

## Cambridge International AS & A Level

CANDIDATE NAME		
CENTRE NUMBER	CANDIDATE NUMBER	

**CHEMISTRY** 

9701/42

Paper 4 A Level Structured Questions

October/November 2022

2 hours

You must answer on the question paper.

No additional materials are needed.

## INSTRUCTIONS

- Answer all questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each guestion in the space provided.
- Do not use an erasable pen or correction fluid.
- Do not write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

## INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.



**1** Calcium chloride,  $CaCl_2$ , is an ionic solid.

The values of some energy changes are shown in Table 1.1.

Table 1.1

energy change	value/kJ mol <sup>-1</sup>
lattice energy, $\Delta H_{\mathrm{latt}}^{\mathrm{e}}$ , $\mathrm{CaC}l_{2}(\mathrm{s})$	-2237
standard enthalpy change of atomisation of calcium	+193
first ionisation energy of calcium	+590
second ionisation energy of calcium	+1150
standard enthalpy change of atomisation of chlorine	+121
first electron affinity of chlorine	-364

(a)	Define fattice energy.
	[1]
/I- \	The the date in Table 4.4 to relevable the standard autholics shows a few although ALIA of
(D)	Use the data in Table 1.1 to calculate the standard enthalpy change of formation, $\Delta H_{\rm f}^{\rm e}$ , of calcium chloride. It may be helpful to draw an energy cycle. Show all your working.

$$\Delta H_{\mathrm{f}}^{\mathrm{e}}(\mathrm{CaC}\,l_{2}(\mathrm{s}))$$
 = ......kJ mol<sup>-1</sup> [2]



(c) Three possible values for the first electron affinity of bromine are shown in Table 1.2. One of them is correct.

Place a tick by the correct value. Explain your choice.

**Table 1.2** 

possible values	place <b>one</b> tick (✓) in this column
−342 kJ mol <sup>−1</sup>	
−364 kJ mol <sup>-1</sup>	
−386 kJ mol <sup>−1</sup>	

explanation	 	 	 	
	 	 	 	[11

(d) The enthalpy change of hydration of the chloride ion can be calculated using the lattice energy of calcium chloride and the data shown in Table 1.3.

Table 1.3

energy change	value/kJ mol <sup>-1</sup>
standard enthalpy change of solution of $CaCl_2(s)$	-83
standard enthalpy change of hydration of Ca <sup>2+</sup> (g)	-1650

(i)	Define the following terms.
	enthalpy change of solution
	enthalpy change of hydration
	[2]

(ii) Calculate the standard enthalpy change of hydration of the chloride ion,  $Cl^-(g)$ . It may be helpful to draw an energy cycle. Show all your working.

 $\Delta H_{\text{hyd}}^{\Theta}(Cl^{-}(g)) = \dots$ 



(e) Calcium fluoride,  $CaF_2(s)$ , can be synthesised directly from its elements.

The	e value of $\Delta H_{\rm f}^{\rm e}({\rm CaF_2(s)})$ is $-1214{\rm kJmol^{-1}}$ .
(i)	Predict the sign of the entropy change, $\Delta S^{\circ}$ , for this synthesis. Explain your answer.
	The sign of the entropy change is
	explanation
	[1]
(ii)	Use the value of $\Delta H_{\rm f}^{\rm e}({\rm CaF_2}(s))$ given in <b>(e)</b> and your answer to <b>(e)(i)</b> to predict how the feasibility for this synthesis will change with increasing temperature.
	[2]
	[Total: 11]



**2** (a) Nitrogen monoxide, NO, reacts with ozone, O<sub>3</sub>.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$

This reaction is first order with respect to both NO and O<sub>3</sub>. At 298 K, the rate constant  $k = 11500 \,\text{mol}^{-1} \,\text{dm}^3 \,\text{s}^{-1}$ .

(i) Complete the rate equation for this reaction.

rate =	 	 	 	 
				[1]

(ii) A reaction is carried out in which the initial concentrations of NO and  $O_3$  are both  $1.20 \times 10^{-6} \, \text{mol dm}^{-3}$ .

