Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Monday 10 June 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9CH0/01**

Chemistry

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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*.
- 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.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

F:1/1/1/1/

P 7 6 8 9 5 A 0 1 2 8

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 This question is about atomic structure.

(a) Complete the table.

(3)

Species	Number of protons	Number of neutrons	Number of electrons
^{32}S			
^{33}S			
$^{34}S^{2-}$			

(b) A sample of sulfur was found to contain only four isotopes.

(i) Complete the table to show the percentage abundance of ^{34}S.

(1)

Isotope	^{32}S	^{33}S	^{34}S	^{36}S
Percentage abundance	95.02	0.75		0.02

(ii) Calculate the relative atomic mass (A_r) of the sulfur in this sample using the data in the table. Give your answer to **two** decimal places.

(2)

(Total for Question 1 = 6 marks)

DO NOT WRITE IN THIS AREA

2 This question is about the formation of ions.

(a) Explain the trend in the values of the first electron affinities of the elements shown.

(4)

Element	First electron affinity / $kJ\,mol^{-1}$
chlorine	−349
bromine	−325
iodine	−295

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(b) Which of these isoelectronic ions has the **smallest** ionic radius?

(1)

☒ **A** S^{2-}

☒ **B** Cl^{-}

☒ **C** K^{+}

☒ **D** Ca^{2+}

(c) Some series of successive ionisation energies in $kJ\,mol^{-1}$ are shown.
The letters do not refer to the symbols of the elements.

Element	Successive ionisation energies / $kJ\,mol^{-1}$				
A	578	1817	2745	11 578	14 831
B	653	1592	2987	4740	6686
C	738	1451	7733	10 541	13 629
D	1086	2353	4621	6223	37 832

(i) Which element in the table could be in Group 4?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(ii) Which element in the table could be described as an *s*-block element?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 2 = 7 marks)

3 This question is about compounds and their chemical analysis.

Three containers of soluble white solids have lost their labels but are known to be calcium bromide, calcium iodide and potassium sulfate.

(a) (i) Describe how to carry out a flame test on these samples.

(3)

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(ii) Give the expected observation for each of the flame tests.

(2)

calcium bromide

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calcium iodide

....

potassium sulfate

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(b) Separate aqueous solutions of calcium bromide and of calcium iodide reacted with acidified silver nitrate to produce a precipitate.
Concentrated aqueous ammonia was added to each precipitate.

Complete the table.

(2)

Solution	Formula of precipitate with silver nitrate	Colour of precipitate with silver nitrate	Observation with concentrated aqueous ammonia
calcium bromide(aq)			
calcium iodide(aq)			

(c) Describe a chemical test for the sulfate ion giving the positive result.

(2)

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(d) What mass of potassium sulfate (K_2SO_4) would be needed to prepare 250 cm^3 of a solution of concentration 0.0450 mol dm^{-3}?

The molar mass of K_2SO_4 is 174.3 g mol^{-1}.

(1)

☒ **A** 1.96 g

☒ **B** 7.84 g

☒ **C** 19.6 g

☒ **D** 31.4 g

(Total for Question 3 = 10 marks)

4 This question is about acids, bases and buffers.

(a) State what is meant by a Brønsted–Lowry acid.

(1)

