- 13 In which equilibrium will an increase in pressure at constant temperature increase the yield of the products on the right-hand side of the equation?



- 14 Hydrogen iodide is added to an evacuated reaction vessel. The vessel is sealed and warmed. A decomposition reaction occurs. Hydrogen and iodine are formed. Some hydrogen iodide remains.

When equilibrium is established, the total pressure is $1.20 \times 10^5 \text{ Pa}$. The partial pressure of hydrogen is $4.00 \times 10^3 \text{ Pa}$.

Hydrogen iodide, hydrogen and iodine are all gaseous under the conditions used.

What is the value of K_p for the equilibrium at this temperature, assuming the decomposition is the forward reaction?



- 15 The equations for two reactions are shown.



The two reactions have similar reaction mechanisms.

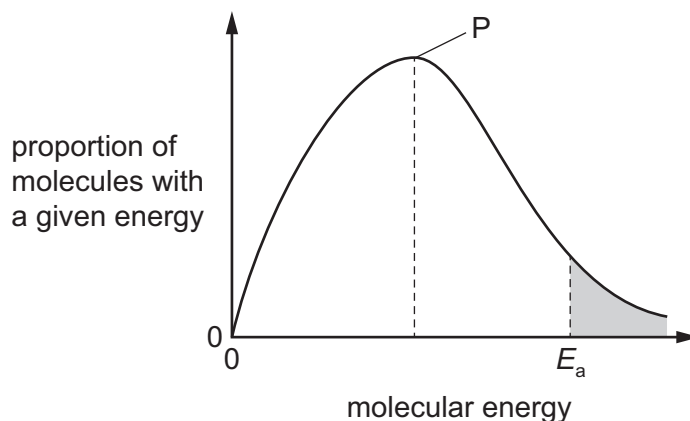
The initial rate of reaction X is greater than that of reaction Y when measured under identical conditions of temperature, pressure and reactant concentration.

Which statements explain this difference?

- 1 The activation energy for reaction X is less than that of reaction Y.
- 2 The Br–Br bond is weaker than the Cl–Cl bond.
- 3 A higher frequency of collisions between molecules of NOBr occur than between molecules of NOCl.



- 16 The diagram shows the Boltzmann distribution of energies in a gas. The gas can take part in a reaction with an activation energy, E_a . The gas is maintained at a constant temperature.



Which statement is correct?

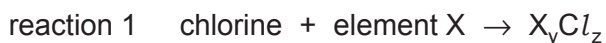
- A If a catalyst is added, peak P will be lower and E_a will move to the left.
 - B If a catalyst is added, peak P will be lower and E_a will move to the right.
 - C If a catalyst is added, peak P will be the same and E_a will move to the left.
 - D If a catalyst is added, peak P will be the same and E_a will move to the right.
- 17 L, M and N are three different elements from Period 3 of the Periodic Table.
- L is the element whose atoms have three unpaired electrons in its 3p sub-shell.
- M is the element with the highest electrical conductivity in the period.
- N is the element with the highest melting point in the period.

Which statement about element L is correct?

- A L has a higher atomic number than M and a lower atomic number than N.
- B L has a lower atomic number than M and a higher atomic number than N.
- C L has a lower atomic number than both M and N.
- D L has a higher atomic number than both M and N.

- 18 In reactions 1 and 2, X represents an element in Period 3.

In each reaction, X is forming a product where X is in its highest oxidation state.



Which ratios show a steady increase from sodium to phosphorus?

- A** neither $z:y$ nor $q:p$
B $z:y$ only
C $q:p$ only
D both $z:y$ and $q:p$
- 19 Sodium, magnesium, aluminium, silicon and phosphorus are all elements in Period 3 of the Periodic Table.

Three statements about the oxides and chlorides of these elements are given.

- 1 The ionically bonded oxides all react with dilute hydrochloric acid.
- 2 All metal chlorides produce neutral solutions when added to water.
- 3 The two most electronegative elements both form covalently bonded chlorides.

Which statements are correct?

- A** 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only
- 20 The table compares calcium with barium and calcium carbonate with barium carbonate.

Which row is correct?

	reactivity of the element with water	thermal stability of the metal carbonate
A	barium is more reactive	barium carbonate is more stable
B	barium is more reactive	calcium carbonate is more stable
C	calcium is more reactive	barium carbonate is more stable
D	calcium is more reactive	calcium carbonate is more stable

- 21** Solutions P and Q each contain a different Group 2 ion at the same concentration. One contains Mg^{2+} and the other contains Ba^{2+} . Tests are carried out on separate 5 cm^3 samples of P and Q.

test 1: add 1 cm^3 of $0.1\text{ mol dm}^{-3}\text{ Na}_2\text{SO}_4(\text{aq})$

test 2: add 1 cm^3 of $0.1\text{ mol dm}^{-3}\text{ NaOH}(\text{aq})$

What are the results of these tests?

	results in test 1	results in test 2
A	more precipitate with Ba^{2+}	more precipitate with Ba^{2+}
B	more precipitate with Ba^{2+}	more precipitate with Mg^{2+}
C	more precipitate with Mg^{2+}	more precipitate with Ba^{2+}
D	more precipitate with Mg^{2+}	more precipitate with Mg^{2+}

- 22** J dissolves in water to give an aqueous solution K.