Calculate the initial rate of the reaction. State its units.

(iii) The reaction described in (a)(ii) is monitored over a period of time.

Predict whether or not the graph of [NO] against time, under these conditions, shows that the reaction has a constant half-life. Explain your answer.

prediction .....

explanation .....

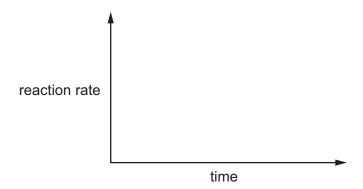
\_\_\_\_\_[1]

(b) Nitrous oxide, N<sub>2</sub>O, decomposes into its elements.

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$$

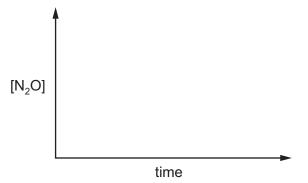
At a high temperature, a small amount of platinum wire is added to a large amount of nitrous oxide. The reaction follows zero order kinetics. The platinum wire behaves as a catalyst.

(i) Sketch a graph, on the axes below, of reaction rate against time for the catalysed decomposition of N<sub>2</sub>O under these conditions.





(ii) Sketch a graph, on the axes below, of [N<sub>2</sub>O] against time for this reaction.



(iii) Platinum behaves as a heterogeneous catalyst in this reaction.

Describe the mode of action of a heterogeneous catalyst.

[3]

(iv) Suggest a reason why this reaction has zero order kinetics when the amount of nitrous oxide is large and the amount of platinum is small.

[1]



[1]

Question 3 starts on the next page.



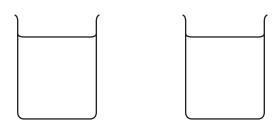
**3** Data should be selected from Table 3.1 in order to answer some parts of this question.

Table 3.1

electrode reaction	E°/V
Mg <sup>2+</sup> + 2e <sup>-</sup> ⇌ Mg	-2.38
Mn²+ + 2e⁻ ⇌ Mn	-1.18
$Mn^{3+} + e^{-} \rightleftharpoons Mn^{2+}$	+1.49
$MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$	+1.23
$MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}$	+0.56
$MnO_4^- + 4H^+ + 3e^- \rightleftharpoons MnO_2 + 2H_2O$	+1.67
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1.52

(a) An electrochemical cell can be constructed from a Mg<sup>2+</sup>/Mg half-cell and a MnO<sub>4</sub><sup>-</sup>/Mn<sup>2+</sup> half-cell. The standard cell potential of this cell can be calculated using the standard electrode potentials of the two half-cells.

(ii) Complete the diagram below to show an electrochemical cell constructed from a Mg<sup>2+</sup>/Mg half-cell and a MnO<sub>4</sub><sup>-</sup>/Mn<sup>2+</sup> half-cell. Label your diagram.



[3]

(iii) Use a positive (+) sign and a negative (-) sign to identify the polarity of each of the two electrodes in your diagram.

Use an arrow and the symbol 'e' to show the direction of electron flow in the external circuit.

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(i)

	(iv)	Calculate the standard cell potential, $E_{\text{cell}}^{\bullet}$ , of this cell.
		E <sub>cell</sub> =V [1]
	(v)	Construct an equation for the cell reaction.
		[1]
	(vi)	Predict how the cell reaction will change, if at all, when the solution in the Mg <sup>2+</sup> /Mg half-cell is diluted by the addition of a large volume of water. Explain your answer.
		[1]
(b)	A n	nolten magnesium salt is electrolysed for 15.0 minutes by a constant current.
	4.7	$5 \times 10^{22}$ magnesium atoms are produced at the cathode.
	Cal	culate the value of the current used.



current = ..... A [2]

[Total: 11]

