Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number

Candidate Number

Chemistry

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Tuesday 13 June 2017 – Afternoon
Time: 1 hour 45 minutes

Paper Reference
9CH0/01

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

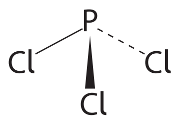
1 A phosphorus atom has mass number 31.

(a) How many of each sub-atomic particle are present in the phosphide ion, P^{3-}?

(1)

	Number of protons	Number of neutrons	Number of electrons
☒ **A**	15	16	12
☒ **B**	15	16	18
☒ **C**	16	15	12
☒ **D**	16	15	18

(b) Phosphorus(III) chloride molecules are pyramidal with a bond angle less than 109.5°.



(i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.

(2)

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(ii) Which describes the polarity of the P—Cl bond and the polarity of the phosphorus(III) chloride molecule?

(1)

	Polarity of P—Cl bond	Polarity of molecule
☒ **A**	non-polar	non-polar
☒ **B**	non-polar	polar
☒ **C**	polar	non-polar
☒ **D**	polar	polar

(c) Phosphorus has one naturally occurring isotope with mass number 31. Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3.

(2)

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(Total for Question 1 = 6 marks)

2 Magnesium nitrate decomposes on heating as shown by the equation.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

(a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

(b) Calcium nitrate decomposes in a similar way to magnesium nitrate, but requires a higher temperature for decomposition.

Explain this observation in terms of the charge and size of the cations.

(3)

(Total for Question 2 = 6 marks)

3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

Halogen	**Boiling temperature / °C**
chlorine	–35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine.

(2)

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(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

Potassium halide	**Products**
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

(c) Use these electrode potentials to answer the following questions.

Electrode reaction	$E^\ominus$ / V
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$MnO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Mn^{2+}(aq) + 2H_2O(l)$	+1.23
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(i) Which species will oxidise $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$?

(1)

☒ **A** $Br_2(aq)$

☒ **B** $Cl^-(aq)$

☒ **C** $I_2(aq)$

☒ **D** $Mn^{2+}(aq)$

(ii) Write the ionic equation and calculate the $E^\ominus_{cell}$ value for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required.

(3)

(Total for Question 3 = 9 marks)

4 Iron and zinc are in the d-block of the Periodic Table.

(a) Which of these is the electronic configuration of an iron(II) ion, Fe^{2+}?

(1)

		3d					4s
☒ **A**	[Ar]	↑↓	↑↓	↑↓			
☒ **B**	[Ar]	↑↓	↑	↑	↑	↑	
☒ **C**	[Ar]	↑↓	↑↓				↑↓
☒ **D**	[Ar]	↑	↑	↑	↑		↑↓

(b) Iron(II) ions, $[Fe(H_2O)_6]^{2+}$, form a pale green solution but zinc ions, $[Zn(H_2O)_6]^{2+}$, form a colourless solution.

Explain why zinc ions are colourless.

(2)

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(c) Hydrated iron(II) ions react with ethanedioate ions, $C_2O_4^{2-}$, to form a complex ion.

$$[Fe(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightleftharpoons [Fe(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$$

(i) Draw a structure of the $[Fe(C_2O_4)_2(H_2O)_2]^{2-}$ ion, showing **all** of the bonds.

(2)

P 4 8 0 5 8 A 0 8 2 8

(ii) Explain, in terms of entropy, why this reaction is feasible.

(2)

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(d) Iodide ions, I^-, react with peroxodisulfate(VI) ions, $S_2O_8^{2-}$

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

This reaction is catalysed by iron(II) ions, Fe^{2+}(aq).

Write **two** ionic equations to show how iron(II) ions act as a catalyst in this reaction. State symbols are not required.

(2)

(Total for Question 4 = 9 marks)

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5 This question is about enthalpy changes and entropy changes.

(a) Which is the equation for the standard enthalpy change of formation, $\Delta_f H^\ominus$, of aluminium oxide?