K gives a dense white precipitate when aqueous silver nitrate is added.

When heated with aqueous potassium hydroxide, K gives off a gas that turns moist universal indicator paper blue.

What is J?

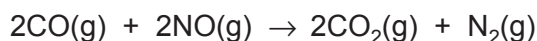
- A** ammonium chloride
 - B** ammonium sulfate
 - C** sodium chloride
 - D** sodium hydroxide
- 23** Ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, and ammonium nitrate, NH_4NO_3 , are used as fertilisers.

These salts have different percentages by mass of nitrogen. They have the same effect as each other on the pH of wet neutral soil.

Which row is correct?

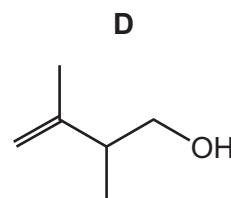
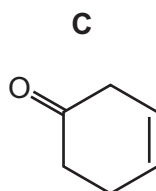
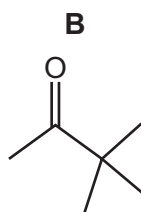
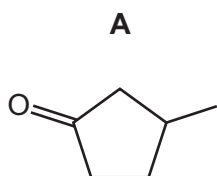
	higher percentage of nitrogen by mass	effect on pH of soil
A	ammonium nitrate	decrease
B	ammonium nitrate	increase
C	ammonium sulfate	decrease
D	ammonium sulfate	increase

- 24 The equation shows a reaction that occurs between carbon monoxide and nitrogen monoxide in a catalytic converter.



Which statement is correct?

- A** The catalyst used is finely divided iron.
B The reaction prevents greenhouse gas emissions into the atmosphere.
C The reaction reduces the possibility of the formation of photochemical smog.
D The reaction results in increased ozone depletion.
- 25 Which compound has the molecular formula $\text{C}_6\text{H}_{10}\text{O}$?



- 26 The general formula for a non-cyclic alcohol is $\text{C}_n\text{H}_{2n+1}\text{OH}$.

How many different structural isomers are there for $n = 3$ and $n = 4$?

	$n = 3$	$n = 4$
A	2	2
B	2	4
C	3	4
D	3	8

- 27 Compound X, $\text{C}_5\text{H}_{10}\text{O}_3$, has one chiral carbon atom per molecule. Compound X produces bubbles with Na but **not** with Na_2CO_3 .

Which formula could represent compound X?

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

- 28 Ethane reacts with an excess of chlorine in the presence of ultraviolet light to form a mixture of products.

How many of these products contain two carbon atoms and one or more chlorine atoms?

- A 6 B 7 C 8 D 9

- 29 When bromoethane reacts with hot ethanolic sodium hydroxide a colourless gas is formed. This gas decolourises aqueous bromine.

What is the colourless gas?

- A 1,2-dibromoethane
B ethanol
C ethene
D hydrogen bromide

- 30 Alkynes are hydrocarbons that contain one triple $\text{C}\equiv\text{C}$ bond.

Like alkenes, alkynes take part in addition reactions. A saturated compound can be formed.

For example, ethyne, $\text{H}-\text{C}\equiv\text{C}-\text{H}$, reacts with an excess of hydrogen to form ethane.

Propyne, C_3H_4 , undergoes an addition reaction with an excess of hydrogen bromide in two stages. Markovnikov's rule applies to the addition of HBr at each stage.

What is the main product obtained when propyne reacts with an excess of hydrogen bromide?

- A $\text{CH}_2\text{BrCH}_2\text{CH}_2\text{Br}$
B $\text{CH}_3\text{CH}_2\text{CHBr}_2$
C $\text{CH}_3\text{CHBrCH}_2\text{Br}$
D $\text{CH}_3\text{CBr}_2\text{CH}_3$

- 31 Bromine reacts with alkenes by an electrophilic addition mechanism in which a cation is formed as an intermediate.

Which mixture will produce the most stable intermediate cation?

- A 3,3-dimethylpent-1-ene + bromine
B ethene + bromine
C methylpropene + bromine
D propene + bromine

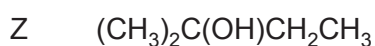
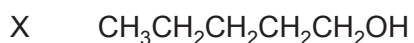
32 Halogenoalkanes react with hot ethanolic potassium cyanide.

The reaction mechanism is either S_N1 or S_N2 .

Which statement is correct?