4	(a)		value of the solubility product, $K_{\rm sp}$ , of iron(III) hydroxide, Fe(OH) $_{\rm 3}$ , is given by the following ression.
			$K_{\rm sp}$ = [Fe <sup>3+</sup> ][OH <sup>-</sup> ] <sup>3</sup> = 2.0 × 10 <sup>-39</sup> mol <sup>4</sup> dm <sup>-12</sup>
		(i)	Calculate the solubility of Fe(OH) <sub>3</sub> in water.
		(ii)	$solubility = mol dm^{-3} [1]$ Calculate the solubility of Fe(OH) <sub>3</sub> in 0.010 mol dm <sup>-3</sup> barium hydroxide, Ba(OH) <sub>2</sub> (aq).
		(,	solubility = mol dm <sup>-3</sup> [2]
	(	(iii)	$Fe(OH)_3$ is less soluble in $Ba(OH)_2(aq)$ than it is in pure water.
	`	,	Name this effect.
			[1]
	(b)	The	numerical value of the $K_a$ of HBrO is $2.00 \times 10^{-9}$ .
			a solution of HBrO which contains $4.00\times10^{-3}\text{mol}$ of HBrO in $100\text{cm}^3$ of solution. In this ation the following equilibrium is established in which there are two conjugate acid-base is.
			$HBrO + H_2O \rightleftharpoons BrO^- + H_3O^+$
		(i)	Define conjugate acid-base pair.
			[1]
		(ii)	Identify the two conjugate acid-base pairs shown in the equation above.
			pair oneacid base
			pair two

base

[1]



acid

(111)	Calculate the ph of solution X. Show all your working.
	pH =[2
(iv)	A solution containing $2.00 \times 10^{-3}$ mol of NaOH is added to solution <b>X</b> . A buffer solution is formed.
	Calculate the pH of this buffer solution.
	pH =[1
	[Total: 9

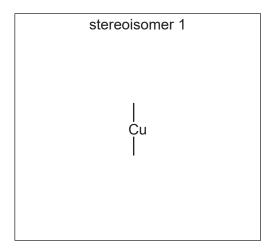


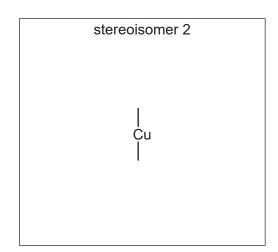
Copper	is a transit	ion element. It forms a w	ide variety of compounds.	
		on element.	ac variety of compounds.	
•••••				[1
exc	ess of con		cid is added to this solutio	$I(H_2O)_6J^{2+}$ complex ions. If and a ligand exchange reaction
(i)		Table 5.1 to state the gle in each of the two com		number of copper, and one
		Т	able 5.1	
com	olex ion	geometry	coordination number	bond angle
[Cu(I	H <sub>2</sub> O) <sub>6</sub> ] <sup>2+</sup>			
[Cu	$ICl_{\scriptscriptstyle 4}]^{\scriptscriptstyle 2-}$			
				[3
(ii)		lated Cu <sup>2+</sup> ion the d-ork ] <sup>2+</sup> the d-orbitals are non-		. In a complex ion such as
	Define de	generate and non-degen	erate in this context.	
	degenera	te		
	non-dege	nerate		
(iii)	Explain w	hy the solutions of the tw	o complex ions in Table 5	[1 i.1 are <b>different</b> colours.
				[1
	e formula o		$_{4})_{2}(H_{2}O)_{2}]^{2-}$ . The ethanedid	dioate ions, C <sub>2</sub> O <sub>4</sub> <sup>2-</sup> , as ligands pate ion is a bidentate ligand

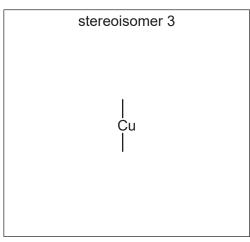


(ii) There are three stereoisomers with the formula  $[Cu(C_2O_4)_2(H_2O)_2]^{2-}$ .

Complete the three-dimensional diagrams to show these three stereoisomers.







[2]

(iii) Use your answer to (c)(ii) to answer this question.

Stereoisomers 1, 2 and 3 show two different types of isomerism.

Name these two types of isomerism.