(1)

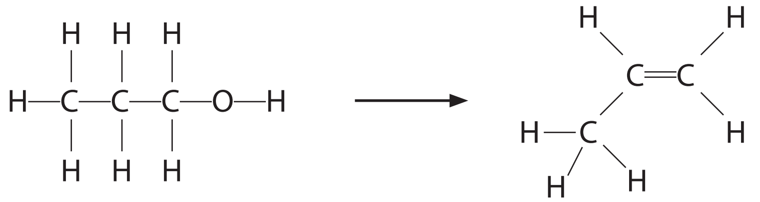
☒ **A** $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

☒ **B** $4Al(s) + 6O(g) \rightarrow 2Al_2O_3(s)$

☒ **C** $2Al(s) + 1\frac{1}{2}O_2(g) \rightarrow Al_2O_3(s)$

☒ **D** $2Al(s) + 3O(g) \rightarrow Al_2O_3(s)$

(b) Propan-1-ol is dehydrated to form propene.



+ H_2O $\Delta_r H^\ominus = +42 \text{ kJ mol}^{-1}$

The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C═C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)

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P 4 8 0 5 8 A 0 1 0 2 8

(c) Which reaction has a negative value for ΔS_{system}?

(1)

☒ **A** $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

☒ **B** $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

☒ **C** $MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l) + CO_2(g)$

☒ **D** $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

(d) What is the expression for ΔS_{total}?

(1)

☒ **A** $\Delta S_{surroundings} + \dfrac{\Delta H}{T}$

☒ **B** $\Delta S_{surroundings} - \dfrac{\Delta H}{T}$

☒ **C** $\Delta S_{system} + \dfrac{\Delta H}{T}$

☒ **D** $\Delta S_{system} - \dfrac{\Delta H}{T}$

(e) Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{system} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

(Total for Question 5 = 9 marks)

6 Magnesium bromide, $MgBr_2$, is an ionic compound.

(a) (i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide. Only outer shell electrons are required.

(1)

(ii) State all the conditions under which magnesium bromide conducts electricity.

(1)

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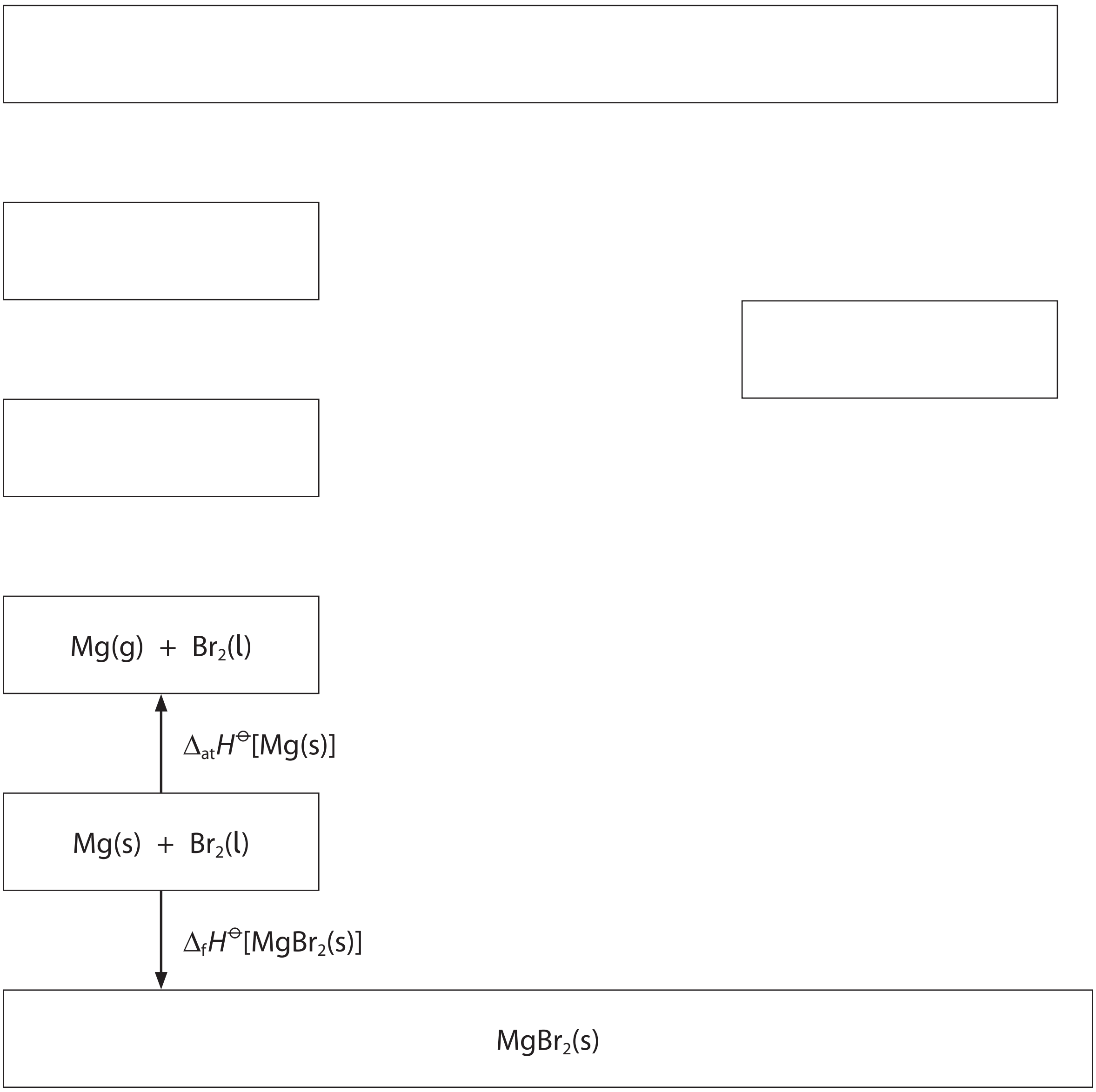
(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	**Value / kJ mol^{-1}**
enthalpy change of atomisation of magnesium, $\Delta_{at}H^{\ominus}[Mg(s)]$	+148
1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
2nd ionisation energy of magnesium, 2nd IE[Mg^{+}(g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{at}H^{\ominus}[\frac{1}{2}Br_2(l)]$	+112
lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	–2 440
enthalpy change of formation of magnesium bromide, $\Delta_f H^{\ominus}[MgBr_2(s)]$	–524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1}.

