A' Level Chemistry
Year 1

Unit 1: Time of Flight

Summer Examination Revision Pack

The questions in this pack should be attempted **AFTER** completing all other revision.

Grade Accelerator
Recall Definitions
Drawing Diagrams
Using Equations
Drawing Graphs

Quizlet

Quizlet Classes
Flashcard Based
Games
Tests & Quizzes
Keyword Spell Checker

Condensed Notes
Keywords & Definitions
Key Concepts
Application
Key Skills

Online Forms
Take Time to Answer
Use Paper & Calculator
Work It Out
Review Missed Marks

Use the 3 Wave Process when completing these revision packs.

1. Complete the questions without assistance
(Can't answer a question? Leave it and move on)
2. Use your notes to fill any gaps after step 1
3. Use the mark scheme to fill in any remaining gaps.

1. Having gaps after step 1 is normal, that's why we are doing revision!
2. If your notes don't help during step 2, they are not good enough!
(Change your note taking method and try to understand the problem)
3. If you don't understand why the mark scheme answer is correct, **see Andy.**

STOP If you struggle with the questions in the pack, **STOP!** and complete some more revision.

STOP If you come to a complete dead-end, **STOP!** and speak to **Andy** asap.

The Periodic Table of the Elements

Key

relative atomic mass
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 (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	96.0 **Mo** molybdenum 42	[97] **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	[267] **Rf** rutherfordium 104	[270] **Db** dubnium 105	[269] **Sg** seaborgium 106	[270] **Bh** bohrium 107	[270] **Hs** hassium 108	[278] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[281] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Nh** nihonium 113	[289] **Fl** flerovium 114	[289] **Mc** moscovium 115	[293] **Lv** livermorium 116	[294] **Ts** tennessine 117	[294] **Og** oganesson 118

* **58 – 71** Lanthanides

140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.3 **Gd** gadolinium 64	158.9 **Tb** terbium 65	162.5 **Dy** dysprosium 66	164.9 **Ho** holmium 67	167.3 **Er** erbium 68	168.9 **Tm** thulium 69	173.0 **Yb** ytterbium 70	175.0 **Lu** lutetium 71

† **90 – 103** Actinides

232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103

0 4 A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in **Table 2**.

Table 2

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

0 4 . 1 Calculate the relative atomic mass of titanium in this sample.
Give your answer to one decimal place.

[2 marks]

Relative atomic mass of titanium in this sample ____________________

0 4 . 2 Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

[2 marks]

Equation ____________________________________

m/z value ____________________________________

0 4 . 3 Calculate the mass, in kg, of one atom of ^{49}Ti

The Avogadro constant $L = 6.022 \times 10^{23}$ mol^{-1}

[1 mark]

Mass ____________________ kg

Do not write outside the box

0 4 . 4 In a TOF mass spectrometer the time of flight, *t*, of an ion is shown by the equation

$$t = d\sqrt{\frac{m}{2E}}$$

In this equation *d* is the length of the flight tube, *m* is the mass, in kg, of an ion and *E* is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is 1.013×10^{-13} J

The time of flight of a $^{49}Ti^{+}$ ion is 9.816×10^{-7} s

Calculate the time of flight of the $^{47}Ti^{+}$ ion.
Give your answer to the appropriate number of significant figures.

[3 marks]

Time of flight ______________________________ s

8

Turn over ►

Question	Answers	Mark	Additional Comments/Guidance
04.1	$\frac{(46 \times 9.1) + (47 \times 7.8) + (48 \times 74.6) + (49 \times 8.5)}{100} = \frac{4782.5}{100}$	1	
	= 47.8	1	Correct answer scores 2 marks. Allow alternative methods. Allow 1dp or more. Ignore units
04.2	$Ti(g) \rightarrow Ti^{+}(g) + e^{-}$ or $Ti(g) + e^{-} \rightarrow Ti^{+}(g) + 2e^{-}$ or $Ti(g) - e^{-} \rightarrow Ti^{+}(g)$	1	State symbols essential Allow electrons without $^{-}$ charge shown.
	46	1	
04.3	$8.1(37) \times 10^{-26}$	1	