For each type of isomerism identify the pair of stereoisomers that demonstrate this isomerism.

type of isomerism	pair of stereoisomers
	and
	and

[2]



(d) A solution contains  $3.70\,\mathrm{g}$  of  $\mathrm{Na_2[Cu(C_2O_4)_2(H_2O)_2]}$  dissolved in  $100\,\mathrm{cm^3}$  of solution. A  $25.0\,\mathrm{cm^3}$  sample of this solution is warmed and then oxidised by  $0.0100\,\mathrm{mol\,dm^{-3}}$  acidified potassium manganate(VII).

The equation for the redox reaction is shown.

$$5C_2O_4^{2-} + 2MnO_4^{-} + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O_4^{-}$$

Calculate the minimum volume of 0.0100 mol dm $^{-3}$  acidified potassium manganate(VII) needed to oxidise all of the ethanedioate ions,  $C_2O_4^{2-}$ , in the 25.0 cm $^3$  sample. Show all your working.

$$[M_r: Na_2[Cu(C_2O_4)_2(H_2O)_2], 321.5]$$

minimum volume =	cm <sup>3</sup>	[3]

(e) Copper(II) nitrate,  $Cu(NO_3)_2$ , and barium nitrate,  $Ba(NO_3)_2$ , both decompose when heated.

Copper(II) nitrate decomposes at a lower temperature than barium nitrate.

 	 •••••	• • • • •	 	 	••••		 	 	••••	••••	• • • •	••••		••••	 	••••		• • • •	 • • • •	 	 		
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 	 		 	 			 	 							 				 	 	 	[2	1

[Total: 16]



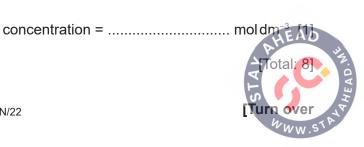
- An aqueous solution of cobalt(II) chloride is a pink colour due to the presence of  $[Co(H_2O)_6]^{2+}$  complex ions.
  - (a) (i) Complete Table 6.1 to describe what is observed when the named reagent is added to an aqueous solution of cobalt( $\Pi$ ) chloride.

Table 6.1

reagent	colour of cobalt-containing product	state of cobalt-containing product					
NaOH(aq)							
an excess of conc. HC <i>l</i>							

(ii)	Write an equation for the reaction between $[Co(H_2O)_6]^{2+}$ ions and NaOH(aq).
	[1]
(iii)	Write an equation for the reaction between $[Co(H_2O)_6]^{2+}$ ions and an excess of conc. $HCl$ .
	[1]
(b) (i)	Define stability constant.
	[1]
(ii)	Write an expression for the stability constant, $K_{\text{stab}}$ , of the $[\text{Co}(\text{NH}_3)_6]^{2+}$ complex ion.
	$K_{\text{stab}} =$ [1]
(iii)	Give the units of the stability constant, $K_{\text{stab}}$ , of the $[\text{Co(NH}_3)_6]^{2+}$ complex ion.
	units =[1]
(iv)	The numerical value of the stability constant, $K_{stab}$ , of the $[Co(NH_3)_6]^{2+}$ complex ion is $7.7\times10^4$ .
	In an aqueous solution the concentration of the $[\text{Co}(\text{NH}_3)_6]^{2^+}$ complex ion is $0.0740\text{moldm}^{-3}$ and the concentration of $\text{NH}_3$ is $0.480\text{moldm}^{-3}$ at equilibrium.
	Calculate the concentration of $[Co(H_2O)_6]^{2+}$ in this solution.

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[2]

7 (a) The structural and displayed formulae of three aromatic compounds, **A**, **B** and **C**, are shown in Fig. 7.1.

C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> CH <sub>2</sub> COOH	CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> OH	$\mathrm{C_6H_5CH_2CHC}{\it l}\mathrm{CO_2H}$
HOO	OH	HO_O C1
A	В	С

	Α	В	С	
		Fig. 7.1		
Coı	mpare the relative acidities	of <b>A</b> , <b>B</b> and <b>C</b> .		
		>	. >	
	most acidic		least acidic	
Exp	olain your answer.			
••••				
				[3]
Me	thylbenzene, C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> , car	n be made from benzen	e by an electrophilic substitutio	n reaction.
(i)	Identify a compound that Identify the catalyst used		form methylbenzene.	
	compound			
	compound			
	catalyst			[1]
				ניו
(ii)	The first step in the react	ion is the generation of	the CH <sub>3</sub> <sup>+</sup> electrophile.	
	Write an equation for the	reaction that generates	s this electrophile.	
				[11