- A** All secondary halogenoalkanes react by the S_N2 mechanism only.
- B** Both the halogenoalkane and the cyanide ion are involved in the initial step of the S_N1 mechanism.
- C** Chloroethane reacts with cyanide ions by the S_N1 mechanism only.
- D** The S_N2 mechanism involves a short-lived negatively charged transition state.

33 X, Y and Z are three isomeric alcohols.



Separate samples of each alcohol are warmed with a mild oxidising agent and the results noted.

One of these alcohols, when dehydrated, will give a pair of cis-trans isomers with molecular formula C_5H_{10} .

Which row is correct?

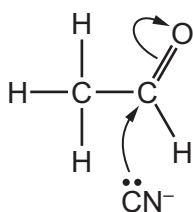
	reacts with mild oxidising reagents	gives cis/trans isomers
A	X, Y and Z	Y only
B	X, Y and Z	Z only
C	X and Y only	Y only
D	X and Y only	Z only

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

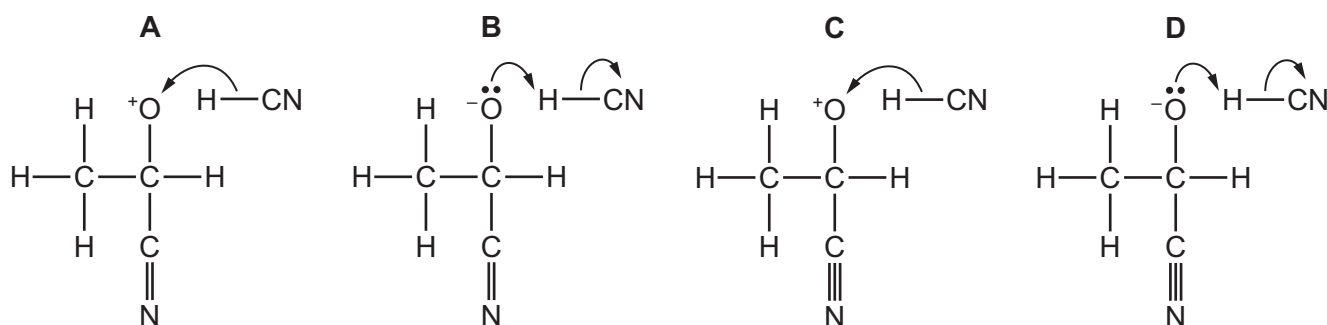
What could be compound G?

- A** pentan-1-ol
- B** pentan-2-ol
- C** pentan-3-ol
- D** 2-methylpentan-2-ol

- 35 The mechanism for the reaction between ethanal and hydrogen cyanide starts with the step shown.



What is the correct structure of the intermediate ion formed, and what is the next step in this mechanism?

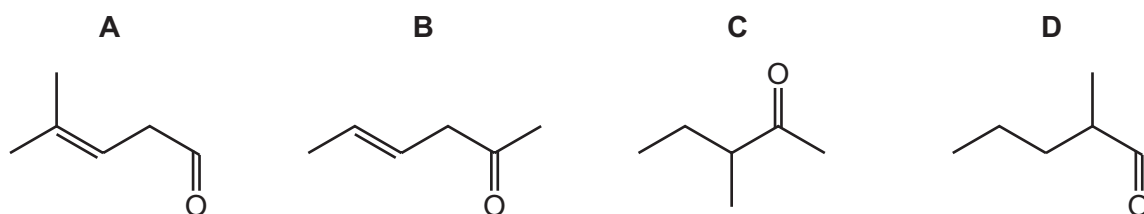


- 36 Which compound reacts with 2,4-dinitrophenylhydrazine reagent but does **not** react with Tollens' reagent?

- A $\text{CH}_3\text{COCO}_2\text{H}$
 B $\text{CH}_3\text{CH}(\text{OH})\text{CHO}$
 C CH_3COCHO
 D $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

- 37 Compound X has stereoisomers and forms a precipitate when warmed with Fehling's reagent.

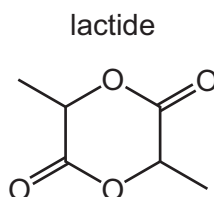
What could be the structure of compound X?



38 Which reaction will form propanoic acid?

- A acidic hydrolysis of propyl ethanoate
- B alkaline hydrolysis of ethyl propanoate
- C acidic hydrolysis of propanenitrile
- D acidic hydrolysis of ethanenitrile

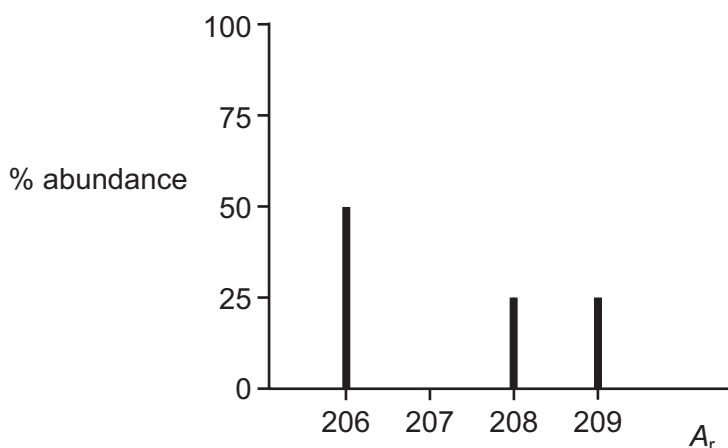
39 Lactide is an intermediate in the manufacture of a synthetic fibre.