Question	Answers	Mark	Additional Comments/Guidance
04.4	M1 is for re-arranging the equation $d = t\sqrt{\frac{2E}{m}}$ or $d = \frac{t}{\sqrt{\frac{m}{2E}}}$ or $d^2 = t^2 \times \frac{2E}{m}$	1	Allow t α square root of m
	$d = t_{47}\sqrt{\frac{2E}{47 \times 10^{-3} / L}} = t_{49}\sqrt{\frac{2E}{49 \times 10^{-3} / L}}$ **Or** d = 1.5(47) This scores 2 marks	1	Allow this expression for M2 $\frac{t_{47}}{\sqrt{47}} = \frac{t_{49}}{\sqrt{49}}$
	$= 9.6(14) \times 10^{-7}$	1	Correct answer scores 3 marks.

Total		8	

Do not write outside the box

0 4 . 6 A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr, ^{87}Sr and ^{88}Sr
In this sample, the ratio of abundances of the isotopes ^{86}Sr : ^{87}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.
Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

[4 marks]

Why isotopes of strontium have identical chemical properties

___

___

___

Percentage abundance of ^{88}Sr ________________ %

0 4 . 7 A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba, ^{137}Ba and ^{138}Ba
The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

[1 mark]

___

Turn over ►

Do not write outside the box

0 4 . 8 A $^{137}Ba^{+}$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of 3.65×10^{-16} J
This ion takes 2.71×10^{-5} s to reach the detector.

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = speed (m s^{-1})

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Calculate the length of the flight tube in metres.
Give your answer to the appropriate number of significant figures.

[5 marks]

Length of flight tube ____________________ m

18

04.6	M1 Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1) M2 $\frac{86x + 87x + 88(100-2x)}{100} = 87.7$ M3 x = 10% (or x = 0.1) M4 (% abundance of 88 isotope is 100 – 2x10) = <u>80(.0)%</u>	*Ignore protons and neutrons unless incorrect numbers* *Not just electrons determine chemical properties* Alternative: M2 $\frac{86 + 87 + 88y}{1 + 1 + y} = 87.7$ M3 y= 8 M4 % of 88 isotope is 100 – 10y = 80(.0) % Allow other alternative methods	1 1 1 1
04.7	$^{138}Ba^{+}$		1

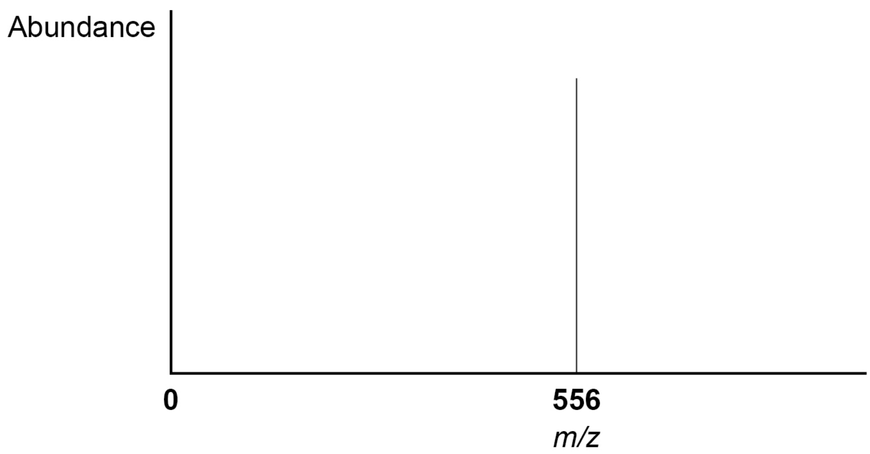
04.8	M1 mass = $\frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275×10^{-25} (kg)	Calculation of m in kg If not converted to kg, max 4 If not divided by L lose M1 and M5, max 3	1
	M2 $v^2 = \frac{2KE}{m} = \frac{2 \times 3.65 \times 10^{-16}}{2.275 \times 10^{-25}} = 3.2088 \times 10^9$	For re-arrangement	1
	M3 v = $\sqrt{2KE/m}$ ($v = 5.6646 \times 10^4$)	For expression with square root	1
	M4 v = d/t or d = vt or with numbers		1
	M5 d = ($5.6646 \times 10^4 \times 2.71 \times 10^{-5}$) = 1.53 - 1.54 (m)	M5 must be to 3sf If not converted to kg, answer = 0.0485-0.0486 (3sf). This scores 4 marks	1
04.8	Alternative Method M1 m = $\frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275×10^{-25} M2 v = d/t M3 $d^2 = \frac{KE \times 2\,t^2}{m}$ M4 d = $\sqrt{\frac{KE\ x\ 2t^2}{m}}$ (= √ ($3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25}$)) M5 d = 1.53 – 1.54 (m)	M1 Calculation of m in kg M2, M3 and M4 are for algebraic expressions or correct expressions with numbers M5 must be to 3sf	1 1 1 1 1
Total			18