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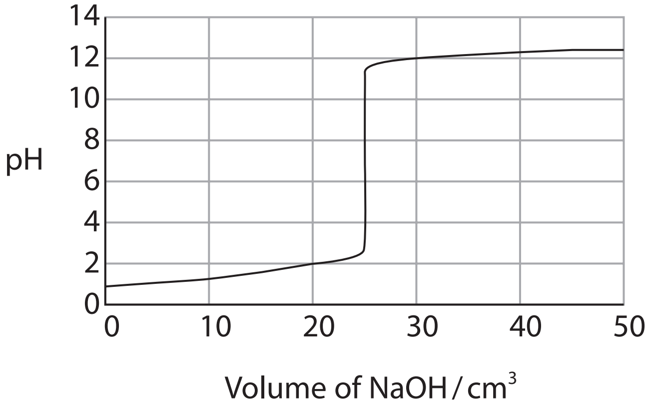
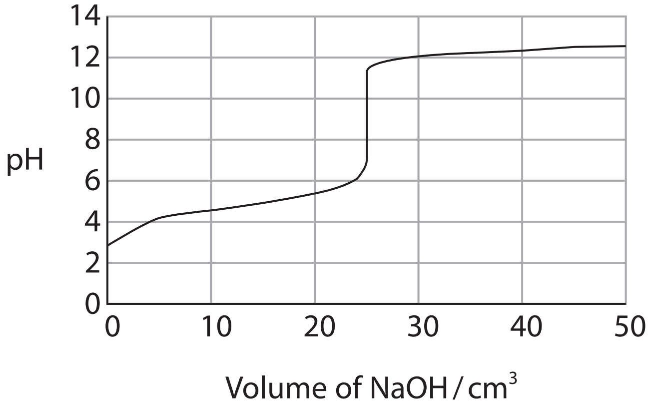
(b) Which could be the titration curve when 0.100 mol dm^{-3} NaOH(aq) is added to 25.0 cm^3 of 0.100 mol dm^{-3} CH_3COOH(aq)?

(1)

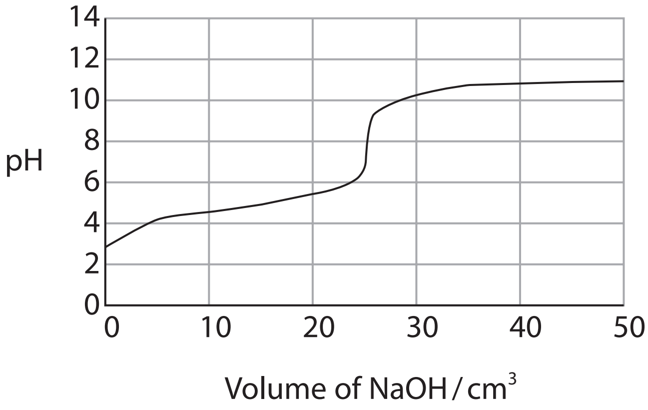
☒ **A**



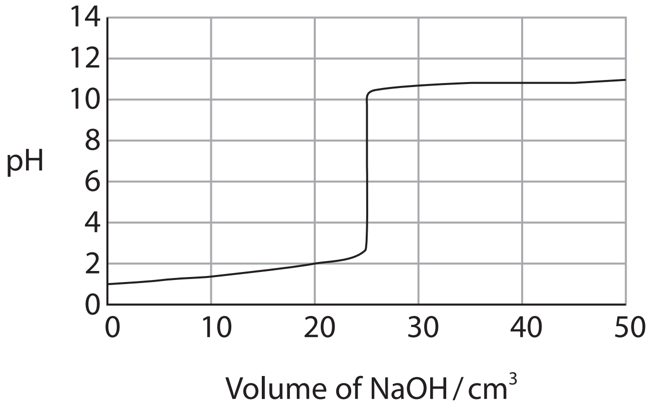
☒ **B**



☒ **C**



☒ **D**



(c) Some information about acids in aqueous solution is given.

Comment on these pH values. No calculations are required.

(4)

Name of acid	Formula of acid	pH of a solution of 0.100 mol dm^{-3} acid
hydrochloric acid	HCl	1.00
sulfuric acid	H_2SO_4	0.98
propanoic acid	CH_3CH_2COOH	2.94

(d) One of the systems controlling the pH of blood is the carbonic acid–hydrogencarbonate buffer system.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

(i) Write the expression for the acid dissociation constant, K_a, for carbonic acid. State symbols are not required.

(1)

(ii) A blood sample taken from an individual was analysed.

Calculate the pH of the blood sample.

Use your expression for K_a and the values shown.

K_a for carbonic acid = 4.50×10^{-7} mol dm^{-3}

$[HCO_3^-]$ = 0.0240 mol dm^{-3} $[H_2CO_3]$ = 0.00200 mol dm^{-3}

(3)

(e) The relevant equilibria that maintain the pH of blood are shown.

Equilibrium **1** $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

Equilibrium **2** $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

(i) When a person exercises vigorously the concentration of carbon dioxide (aq) in the blood increases.

Explain how this increase in the concentration of carbon dioxide affects the pH of the blood.
Refer to the equilibria in your answer. No calculation is required.