Which compound, on heating with an acid catalyst, can produce lactide?

- A hydroxyethanoic acid
- B 2-hydroxybutanoic acid
- C 2-hydroxypropanoic acid
- D 3-hydroxypropanoic acid

40 The diagram shows the relative abundance of different isotopes of lead in a sample of lead ore. The abundance of 208 is half that of 206. The abundances of 208 and 209 are equal.



What is the relative atomic mass of the lead in the sample?

- A 207.00
- B 207.25
- C 207.50
- D 207.67

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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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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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Cambridge International AS & A Level

CHEMISTRY

9701/13

Paper 1 Multiple Choice

May/June 2023

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

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

INSTRUCTIONS

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

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **16** pages.

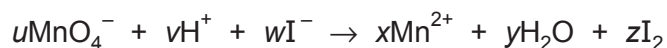


- 1 Propanoic acid is treated with reagent X at room temperature. The organic product of the reaction is sodium propanoate. No gas is produced during the reaction.

What could be reagent X?

- A** $\text{NaHCO}_3(\text{aq})$ **B** $\text{NaOH}(\text{aq})$ **C** $\text{Na}_2\text{CO}_3(\text{aq})$ **D** $\text{Na}_2\text{SO}_4(\text{aq})$

- 2 The ionic equation shows iodide ions reacting with manganate(VII) ions in acidic solution.



The letters u , v , w , x , y and z all represent whole numbers. Two or more of u , v , w , x , y and z are the same as each other.

What is the lowest possible value of v ?

- A** 2 **B** 8 **C** 10 **D** 16

- 3 A piece of rock has a mass of 2.00 g. It contains calcium carbonate, but no other basic substances. It neutralises exactly 36.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid.

What is the percentage by mass of calcium carbonate in the 2.00 g piece of rock?

- A** 22.5% **B** 45.0% **C** 72.0% **D** 90.1%

- 4 L and M are elements in Period 3 of the Periodic Table. Neither element is argon.

Information about the Pauling electronegativity values of L and M is given.

element	Pauling electronegativity value
L	the highest of the seven elements Na to Cl
M	the lowest of the seven elements Na to Cl

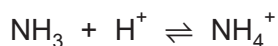
Three statements about elements L and M are given.

- 1 Element L contains covalent bonds.
- 2 Element L has a higher atomic number than element M.
- 3 A compound of L and M contains ionic bonds.

Which statements are correct?

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

- 5 Ammonia reacts with acids to form the ammonium ion.



Which row is correct?

	shape of NH_4^+	bond angle in NH_4^+ / °
A	pyramidal	107
B	pyramidal	109.5
C	tetrahedral	107
D	tetrahedral	109.5

- 6 Electronegativity differences can be used to help determine the oxidation number of an atom in different species. A number of rules are used which include:

- The more electronegative atom is given a negative oxidation number.
- Hydrogen is more electronegative than Group 1 metals.
- Oxygen is more electronegative than hydrogen.

Which row is correct?

	equation of reaction	redox reaction	disproportionation reaction
A	$2\text{CrO}_4^{2-} + 2\text{H}^+ \rightarrow \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$	✓	✗
B	$\text{NaH} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{H}_2$	✓	✓
C	$3\text{MnO}_4^{2-} + 4\text{H}^+ \rightarrow \text{MnO}_2 + 2\text{MnO}_4^-$	✓	✓
D	$\text{VO}_3^- + 2\text{H}^+ \rightarrow \text{VO}_2^+ + \text{H}_2\text{O}$	✓	✗

- 7 Which assumptions are made about ideal gases?

- 1 Ideal gases contain molecules with no mass.
- 2 Ideal gases contain molecules with no volume.
- 3 Ideal gases have no intermolecular forces.

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

- 8 A 200 cm³ sample of water has an amount of oxygen gas dissolved in it.

This amount of oxygen gas has a volume of 6.00 cm³ when measured at 1.00×10^5 Pa and 35 °C.

What is the concentration of oxygen gas in the water? (You should assume that oxygen behaves as an ideal gas.)