Do not write outside the box

0 2 Time of flight (TOF) mass spectrometry can be used to analyse large molecules such as the pentapeptide, leucine encephalin (**P**).

P is ionised by electrospray ionisation and its mass spectrum is shown in **Figure 2**.

Figure 2



0 2 . 1 Describe the process of electrospray ionisation.

Give an equation to represent the ionisation of **P** in this process.

[4 marks]

Description

Equation

Do not write outside the box

0 2 . 2 What is the relative molecular mass of **P**?

Tick (✓) **one** box.

[1 mark]

555 ☐ 556 ☐ 557 ☐

0 2 . 3 A molecule **Q** is ionised by electron impact in a TOF mass spectrometer.
The $\mathbf{Q}^+$ ion has a kinetic energy of 2.09×10^{-15} J
This ion takes 1.23×10^{-5} s to reach the detector.
The length of the flight tube is 1.50 m

Calculate the relative molecular mass of **Q.**

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = speed (m s^{-1})

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

[5 marks]

Relative molecular mass ______________________

10

Turn over ►

Question	Answers	Additional Comments/Guidelines	Mark
02.1	M1: P dissolved or put in/added to a solvent M2: (injected through) a needle or nozzle or capillary <u>and</u> at high voltage/4000 volts or high potential M3: Gains a proton / H^+ M4: $P + H^+ \rightarrow PH^+$	M1: Allow named solvent eg water or methanol M2: Allow needle is positively charged M3: Not atoms gain a proton M3: Could be scored from equation Correct equation gains M3 and M4 Ignore state symbols	1 1 1 1
02.2	555		1
02.3	M1 V = d/t or = 1.22×10^5 ms^{-1} M2 $m = \frac{2KE}{v^2}$ or $\frac{2 \times 2.09 \times 10^{-15}}{(1.22 \times 10^5)^2}$ or M2 $m = \frac{2KE \times t^2}{d^2}$ or $\frac{2 \times 2.09 \times 10^{-15} \times (1.23 \times 10^{-5})^2}{1.50^2}$ M3 m = <u>$2.8(1) \times 10^{-25}$</u> (kg) M4 = 2.81×10^{-25} <u>x L</u> = 0.169 M5 0.169 <u>x 1000</u> = 169.(2)	Recall this equation Rearrangement to give m M3: Calculation of m. M4: Allow M3 x L M5: Allow M4 x 1000 169 only scores 5 marks Allow answers to 2 significant figures or more ignore units	1 1 1 1 1

Do not write outside the box

0 2 This question is about the isotopes of chromium.

0 2 . 1 Give the meaning of the term relative atomic mass.

[2 marks]

____

____

____

____

0 2 . 2 A sample of chromium containing the isotopes ^{50}Cr, ^{52}Cr and ^{53}Cr has a relative atomic mass of 52.1

The sample contains 86.1% of the ^{52}Cr isotope.

Calculate the percentage abundance of each of the other two isotopes.

[4 marks]

Abundance of ^{50}Cr ______________ %   Abundance of ^{53}Cr ______________ %

Do not write outside the box

0 2 . 3 State, in terms of the numbers of fundamental particles, **one** similarity and **one** difference between atoms of ^{50}Cr and ^{53}Cr

[2 marks]

Similarity ____________________

____

Difference ____________________

____

____

The sample of chromium is analysed in a time of flight (TOF) mass spectrometer.

0 2 . 4 Give **two** reasons why it is necessary to ionise the isotopes of chromium before they can be analysed in a TOF mass spectrometer.