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

(ii) Write the equation, including state symbols, to show the **third** ionisation energy of magnesium.

(1)

(Total for Question 6 = 11 marks)

7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is $-53.4\ \text{kJ mol}^{-1}$.

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

Calculate the temperature change you would expect when $25.0\ \text{cm}^3$ of $1.00\ \text{mol dm}^{-3}$ hydrochloric acid is mixed with $25.0\ \text{cm}^3$ of $1.00\ \text{mol dm}^{-3}$ aqueous ammonia.

Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is $1.00\ \text{g cm}^{-3}$
the specific heat capacity of the solution is $4.18\ \text{J g}^{-1}\ {}^\circ\text{C}^{-1}$]

(3)

P 4 8 0 5 8 A 0 1 6 2 8

*(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid, HCl	–58
nitric acid, HNO_3	–58
sulfuric acid, H_2SO_4	–115
ethanoic acid, CH_3COOH	–56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

(Total for Question 7 = 9 marks)

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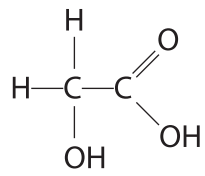
8 2-Hydroxyethanoic acid, also known as glycolic acid, $CH_2OHCOOH$, is an alpha hydroxy acid used in some skincare products.
It has a K_a value of 1.5×10^{-4} mol dm^{-3}.

The structure of glycolic acid is



(a) A solution of glycolic acid of concentration 0.1 mol dm^{-3} has a pH of 2.4

What is the approximate pH of the resulting solution after it has been diluted by a factor of 100?