- A $2.34 \times 10^{-4} \text{ mol dm}^{-3}$
- B $1.17 \times 10^{-3} \text{ mol dm}^{-3}$
- C $1.25 \times 10^{-3} \text{ mol dm}^{-3}$
- D $1.03 \times 10^{-2} \text{ mol dm}^{-2}$
- 9 Which statement explains why buckminsterfullerene has a lower melting point than graphite?
- A Buckminsterfullerene exists as discrete molecules with weak intermolecular bonding.
- B Graphite is partly ionic as its structure contains mobile electrons and it conducts electricity.
- C The carbon–carbon bonds in buckminsterfullerene are shorter and more strained.
- D The mobile electrons in graphite mean it has a metallic structure.
- 10 Which equation represents the reaction whose standard enthalpy change is the standard enthalpy change of formation of water?
- A $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$
- B $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- C $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
- D $2\text{H}(\text{g}) + \text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- 11 Which mixture will react to form exactly one mole of water?

	volume 2.00 mol dm^{-3} $\text{H}_2\text{SO}_4 / \text{cm}^3$	volume 1.00 mol dm^{-3} $\text{NaOH} / \text{cm}^3$
A	250	500
B	250	1000
C	500	500
D	500	1000

- 12** The enthalpy change for neutralisation of $\text{HNO}_3(\text{aq})$ with $\text{NaOH}(\text{aq})$ is $-57.0 \text{ kJ mol}^{-1}$.

In an experiment, 20.0 cm^3 of 4.00 mol dm^{-3} HNO_3 is mixed with 30.0 cm^3 of 2.00 mol dm^{-3} NaOH in an insulated container. The initial temperature of both solutions is 25.0°C .

It can be assumed that the heat capacity of the product mixture is $4.2 \text{ J cm}^{-3}^\circ\text{C}^{-1}$ and that there are no heat losses.

What is the maximum final temperature of the mixture?

- A** 41.3°C **B** 44.0°C **C** 46.7°C **D** 52.1°C

- 13** Some bond energies are listed.

bond	bond energy / kJ mol^{-1}
H–H	436
O–H	463
O–O	146
O=O	496

One mole of hydrogen reacts with oxygen to give water vapour.

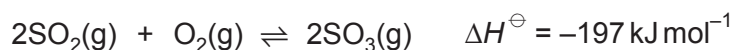
Using the bond energy data, what is the value for the enthalpy change of this reaction?

- A** $+221 \text{ kJ mol}^{-1}$
B $+6 \text{ kJ mol}^{-1}$
C -242 kJ mol^{-1}
D -417 kJ mol^{-1}

- 14** Which particle contains nitrogen in the same oxidation state as in the ion $\text{N}_2\text{O}_2^{2-}$?

- A** NH_2F **B** N_2O_4 **C** NO_3^- **D** HNF_2

15 Sulfur dioxide reacts with oxygen as shown.

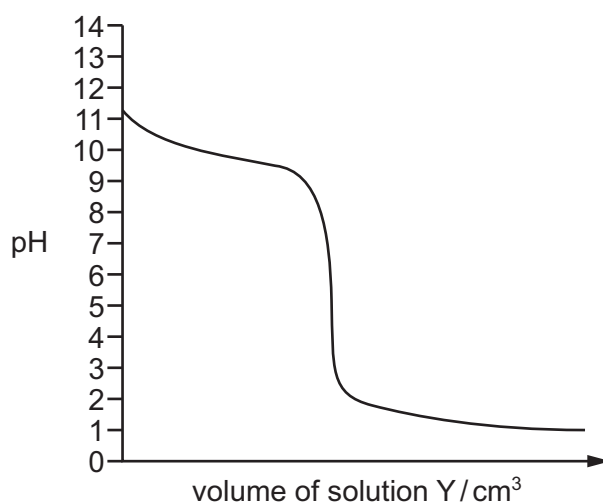


Which change will move the equilibrium position to the right side and change the value of the equilibrium constant, K_c ?

- A the addition of a catalyst
- B increasing the pressure of the reaction
- C decreasing the temperature of the reaction
- D decreasing the concentration of product

16 Solutions X and Y both have a concentration of 0.10 mol dm^{-3} . A fixed volume of solution X is added to a conical flask, and solution Y is added from a burette to the conical flask. A titration is performed.

The diagram shows the pH titration curve for the acid–base reaction between the solutions.



