Cambridge Assessment International Education

# 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.


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**[Turn over**

**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** $NaHCO_3(aq)$ **B** $NaOH(aq)$ **C** $Na_2CO_3(aq)$ **D** $Na_2SO_4(aq)$

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

$$u\mathrm{MnO_4^-} + v\mathrm{H^+} + w\mathrm{I^-} \rightarrow x\mathrm{Mn^{2+}} + y\mathrm{H_2O} + z\mathrm{I_2}$$

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

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

$$NH_3 + H^+ \rightleftharpoons NH_4^+$$

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** | $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ | ✓ | ✗ |
| **B** | $NaH + H_2O \rightarrow NaOH + H_2$ | ✓ | ✓ |
| **C** | $3MnO_4^{2-} + 4H^+ \rightarrow MnO_2 + 2MnO_4^-$ | ✓ | ✓ |
| **D** | $VO_3^- + 2H^+ \rightarrow VO_2^+ + H_2O$ | ✓ | ✗ |

**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 $cm^3$ sample of water has an amount of oxygen gas dissolved in it.

This amount of oxygen gas has a volume of 6.00 $cm^3$ when measured at $1.00 \times 10^5$ 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** $2.34 \times 10^{-4}$ mol $dm^{-3}$

**B** $1.17 \times 10^{-3}$ mol $dm^{-3}$

**C** $1.25 \times 10^{-3}$ mol $dm^{-3}$

**D** $1.03 \times 10^{-2}$ mol $dm^{-3}$

**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** $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

**B** $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$

**C** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

**D** $2H(g) + O(g) \rightarrow H_2O(l)$

**11** Which mixture will react to form exactly one mole of water?

| | volume 2.00 mol $dm^{-3}$ $H_2SO_4$ / $cm^3$ | volume 1.00 mol $dm^{-3}$ NaOH / $cm^3$ |
|---|---|---|
| **A** | 250 | 500 |
| **B** | 250 | 1000 |
| **C** | 500 | 500 |
| **D** | 500 | 1000 |

**12** The enthalpy change for neutralisation of $HNO_3(aq)$ with NaOH(aq) is $-57.0\,kJ\,mol^{-1}$.

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 $4.2\,J\,cm^{-3}\,°C^{-1}$ 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** $+221\,kJ\,mol^{-1}$

**B** $+6\,kJ\,mol^{-1}$

**C** $-242\,kJ\,mol^{-1}$

**D** $-417\,kJ\,mol^{-1}$

**14** Which particle contains nitrogen in the same oxidation state as in the ion $N_2O_2^{2-}$?

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

**15** Sulfur dioxide reacts with oxygen as shown.

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

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

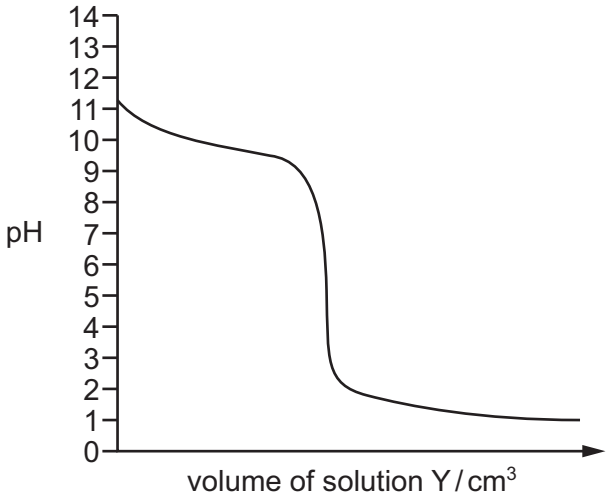
**B** increasing the pressure of the reaction