[2 marks]

1 ____________________

____

2 ____________________

____

Question 2 continues on the next page

Do not write outside the box

0 2 . 5 A $^{53}Cr^{+}$ ion travels along a flight tube of length 1.25 m
The ion has a constant kinetic energy (*KE*) of 1.102 × 10^{-13} J

$$KE = \frac{mv^2}{2}$$

m = mass of the ion / kg
v = speed of ion / m s^{-1}

Calculate the time, in s, for the $^{53}Cr^{+}$ ion to travel down the flight tube to reach the detector.

The Avogadro constant, *L* = 6.022 × 10^{23} mol^{-1}

[5 marks]

Time ____________________ s

15

Question	Answers	Additional comments/Guidelines	Mark
02.1	Average / mean mass of 1 atom (of an element) 1/12 mass of one atom of ^{12}C **OR** Average / mean mass of atoms of an element 1/12 mass of one atom of ^{12}C **OR** Average / mean mass of atoms of an element ×12 mass of one atom of ^{12}C **OR** (Average) mass of one mole of atoms 1/12 mass of one mole of ^{12}C **OR** (Weighted) average mass of all the isotopes 1/12 mass of one atom of ^{12}C **OR** Average mass of an atom/isotope compared to/relative to C−12 on a scale in which an atom of C−12 has a mass of 12 This expression = 2 marks	If moles and atoms mixed, max = 1 Mark top and bottom line independently. All key terms must be present for each mark.	1 1

02.2	M1 % of ^{50}Cr and ^{53}Cr = 13.9% Let % of ^{53}Cr = x% and Let % of ^{50}Cr = (13.9 - x)% M2 $52.1 = \frac{50(13.9 - x) + (52 \times 86.1) + 53(x)}{100}$ OR 3x = 37.8 M3 x = % of ^{53}Cr = 12.6% M4 % of ^{50}Cr = 1.3%	If x used for ^{50}Cr and ^{53}Cr or x and y, max 2 marks = M1 and M4 Alternative M2 Let % of ^{53}Cr = (13.9%-x)% and % of ^{50}Cr = x% M2 $52.1 = \frac{53(13.9 - x)+(52 \times 86.1)+50x}{100}$ OR 3x = 3.9 M4 = M1- M3	1 1 1 1
02.3	M1 (Same) number of protons <u>OR</u> electrons M2 (Different) number of neutrons	Do not allow same electronic configuration for M1	1 1
02.4	M1 (Ions will interact with and) be <u>accelerated</u> (by an electric field) M2 Ions create a current when hitting the detector OR ions create a current in the detector/electron multiplier.	Allow (ions) accelerated to a negative plate Do not allow magnetic field Allow (ions) can be detected	1 1

02.5	M1 Mass of ion = $\underline{8.8. \times 10^{-26}}$ kg M2 $v^2 = \frac{2KE}{m} = v^2 = \frac{2 \times 1.102 \times 10^{-13}}{8.8. \times 10^{-26}}$ (= 2.504×10^{12}) M3 $v = \sqrt{\left(\frac{2 \times 1.102 \times 10^{-13}}{8.8. \times 10^{-26}}\right)} = 1.58 \times 10^6$ (ms^{-1}) M4 $v = \frac{d}{t}$ M5 $t = 7.9(0) \times 10^{-7}$ (s) (2sf or more) Alternative M1 Mass of ion = $\underline{8.8. \times 10^{-26}}$ kg M2 $KE = \frac{md^2}{2t^2}$ or $v = \frac{d}{t}$ M3 $t^2 = \frac{md^2}{2KE}$ OR $\frac{8.8. \times 10^{-26} \times 1.25^2}{2 \times 1.102 \times 10^{-13}}$ M4 $t^2 = 6.24 \times 10^{-13}$ M5 $t = 7.9(0) \times 10^{-7}$ (s) (2sf or more)	M1 Mass of ion in kg M2 Rearrangement Alternative M2 $v = \sqrt{\frac{2KE}{m}}$ M3: Calculating v by taking $\sqrt{v}$ M4: Recall of v = d/t M5: Calculating t Alternative M1 Mass of ion in kg M2 Recall of v = d/t M3 Rearrangement M4: Correct calculation to get t^2 M5: Calculating t by taking square root of M4 Allow answers consequential on incorrect M1 If mass in g calculated = $8.8. \times 10^{-23}$, then $t = 2.5 \times 10^{-5}$ s (4 marks)	1 1 1 1 1 1 1 1 1 1

A sample of rhenium is ionised by electron impact in a time of flight (TOF) mass spectrometer.