What are solutions X and Y?

	solution X	solution Y
A	ammonia	nitric acid
B	ammonia	ethanoic acid
C	potassium hydroxide	nitric acid
D	potassium hydroxide	ethanoic acid

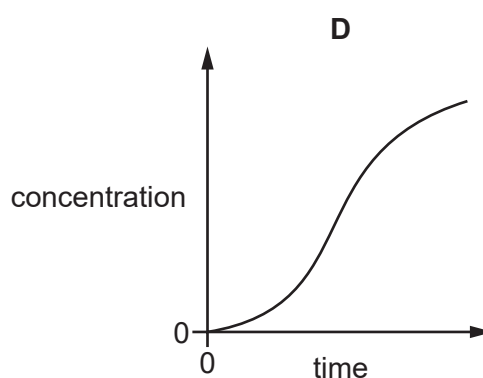
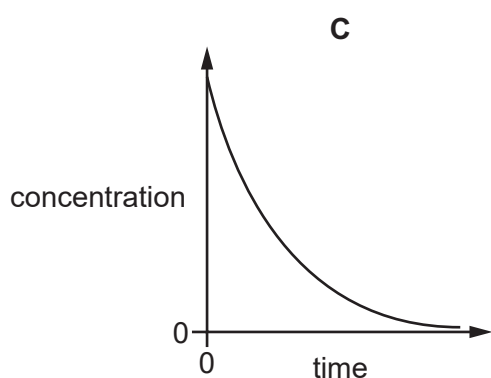
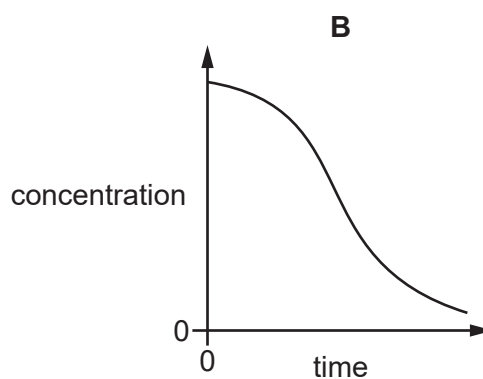
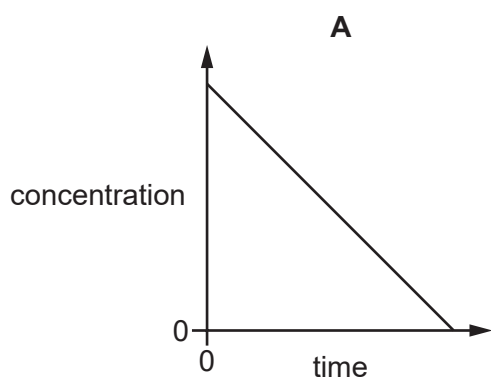
- 17 Which row shows the expected properties of the element astatine when compared to the properties of the element iodine?

	electronegativity of astatine compared to iodine	volatility of astatine compared to iodine
A	less electronegative	higher
B	more electronegative	higher
C	less electronegative	lower
D	more electronegative	lower

- 18 The rate of an exothermic reaction is followed by measuring the concentration of a reactant at regular time intervals.

During the experiment the temperature of the reaction mixture is **not** controlled.

Which graph shows the change in concentration of reactant against time?



- 19 For a particular reversible reaction the backward reaction is endothermic.

The activation energy of the backward reaction is 160 kJ mol^{-1} .

It can be assumed that the backward reaction proceeds by a mechanism that is the exact reverse of the mechanism for the forward reaction.

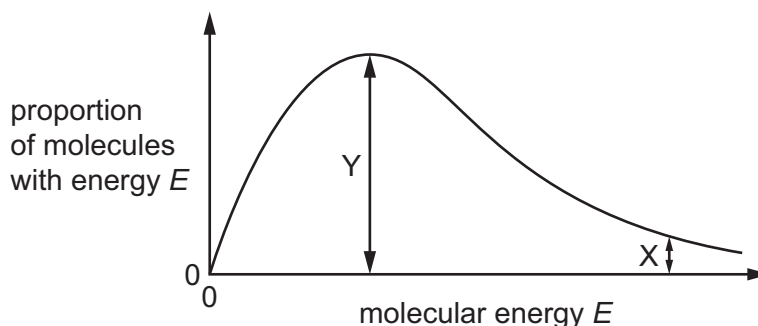
Which statement about the activation energy of the forward reaction is correct?

- A The activation energy of the forward reaction is equal to -160 kJ mol^{-1} .
 - B The activation energy of the forward reaction is 0 kJ mol^{-1} but less than $+160 \text{ kJ mol}^{-1}$.
 - C The activation energy of the forward reaction is equal to $+160 \text{ kJ mol}^{-1}$.
 - D The activation energy of the forward reaction is greater than $+160 \text{ kJ mol}^{-1}$.
- 20 HCN has been detected in interstellar gas. The molecules below have also been detected in interstellar gas.

Which molecule contains the same total number of valence shell (outer shell) electrons as HCN?

- A HNO B NH_3 C NO D PN

- 21 The diagram shows the Boltzmann distribution of the energy of gaseous molecules at a particular temperature.



Which statement is correct?

- A If the temperature of the gas is raised, the height of the maximum of the curve increases.
- B If the temperature of the gas is raised, the maximum of the curve moves to the right.
- C The length of the line labelled X shows the activation energy for the reaction.
- D The length of the line labelled Y shows the enthalpy change of the reaction.