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(b)

(iii)	Describe the mechanism for the reaction between benzene and the $CH_3^+$ electrophile. Include all relevant curly arrows and charges.
	$\rightarrow$
	CH <sub>3</sub> <sup>+</sup>
	[3]
(iv)	Identify a suitable reagent to oxidise methylbenzene to benzoic acid, C <sub>6</sub> H <sub>5</sub> COOH.
	Write an equation for this reaction using [O] to represent one atom of oxygen from the oxidising agent.
	reagent
	equation[2]
(v)	Methylbenzene and benzoic acid are both nitrated with a mixture of concentrated nitric acid and sulfuric acid to give mononitrated products. The structural formulae of these products are $\mathrm{CH_3C_6H_4NO_2}$ and $\mathrm{HOOCC_6H_4NO_2}$ respectively.
	Draw the structures of these two products.

[1]



(c) A reaction scheme is shown in Fig. 7.2.

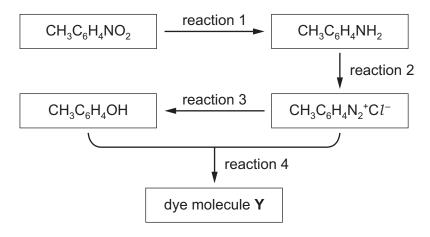


Fig. 7.2

(i)	Describe the reagents and conditions to produce $CH_3C_6H_4N_2^+Cl^-$ from $CH_3C_6H_4N_4N_5$ reaction 2.	Ⅎ₂ in
	reagents	
	conditions	
(ii)	Describe how $CH_3C_6H_4OH$ can be produced from $CH_3C_6H_4N_2^+Cl^-$ in reaction 3.	[1]
		. [1]
(iii)	Draw the structure of the dye molecule <b>Y</b> formed when $CH_3C_6H_4N_2^+Cl^-$ and $CH_3C_6H_4N_2^+Cl^-$	l₄OH
	structure	
	conditions	[2]



[Total: 15]

When answering this question it should be assumed that together all the hydrogen atoms in a benzene ring result in a single unsplit peak at  $\delta$  = 7.2 in a proton (<sup>1</sup>H) NMR spectrum. The structures of five isomeric ketones, **P**, **Q**, **R**, **S** and **T** are given.

 $P C_6H_5COCH(CH_3)_2$ 

S C<sub>6</sub>H<sub>5</sub>CH<sub>2</sub>CH<sub>2</sub>COCH<sub>3</sub>

Q C<sub>6</sub>H<sub>5</sub>COCH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>

T C<sub>6</sub>H<sub>5</sub>CH(CH<sub>3</sub>)COCH<sub>3</sub>

R C<sub>6</sub>H<sub>5</sub>CH<sub>2</sub>COCH<sub>2</sub>CH<sub>3</sub>

- (a) Identify all the chiral carbon atoms on the structures above. Label each chiral carbon atom with an asterisk (\*).
- (b) The proton (<sup>1</sup>H) NMR spectrum of one of the five isomers, **P**, **Q**, **R**, **S** or **T**, is shown in Fig. 8.1.

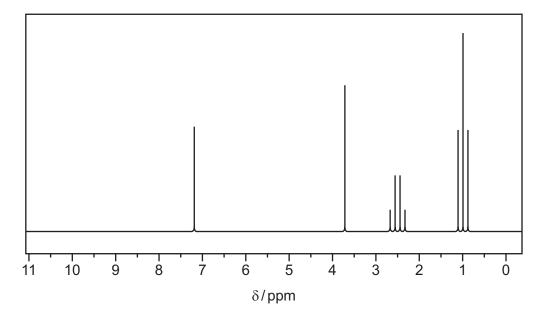


Fig. 8.1

(i) Identify which of the compounds **P**, **Q**, **R**, **S** or **T** gives this spectrum. Draw the displayed formula of the compound you have identified. Identify the protons responsible for the peaks at  $\delta = 3.7$ ,  $\delta = 2.5$  and  $\delta = 1.0$  on the structure you have drawn.