(2)

(ii) Explain how the carbonic acid–hydrogencarbonate buffer system in Equilibrium **2** acts to restore the pH of the blood after a person has exercised.

(2)

(Total for Question 4 = 14 marks)

5 This question is about 'Direct Ethanol Fuel Cells' which are being developed to power small electronic devices.

The overall reaction in these fuel cells is shown.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)$$

(a) Calculate the enthalpy change for the reaction using the mean bond enthalpy data.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C—H	413
C—O	358
O—H	464
O═O	498
C═O	805

Enthalpy change = ... kJ mol^{-1}

P 7 6 8 9 5 A 0 1 1 2 8

Turn over ▶

(b) (i) Complete the enthalpy cycle for the overall reaction in the Direct Ethanol Fuel Cell. Include labels.

(2)

Substance	$\Delta_f H^\ominus$ / kJ mol^{-1}
$C_2H_5OH(l)$	−277
$CO_2(g)$	−394
$H_2O(l)$	−286

$C_2H_5OH(l) + 3O_2(g) \xrightarrow{\Delta_r H} 3H_2O(l) + 2CO_2(g)$

(ii) Calculate a value for the enthalpy change of the Direct Ethanol Fuel Cell reaction, using your cycle.

(1)

Enthalpy change = ... kJ mol^{-1}

(c) Give **two** reasons for the difference between your calculated values in (a) and (b).

(2)

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(d) In the Direct Ethanol Fuel Cell under acidic conditions, at one electrode the ethanol is oxidised in the presence of water to produce carbon dioxide, hydrogen ions and electrons.

At the other electrode, the hydrogen ions and electrons combine with oxygen to form water.

Write the two ionic half-equations for this process.
State symbols are not required.

(2)

Oxidation half-equation

Reduction half-equation

(Total for Question 5 = 10 marks)

***6** Explain why aqueous solutions of Cu^{2+} ions and Fe^{2+} ions are coloured but have different colours, whereas aqueous solutions of Zn^{2+} ions are colourless.
Include any relevant electronic configurations.

(6)

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(Total for Question 6 = 6 marks)

7 This question is about vanadium.

The contact process is used in the manufacture of sulfuric acid. In the second stage, sulfur dioxide is converted into sulfur trioxide by passing sulfur dioxide and air over a solid V_2O_5 catalyst.

The equation for the second stage is shown.

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -196\,\text{kJ mol}^{-1}$$

(a) (i) What are the expression and the units for the equilibrium constant (K_p) for this reaction?

(1)

		Expression	Units
☒	**A**	$\frac{p(SO_3)}{p(SO_2)\,p(O_2)^{1/2}}$	atm^2
☒	**B**	$\frac{p(SO_2)\,p(O_2)^{1/2}}{p(SO_3)}$	$atm^{1/2}$
☒	**C**	$\frac{p(SO_2)\,p(O_2)^{1/2}}{p(SO_3)}$	$atm^{-1/2}$
☒	**D**	$\frac{p(SO_3)}{p(SO_2)\,p(O_2)^{1/2}}$	$atm^{-1/2}$

(ii) Which variable affects the value of K_p?

(1)

☒ **A** pressure

☒ **B** temperature

☒ **C** surface area of the catalyst

☒ **D** concentration of O_2(g)

(b) Write **two** equations that show the conversion of SO_2 and O_2 into SO_3 by using V_2O_5 as the catalyst.
State symbols are not required.

(2)

(c) Which row of the table shows the correct colour of the solution and oxidation number of vanadium in the aqueous ions shown?

(1)

	Aqueous ion	Colour of solution	Oxidation number of vanadium
☒ **A**	VO_2^+	yellow	+3
☒ **B**	VO^{2+}	green	+4
☒ **C**	VO_2^+	yellow	+5
☒ **D**	VO^{2+}	blue	+5

(d) What is the value of the cell potential for the reaction of Zn and VO_2^+?
Use your Data Booklet.

$$2VO_2^+(aq) + 4H^+(aq) + Zn(s) \rightarrow 2VO^{2+}(aq) + 2H_2O(l) + Zn^{2+}(aq)$$

(1)

☒ **A** +1.76 V

☒ **B** +0.24 V

☒ **C** −0.24 V

☒ **D** −1.76 V

(Total for Question 7 = 6 marks)

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8 This question is about ionic compounds.