- 22** The elements magnesium and phosphorus are reacted separately with an excess of oxygen to form their oxides. Each oxide is then added separately to water and the pH values of the resulting solutions are measured.

The same two elements are reacted separately with an excess of chlorine to form their chlorides. Each chloride is then added separately to water and the pH values of the resulting solutions are measured.

Which row is correct?

	oxide giving the higher pH	chloride giving the higher pH
A	magnesium	magnesium
B	magnesium	phosphorus
C	phosphorus	magnesium
D	phosphorus	phosphorus

- 23** Equal volumes of saturated solutions of magnesium hydroxide, calcium hydroxide and strontium hydroxide are completely neutralised with dilute sulfuric acid.

The water is gently evaporated from each of the resulting solutions, leaving the corresponding solid sulfates.

These solid sulfates are completely dissolved in the minimum volume of water needed to produce saturated solutions.

Which statement about the volumes of water needed to dissolve the sulfates is correct?

- A** The calcium sulfate will require the greatest volume of water.
- B** The magnesium sulfate will require the greatest volume of water.
- C** The strontium sulfate will require the greatest volume of water.
- D** They will all require the same volume of water.

- 24** Which statement about the halogens is correct?

- A** Iodine cannot behave as an oxidising agent.
- B** The volatility of the elements increases from chlorine to iodine because of the increase in molecular size down the group.
- C** When an equimolar mixture of chlorine and hydrogen is exploded, only one product is formed.
- D** When concentrated sulfuric acid is added to solid sodium bromide, hydrogen sulfide is one of the products.

- 25 When concentrated sulfuric acid is added to solid sodium bromide, bromine gas is produced, along with a number of other products. However, when concentrated sulfuric acid is added to solid sodium chloride, only hydrogen chloride and sodium hydrogensulfate are produced.

What is the reason for this difference?

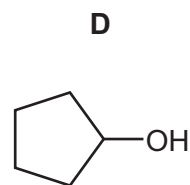
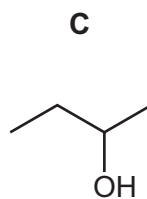
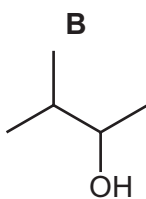
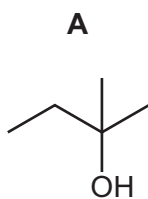
- A Bromine is less volatile than chlorine.
 - B Hydrochloric acid is a weak acid.
 - C Sulfuric acid is **not** an oxidising agent.
 - D The bromide ion is a stronger reducing agent than the chloride ion.
- 26 Which statement about the oxides of nitrogen is correct?
- A During lightning storms, atmospheric oxygen and nitrogen combine to form oxides of nitrogen.
 - B In a catalytic converter, nitrogen monoxide is removed by reaction with carbon dioxide.
 - C In car engines, the restricted supply of oxygen eliminates the possibility of the formation of oxides of nitrogen.
 - D In the atmosphere, nitrogen monoxide reacts with sulfur dioxide to produce sulfur trioxide.
- 27 Structural isomerism and stereoisomerism should be considered when answering this question.

2-bromopentane is heated with an excess of ethanolic sodium hydroxide.

How many different hydrocarbons are produced?

- A 1 B 2 C 3 D 4

- 28 Which compound is a secondary alcohol that can be dehydrated to form an alkene with $M_r = 70$?



- 29 The conversion of propan-1-ol into propan-2-ol can be completed in a two-stage synthesis.

The first stage is to heat the propan-1-ol with concentrated sulfuric acid.

Which reagent would be needed to complete the second stage?

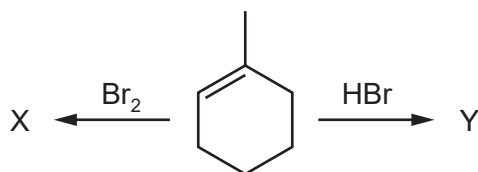
- A cold dilute acidified manganate(VII) ions
 - B hot concentrated acidified manganate(VII) ions
 - C steam with phosphoric acid
 - D aqueous sodium hydroxide
- 30 Which type of reaction happens during the hydrolysis of 2-bromopropane?
- A electrophilic addition
 - B free radical substitution
 - C nucleophilic addition
 - D nucleophilic substitution

- 31 A mixture of ethane and an excess of chlorine is exposed to UV light.

How many different products, each containing only two carbon atoms and at least one chlorine atom per molecule, can be formed?

- A 8
 - B 9
 - C 10
 - D 12
- 32 When 1-methylcyclohexene reacts with Br_2 the product is X.

When 1-methylcyclohexene reacts with HBr the **major** product is Y.



Which statement is correct?