[2]

(ii) Name the splitting pattern of the peak at  $\delta$  = 3.7. Explain why it has this splitting pattern.



(c)	Cho	pose from the letters <b>P</b> , <b>Q</b> , <b>R</b> , <b>S</b> and <b>T</b> to identify:	
	(i)	the <b>two</b> compounds that each have a doublet peak in the proton ( <sup>1</sup> H) NMR spectrum	
			[1]
	(ii)	the compound with only three peaks in its proton ( <sup>1</sup> H) NMR spectrum.	
			[1]
(d)	Suç	ggest a suitable solvent that should be used for obtaining the spectrum shown in Fig. 8.1	
			[1]
(e)		e proton ( $^{1}$ H) NMR spectrum of compound <b>T</b> is compared in the presence of D $_{2}$ O and in the presence of D $_{2}$ O.	пе
	Des	scribe any difference between the two spectra. Explain your answer.	
			[1]
(f)		mplete Table 8.1 below to give the number of peaks in the carbon-13 NMR spectrum of each	ch

Table 8.1

compound	number of peaks	compound	number of peaks

[2]

[Total: 10]

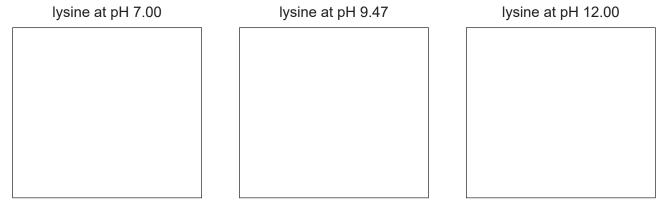


**9** Tyrosine and lysine, shown in Fig. 9.1, are naturally occurring amino acids found in proteins.

Fig. 9.1

(a) The isoelectric point of lysine is 9.47.

Draw the structure of lysine at the stated pH in the boxes below.



[2]

(b) When ethanoic acid is treated with  $PCl_5$  product **D** is formed.

When **D** is added to tyrosine two different isomeric products, **E** and **F**, are formed.

**E** has an ester linkage, **F** does not.

Draw the structures of **D**, **E** and **F** in the boxes below.

D E F



(c) Complete Table 9.1 by drawing the structure of the organic product formed when tyrosine reacts with each named reagent.

Ignore the directing effect of the –CH<sub>2</sub>CHNH<sub>2</sub>COOH substituent.

Table 9.1

reagent	structure
an excess of Br <sub>2</sub> (aq)	
an excess of NaOH(aq)	
an excess of HNO <sub>3</sub> (aq)	

(d)	A mixture of tyrosine and lysine can be separated by thin-layer chromatography. Under certain
	conditions the $R_f$ value of lysine is 0.14 and the $R_f$ value of tyrosine is 0.45.

(i)	Explain what is meant by $R_{\rm f}$ value.	
		[1]
(ii)	Suggest an explanation for the difference in $R_{\rm f}$ values.	
		[1]
	[Total:	10]



23

## Important values, constants and standards

molar gas constant	$R = 8.31 \mathrm{J}\mathrm{K}^{-1}\mathrm{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \mathrm{C}\mathrm{mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \mathrm{C}$
molar volume of gas	$V_{\rm m} = 22.4 {\rm dm^3  mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_{\rm m} = 24.0 {\rm dm^3  mol^{-1}}$ at room conditions
ionic product of water	$K_{\rm w} = 1.00 \times 10^{-14} \rm mol^2  dm^{-6}  (at  298  K  (25  {}^{\circ}C))$
specific heat capacity of water	$c = 4.18 \mathrm{kJ  kg^{-1}  K^{-1}}  (4.18 \mathrm{J  g^{-1}  K^{-1}})$