(a) Draw dot-and-cross diagrams of the ions in magnesium hydroxide, showing the outer shell electrons only.

Use ✕ for magnesium electrons, ● for oxygen electrons and △ for each hydrogen electron.

(2)

(b) Which definition correctly describes the enthalpy change of solution, $\Delta_{sol}H$?

(1)

		Enthalpy change of solution, $\Delta_{sol}H$
☒	**A**	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give an infinitely dilute solution.
☒	**B**	The enthalpy change when 1 mol of an ionic substance dissolves in water to give an infinitely dilute solution.
☒	**C**	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give a solution of concentration 1 mol dm^{-3}.
☒	**D**	The enthalpy change when 1 mol of an ionic substance dissolves in water to give a solution of concentration 1 mol dm^{-3}.

(c) The table shows the information needed to calculate the standard enthalpy change of formation of magnesium fluoride.

Label	Description	Value / $kJ\,mol^{-1}$
A	enthalpy change of formation of magnesium fluoride	
B	lattice energy of magnesium fluoride	–2957
C	enthalpy change of atomisation of magnesium	+148
D	1st ionisation energy of magnesium	+738
E	2nd ionisation energy of magnesium	+1451
F	enthalpy change of atomisation of fluorine	+79
G	1st electron affinity of fluorine	–328

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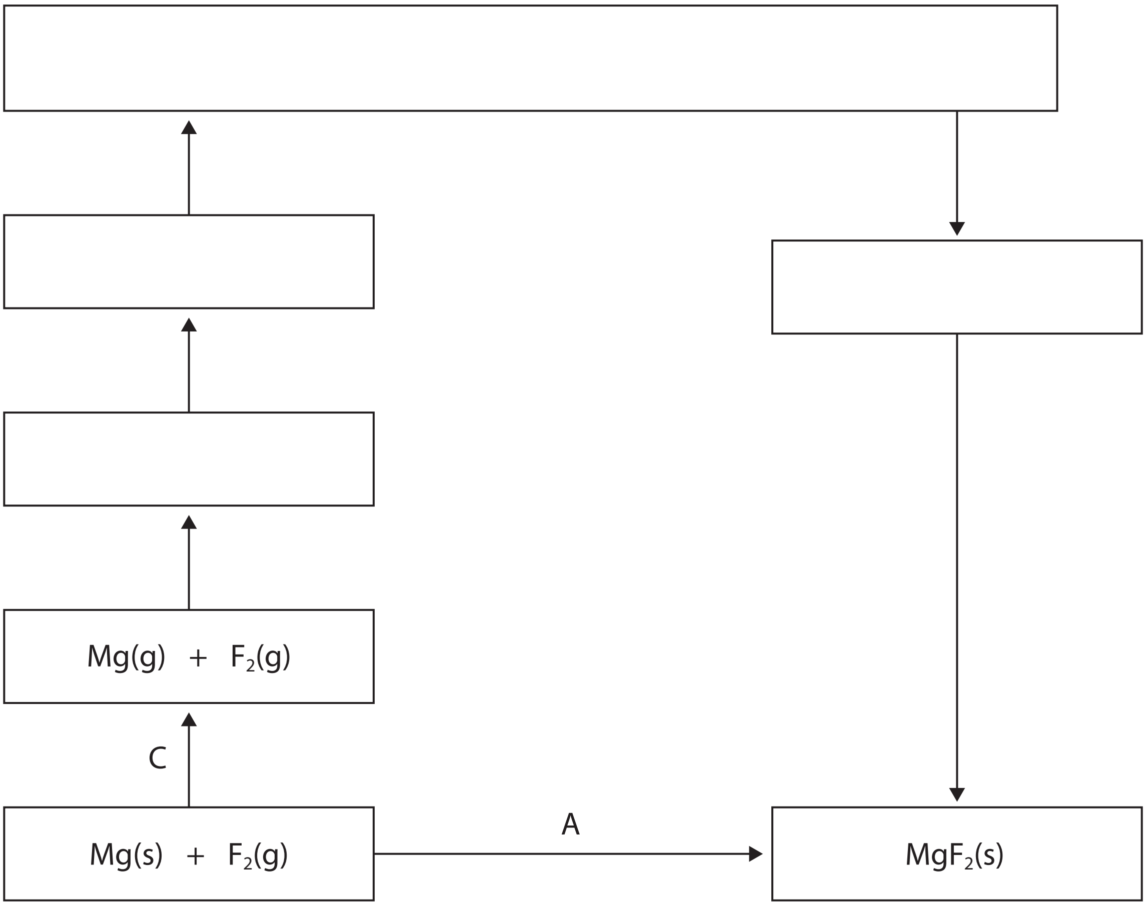
(i) Complete the Born–Haber cycle for magnesium fluoride with formulae, state symbols, electrons and correctly labelled arrows.
The cycle is not drawn to scale.