- A X is a mixture of two stereoisomers; Y does **not** have stereoisomers.
- B X is a mixture of two stereoisomers; Y is a mixture of four stereoisomers.
- C X is a mixture of four stereoisomers; Y does **not** have stereoisomers.
- D X is a mixture of four stereoisomers; Y is a mixture of four stereoisomers.

- 33 T is an organic compound which contains 66.7% by mass of carbon. T also contains one atom of oxygen per molecule.

T reacts with alkaline $I_2(aq)$ to produce a yellow precipitate.

What is T?

- A methylpropan-2-ol
 - B butan-2-ol
 - C butanal
 - D butanone
- 34 Which statement about butanone is correct?
- A Butanone can be dehydrated by concentrated sulfuric acid to give $CH_2=CHCH=CH_2$.
 - B Butanone gives a positive result with Tollens' reagent.
 - C Butanone reacts with HCN by an electrophilic addition mechanism.
 - D Butanone reacts with $NaBH_4$ to give a chiral product.
- 35 Methylbut-2-ene reacts with HBr at room temperature to produce compound X as a major product.

Compound X reacts with KCN in ethanol to produce compound Y.

Compound Y is hydrolysed with acid to produce compound Z.

What is compound Z?

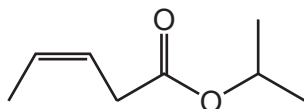
- A 2,2-dimethylbutanoic acid
 - B 2,3-dimethylbutanoic acid
 - C 2-methylpentanoic acid
 - D 3-methylpentanoic acid
- 36 Compound Q can be hydrolysed by $HCl(aq)$. The two products of this hydrolysis have the same empirical formula.

What could Q be?

- A $CH_3CO_2CH_2CH_2OH$
- B $CH_3CO_2CH_2CH_2CO_2H$
- C $CH_3CH_2CO_2CH_2CH_2CH_3$
- D $CH_3CH_2CH(OH)CH(OH)CH_2CH_3$

- 37 An unsaturated carboxylic acid reacts with alcohol X to form an ester.

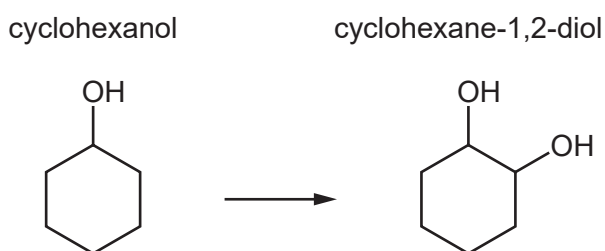
The structure of the ester is shown.



Which geometrical isomer is shown in this ester and to which class of alcohol does X belong?

	geometrical isomer	class of alcohol X
A	<i>cis</i>	secondary
B	<i>cis</i>	tertiary
C	<i>trans</i>	secondary
D	<i>trans</i>	tertiary

- 38 Which two-step process converts cyclohexanol into cyclohexane-1,2-diol?



	step 1	step 2
A	heat strongly with Al_2O_3	add cold dilute $KMnO_4$ and H_2SO_4
B	heat strongly with Al_2O_3	heat with steam and H_2SO_4
C	reflux with ethanolic NaOH	add cold dilute $KMnO_4$ and H_2SO_4
D	reflux with ethanolic NaOH	heat with steam and H_2SO_4

- 39** In polymer G every carbon atom in the polymer chain is bonded to one hydrogen atom and one methyl group.

Which alkene could be polymerised to make polymer G?

- A** but-1-ene
- B** but-2-ene
- C** methylpropene
- D** propene

- 40** The mass spectrum of compound X has M, M+1 and M+2 peaks. Other peaks are also present.

Peak M is the molecular ion peak, M^+ . Peak M has a relative abundance fifteen times that of peak M+1.

Peaks M and M+2 are of equal height.

What could be compound X?

- A** 1-chloro-2,2-dimethylpentane
- B** 2-chloro-3-methylpentane
- C** 2-bromo-2-methylhexane
- D** 3-bromo-2,2-dimethylbutane

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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

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The Periodic Table of Elements

Group																							
1	2													13	14	15	16	17	18				
		1 H hydrogen 1.0																		2 He helium 4.0			
		Key atomic number atomic symbol name relative atomic mass																					
3	4													5	6	7	8	9	10	11	12		
Li lithium 6.9	Be beryllium 9.0													B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0					
11	12													13	14	15	16	17	18				
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9				
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36						
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8						
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54						
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3						
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86						
Cs caesium 132.9	Ba barium 137.3	lanthanoids	Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —						
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118						
Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganeson —						

lanthanoids

57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.4	61	Pm promethium —	62	Sm samarium 150.4	63	Eu europium 152.0	64	Gd gadolinium 157.3	65	Tb terbium 158.9	66	Dy dysprosium 162.5	67	Ho holmium 164.9	68	Er erbium 167.3	69	Tm thulium 168.9	70	Yb ytterbium 173.1	71	Lu lutetium 175.0
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 —

actinoids