0 2 . 4 A $^{185}Re^{+}$ ion with a kinetic energy of 1.153×10^{-13} J travels through a 1.450 m flight tube.

The kinetic energy of the ion is given by the equation $KE = \frac{1}{2}mv^2$

where
m = mass / kg
v = speed / m s^{-1}
KE = kinetic energy / J

Calculate the time, in seconds, for the ion to reach the detector.

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

[5 marks]

Time ____________________ s

Do not write outside the box

0 2 . 5 State how the relative abundance of $^{185}Re^{+}$ is determined in a TOF mass spectrometer.

[2 marks]

12

Question	Answers	Additional Comments/Guidelines	Mark
02.4	M1 mass ^{185}Re $\left(= \frac{185}{6.02 \times 10^{23} \times 1000}\right)$ = 3.072 x 10^{-25} (kg)	calculate mass in kg	1
	M2 $v = \frac{d}{t}$	recall of v = d/t	1
	M3 $v^2 = \frac{2KE}{m}$ **or** 7.5(0) × 10^{11}	rearrangement to get v^2	1
	M4 $v = \sqrt{\frac{2KE}{m}}$ **or** 8.66 × 10^5	allow $\sqrt{\frac{2 \times 1.153 \times 10^{-13}}{M1}}$	1
	M5 t $\left(= \frac{1.45}{8.66 \times 10^5}\right)$ = 1.67 × 10^{-6} (s)	M5 $t = \frac{1.45}{M4}$ allow 1.67 × 10^{-6} to 1.68 × 10^{-6} (s)	1 AO1 AO2

02.4	**alternative method:**		
	M1 mass ^{185}Re $\left(= \dfrac{185}{6.02 \times 10^{23} \times 1000}\right) = 3.072 \times 10^{-25}$ (kg)	calculate mass in kg	1
	M2 $v = \dfrac{d}{t}$ **or** $KE = \dfrac{md^2}{2t^2}$	recall of v = d/t	1
	M3 $t^2 = \dfrac{md^2}{2KE}$	rearrangement to get t^2	1
	M4 $t = d\sqrt{\dfrac{m}{2KE}}$ **or** $\sqrt{\dfrac{md^2}{2KE}}$ **or** $\sqrt{\dfrac{3.072 \times 10^{-25}}{2 \times 1.153 \times 10^{-13}}}$	allow $\sqrt{\dfrac{M1}{2 \times 1.153 \times 10^{-13}}}$	1
	M5 $t = 1.67 \times 10^{-6}$ (s)	allow 1.67×10^{-6} to 1.68×10^{-6} (s)	1 AO1 AO2

Question	Answers	Additional Comments/Guidelines	Mark
02.5	at the detector/(negative) plate the ions/Re^+ gain an electron (relative) abundance depends on the size of the current	alternative answer M1 ion knocks out an electron into electron multiplier M2 signal from electron multiplier proportional to number of ions	1 1 AO1

The Periodic Table of the Elements

Key

relative atomic mass
symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(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
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[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac** † actinium 89	[267] **Rf** rutherfordium 104	[270] **Db** dubnium 105	[269] **Sg** seaborgium 106	[270] **Bh** bohrium 107	[270] **Hs** hassium 108	[278] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[281] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Nh** nihonium 113	[289] **Fl** flerovium 114	[289] **Mc** moscovium 115	[293] **Lv** livermorium 116	[294] **Ts** tennessine 117	[294] **Og** oganesson 118

* **58 – 71** Lanthanides	140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.3 **Gd** gadolinium 64	158.9 **Tb** terbium 65	162.5 **Dy** dysprosium 66	164.9 **Ho** holmium 67	167.3 **Er** erbium 68	168.9 **Tm** thulium 69	173.0 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
† **90 – 103** Actinides	232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103