(4)



(ii) Calculate the value of $\Delta_f H^\ominus$ [MgF_2(s)].

(1)

(iii) The experimental and theoretical values of the lattice energy for MgF_2 and MgI_2 are given in the table.

Explain the differences in these values.

(4)

Compound	Experimental lattice energy / $kJ\,mol^{-1}$	Theoretical lattice energy / $kJ\,mol^{-1}$
MgF_2	−2957	−2913
MgI_2	−2327	−1944

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(Total for Question 8 = 12 marks)

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9 Sodium hydrogencarbonate is used as a raising agent in baking as carbon dioxide gas is released when it undergoes thermal decomposition.

(a) Show that this reaction is **not** feasible at 298 K by calculating ΔG.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l) \qquad \Delta_r H = +91.6\ kJ\ mol^{-1}$$

(3)

Compound	$NaHCO_3(s)$	$Na_2CO_3(s)$	$CO_2(g)$	$H_2O(l)$
Standard molar entropy / $J\ K^{-1}\ mol^{-1}$	101.7	135.0	213.6	69.9

(b) Calculate the minimum temperature, in degrees Celsius (°C), at which an oven should be set for this reaction to be thermodynamically feasible.

(2)

Minimum temperature = ... °C

(Total for Question 9 = 5 marks)

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10 Vitamin C has the molecular formula $C_6H_8O_6$.

The label on a bottle of vitamin C tablets stated that a 2.50 g tablet contained 6% of vitamin C by mass. The tablet was analysed to check the accuracy of the label. The procedure involved a series of steps.

(a) Step **1** Dissolving the tablet.

A 2.50 g vitamin C tablet was crushed and dissolved to make an aqueous solution of volume 250.0 cm^3.

Describe how to make this solution from the crushed tablet.

(3)

(b) Step **2** Producing a known amount of iodine.

Iodine was produced by reacting 25.0 cm^3 of 0.0100 mol dm^{-3} potassium iodate with excess potassium iodide and hydrochloric acid in a conical flask.

(i) Complete the ionic equation for the formation of the iodine from 1 mol of IO_3^- ions.

(1)

$$IO_3^- \; + \; ....I^- \; + \; ....H^+ \; \rightarrow \; 3I_2 \; + \; ....$$

(ii) Show, by calculation, that 7.50×10^{-4} moles of iodine were produced in the flask.

(2)

(c) Step **3** Titrating with sodium thiosulfate solution.

10.0 cm^3 of the vitamin C tablet solution from Step **1** was added to the conical flask from Step **2** to react with the iodine produced, as shown in the equation.

$$C_6H_8O_6(aq) \; + \; I_2(aq) \; \rightarrow \; C_6H_6O_6(aq) \; + \; 2HI(aq)$$

The unreacted iodine in the conical flask was titrated with a solution of 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3(aq)$.

The mean titre was 14.40 cm^3.

$$2S_2O_3^{2-}(aq) \; + \; I_2(aq) \; \rightarrow \; 2I^-(aq) \; + \; S_4O_6^{2-}(aq)$$

(i) State the indicator used in this titration, giving the colour change that would be observed at the end-point.

(2)

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(ii) Deduce, by calculation, whether the label on the bottle of vitamin C tablets is correct.

(6)

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

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

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)
							1.0 **H** hydrogen 1										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