**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 |

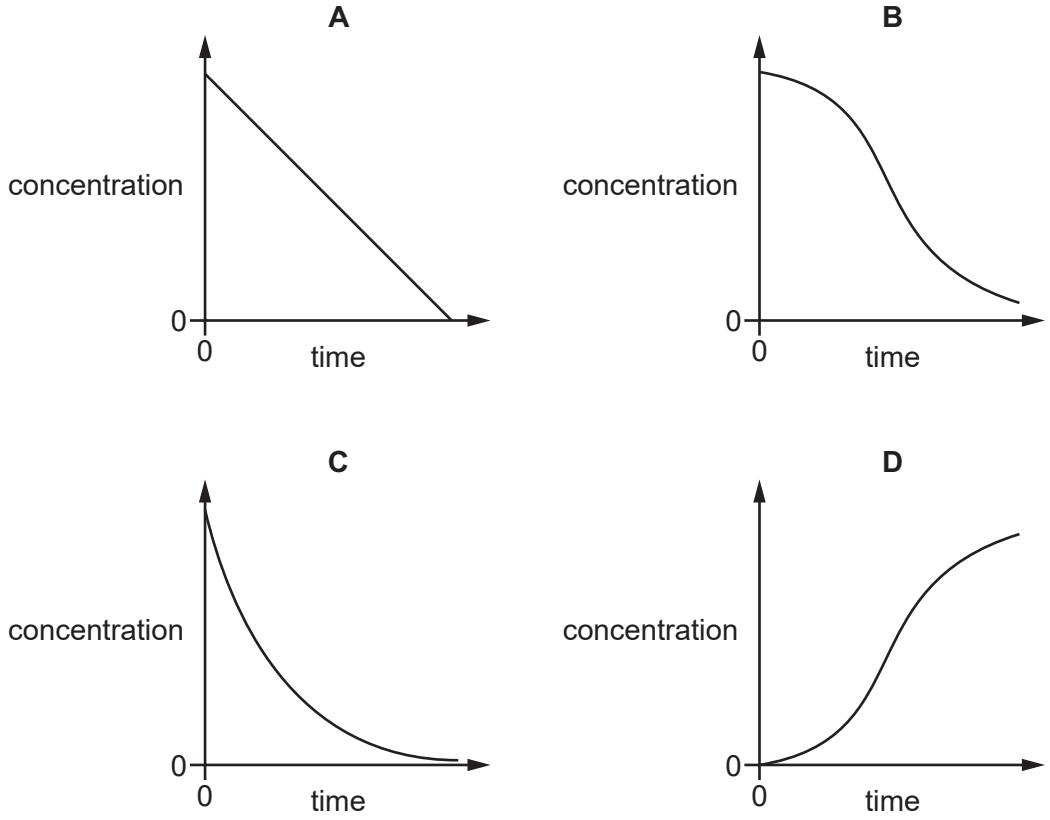
**17** Which row shows the expected properties of the element astatine when compared to the properties of the element iodine?

| | 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 kJ mol$^{-1}$.

**C** The activation energy of the forward reaction is equal to +160 kJ mol$^{-1}$.

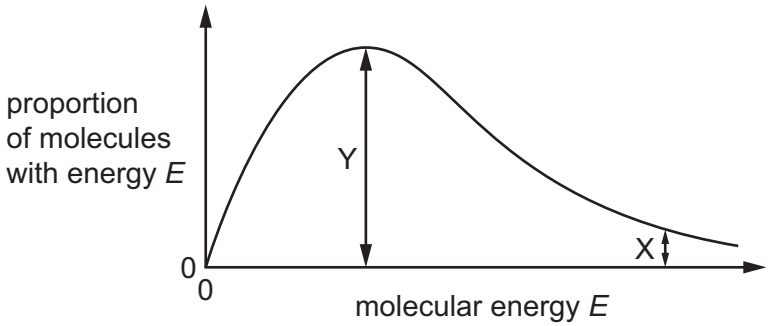
**D** The activation energy of the forward reaction is greater than +160 kJ mol$^{-1}$.

**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.

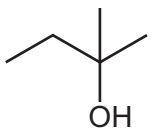
2-bromopentane is heated with an excess of ethanolic sodium hydroxide.

How many different hydrocarbons are produced?

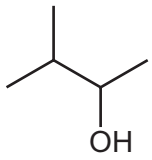
**A** 1 **B** 2 **C** 3 **D** 4

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

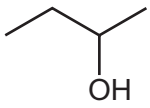
**A**



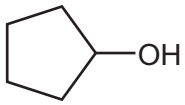

**B**




**C**




**D**



**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

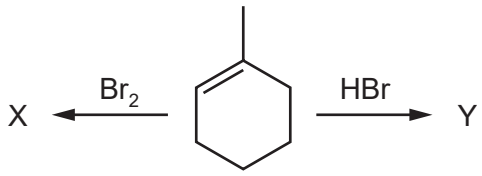
**31** A mixture of ethane and an excess of chlorine is exposed to UV light.

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 HC$l$(aq). The two products of this hydrolysis have the same empirical formula.

What could Q be?