(1)

☒ **A** 1.4

☒ **B** 2.4

☒ **C** 3.4

☒ **D** 4.4

(b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)

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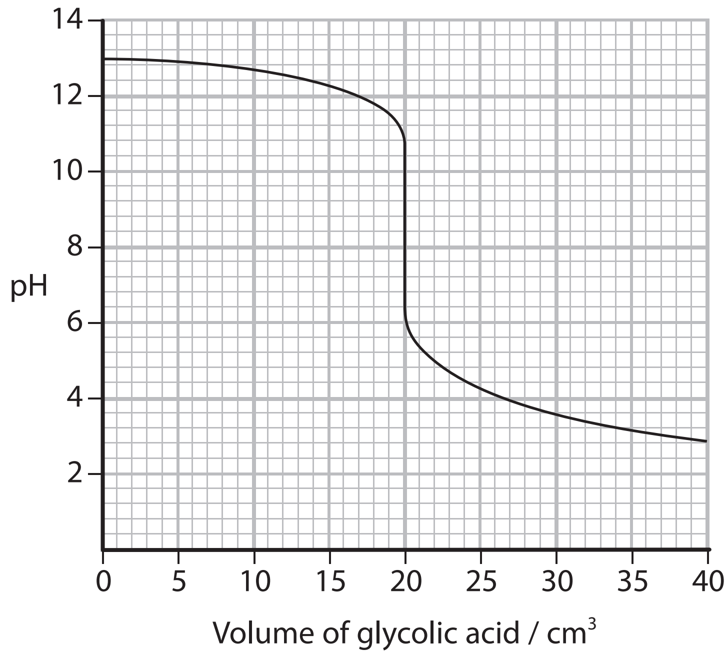
(c) The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.



(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

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(ii) What is the concentration of this glycolic acid in mol dm^{-3}?

(1)

☒ **A** 0.080

☒ **B** 0.100

☒ **C** 0.125

☒ **D** 0.250

(iii) The pH of the solution containing just sodium glycolate and water is

(1)

- ☒ **A** 2.8
- ☒ **B** 6.0
- ☒ **C** 8.3
- ☒ **D** 11.0

(d) Glycolic acid has an acid dissociation constant of 1.5×10^{-4} mol dm^{-3} compared with a value of 1.7×10^{-5} mol dm^{-3} for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

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(ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed.

(1)

$CH_2OHCOOH + CH_3COOH \rightarrow$ .... + ...

(Total for Question 8 = 12 marks)

9 This question is about buffer solutions.

(a) A buffer solution is formed from disodium hydrogenphosphate, containing HPO_4^{2-} ions, and sodium dihydrogenphosphate, containing $H_2PO_4^-$ ions.

Write the **ionic** equations involving HPO_4^{2-} and $H_2PO_4^-$ ions to show how this solution acts as a buffer solution.

(2)

(b) Another buffer solution was formed by mixing 20.0 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} with 25.0 cm^3 of ethanoic acid of concentration 0.150 mol dm^{-3}.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

Calculate the pH of this buffer solution.

[K_a for ethanoic acid = 1.74×10^{-5} mol dm^{-3}]

(5)

(Total for Question 9 = 7 marks)

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10 Hydrogen is produced on a large scale by several different processes.

(a) One process for producing hydrogen involves reacting white-hot carbon with steam.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) \qquad \Delta H = +131\ \text{kJ mol}^{-1}$$

The expression for the equilibrium constant, K_p, is

$$K_p = \frac{p(H_2)\,p(CO)}{p(H_2O)}$$

(i) Give a reason why the partial pressure of carbon is not included in the expression.
(1)

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(ii) Explain the effect of an increase in pressure on the equilibrium position of this reaction.
(2)

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(iii) Explain, by reference to any change in the value of K_p, the effect of an increase in temperature on the equilibrium position of this reaction.
(2)

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(iv) At 1000 K and a total pressure of 2.0 atm, 1.00 mol of steam reacted with excess carbon.

At equilibrium, 0.81 mol of hydrogen was present.

Calculate the value of K_p at 1000 K, stating any units.

(4)

(b) Carbon monoxide reacts with steam.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

At 1100 K, $K_c = 1.00$

In an experiment, 1 mol of carbon monoxide was mixed with 1 mol of steam, 2 mol of carbon dioxide and 2 mol of hydrogen.

Deduce, with reasons, the direction in which the reaction will shift to reach equilibrium.

(3)

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1.0 **H** hydrogen 1

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
																	4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103