The Periodic Table of Elements

	18	2	บ	helium 4.0	10	Ne	neon 20.2	18	Ā	argon 39.9	36	궃	krypton 83.8	54	Xe	xenon 131.3	98	Rn	radon -	118	Og	anesson	
																						<u> </u>	1
	17				6	ш	fluori 19.	17	<u></u>	chlorine 35.5	35	ā	brom 79.	53	<u> </u>	iodir 126	85	₹	astati	11.	<u>~</u>	tennes	
	16				80	0	oxygen 16.0	16	S	sulfur 32.1	34	Se	selenium 79.0	52	Те	tellurium 127.6	84	Ъо	polonium	116	^	livermorium -	
	15				7	z	nitrogen 14.0	15	۵	phosphorus 31.0	33	As	arsenic 74.9	51	Sb	antimony 121.8	83	<u>.</u>	bismuth 209.0	115	Mc	moscovium	
	14				9	ပ	carbon 12.0	14	S	silicon 28.1	32	Ge	germanium 72.6	20	Sn	tin 118.7	82	Ър	lead 207.2	114	Εl	flerovium	
	13				2	В	boron 10.8	13	Αl	aluminium 27.0	31	Ga	gallium 69.7	49	In	indium 114.8	81	1L	thallium 204.4	113	R	nihonium	
										12	30	Zu	zinc 65.4	48	පි	cadmium 112.4	80	윈	mercury 200.6	112	ပ်	copernicium	
										7	29	Cn	copper 63.5	47	Ag	silver 107.9	62	Au	gold 197.0	111	Rg	roentgenium	
dn										10	28	z	nickel 58.7	46	Pd	palladium 106.4	78	చ	platinum 195.1	110	Ds	darmstadtium	
Group										6	27	රි	cobalt 58.9	45	돈	rhodium 102.9	77	'n	iridium 192.2	109	¥	meitnerium -	
		- ]	Г	hydrogen 1.0						œ	26	Pe	iron 55.8	4	Ru	ruthenium 101.1	9/	Os	osmium 190.2	108	¥	hassium	
					J					7	25	Mn	manganese 54.9	43	ည	technetium -	75	Re	rhenium 186.2	107	Bh	bohrium	
						loc	SSI			9	24	ပ်	chromium 52.0	42	Mo	molybdenum 95.9	74	>	tungsten 183.8	106	Sg	seaborgium -	
				Key	atomic number	atomic symbo	name relative atomic mass			2	23	>	vanadium 50.9	41	g	niobium 92.9	73	д	tantalum 180.9	105	g C	dubnium	
						ato	rela			4	22	F	titanium 47.9	40	Zr	zirconium 91.2	72	Ξ	hafnium 178.5	104	쪼	rutherfordium	
								-		က	21	Sc	scandium 45.0	39	>	yttrium 88.9	57-71	lanthanoids		89-103	actinoids		
	2				4	Be	beryllium 9.0	12	Mg	magnesium 24.3	20	Ca	calcium 40.1	38	S	strontium 87.6	26	Ba	barium 137.3	88	Ra	radium	
	1				3	:=	lithium 6.9	1	Na	sodium 23.0	19	×	potassium 39.1	37	Rb	rubidium 85.5	55	S	caesium 132.9	87	ъ́	francium	1

7.1	P	lutetium 175.0	103	۲	lawrencium	ı
		ytterbium 173.1				_
69	H	thulium 168.9	101	Md	mendelevium	_
89	ш	erbium 167.3	100	Fm	ferminm	_
29	운	holmium 164.9	66	Es	einsteinium	_
99	ò	dysprosium 162.5	86	Ç	californium	_
65	Q L	terbium 158,9	97	Ř	berkelium	_
49	P O	gadolinium 157.3	96	Cm	curium	_
63	Ш	europium 152.0	95	Am	americium	-
62	Sm	samarium 150,4	26	Pu	plutonium	-
61	Pm	promethium	93	ď	neptunium	_
09	PZ	neodymium 144.4	92	$\supset$	uranium	238.0
69	Ā	praseodymium 140.9	91	Ра	protactinium	231.0
58	Ö	cerium 140.1	06	T	thorium	232.0
57	Га	anthanum 138.9	89	Ac	actinium	1

lanthanoids

actinoids

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