**A** $CH_3CO_2CH_2CH_2OH$

**B** $CH_3CO_2CH_2CH_2CO_2H$

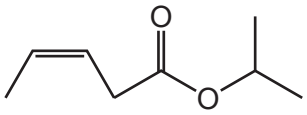
**C** $CH_3CH_2CO_2CH_2CH_2CH_3$

**D** $CH_3CH_2CH(OH)CH(OH)CH_2CH_3$

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

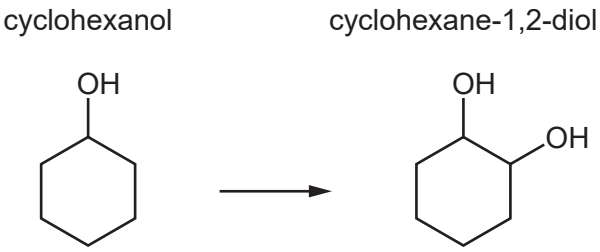
The structure of the ester is shown.



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

| | geometrical isomer | class of alcohol X |
|---|---|---|
| **A** | *cis* | secondary |
| **B** | *cis* | tertiary |
| **C** | *trans* | secondary |
| **D** | *trans* | 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

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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)<br>$V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions |
| ionic product of water | $K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C)) |
| specific heat capacity of water | $c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$) |

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## The Periodic Table of Elements

| Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | | | 1 H hydrogen 1.0 | | | | | | | | | | 2 He helium 4.0 |
| 3 Li lithium 6.9 | 4 Be beryllium 9.0 | | Key: atomic number / atomic symbol / name / relative atomic mass | | | | | | | | | 5 B boron 10.8 | 6 C carbon 12.0 | 7 N nitrogen 14.0 | 8 O oxygen 16.0 | 9 F fluorine 19.0 | 10 Ne neon 20.2 |
| 11 Na sodium 23.0 | 12 Mg magnesium 24.3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 Al aluminium 27.0 | 14 Si silicon 28.1 | 15 P phosphorus 31.0 | 16 S sulfur 32.1 | 17 Cl chlorine 35.5 | 18 Ar argon 39.9 |
| 19 K potassium 39.1 | 20 Ca calcium 40.1 | 21 Sc scandium 45.0 | 22 Ti titanium 47.9 | 23 V vanadium 50.9 | 24 Cr chromium 52.0 | 25 Mn manganese 54.9 | 26 Fe iron 55.8 | 27 Co cobalt 58.9 | 28 Ni nickel 58.7 | 29 Cu copper 63.5 | 30 Zn zinc 65.4 | 31 Ga gallium 69.7 | 32 Ge germanium 72.6 | 33 As arsenic 74.9 | 34 Se selenium 79.0 | 35 Br bromine 79.9 | 36 Kr krypton 83.8 |
| 37 Rb rubidium 85.5 | 38 Sr strontium 87.6 | 39 Y yttrium 88.9 | 40 Zr zirconium 91.2 | 41 Nb niobium 92.9 | 42 Mo molybdenum 95.9 | 43 Tc technetium – | 44 Ru ruthenium 101.1 | 45 Rh rhodium 102.9 | 46 Pd palladium 106.4 | 47 Ag silver 107.9 | 48 Cd cadmium 112.4 | 49 In indium 114.8 | 50 Sn tin 118.7 | 51 Sb antimony 121.8 | 52 Te tellurium 127.6 | 53 I iodine 126.9 | 54 Xe xenon 131.3 |
| 55 Cs caesium 132.9 | 56 Ba barium 137.3 | 57–71 lanthanoids | 72 Hf hafnium 178.5 | 73 Ta tantalum 180.9 | 74 W tungsten 183.8 | 75 Re rhenium 186.2 | 76 Os osmium 190.2 | 77 Ir iridium 192.2 | 78 Pt platinum 195.1 | 79 Au gold 197.0 | 80 Hg mercury 200.6 | 81 Tl thallium 204.4 | 82 Pb lead 207.2 | 83 Bi bismuth 209.0 | 84 Po polonium – | 85 At astatine – | 86 Rn radon – |
| 87 Fr francium – | 88 Ra radium – | 89–103 actinoids | 104 Rf rutherfordium – | 105 Db dubnium – | 106 Sg seaborgium – | 107 Bh bohrium – | 108 Hs hassium – | 109 Mt meitnerium – | 110 Ds darmstadtium – | 111 Rg roentgenium – | 112 Cn copernicium – | 113 Nh nihonium – | 114 Fl flerovium – | 115 Mc moscovium – | 116 Lv livermorium – | 117 Ts tennessine – | 118 Og oganesson – |

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



PMT