Cambridge International AS & A Level

Data Booklet

Cambridge International Advanced Subsidiary and Advanced Level in Chemistry (9701)

For use from 2016 in all papers for the above syllabus, except practical examinations.

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Contents: Tables of Chemical Data

1 Important values, constants and standards

molar gas constant	R = 8.31 J K^{-1} mol^{-1}
the Faraday constant	F = 9.65 × 10^{4} C mol^{-1}
the Avogadro constant	L = 6.02 × 10^{23} mol^{-1}
the Planck constant	h = 6.63 × 10^{-34} J s
speed of light in a vacuum	c = 3.00 × 10^{8} m s^{-1}
rest mass of proton, ${}^{1}_{1}H$	m_p = 1.67 × 10^{-27} kg
rest mass of neutron, ${}^{1}_{0}n$	m_n = 1.67 × 10^{-27} kg
rest mass of electron, ${}^{0}_{-1}e$	m_e = 9.11 × 10^{-31} kg
electronic charge	e = –1.60 × 10^{-19} C
molar volume of gas	V_m = 22.4 dm^{3} mol^{-1} at s.t.p. V_m = 24.0 dm^{3} mol^{-1} under room conditions (where s.t.p. is expressed as 101 kPa, approximately, and 273 K [0 °C])
ionic product of water	K_w = 1.00 × 10^{-14} mol^{2} dm^{-6} (at 298 K [25 °C])
specific heat capacity of water	= 4.18 kJ kg^{-1} K^{-1} (= 4.18 J g^{-1} K^{-1})

2 Ionisation energies (1st, 2nd, 3rd and 4th) of selected elements, in kJ mol^{-1}

	Proton number	First	Second	Third	Fourth
H	1	1310	–	–	–
He	2	2370	5250	–	–
Li	3	519	7300	11800	–
Be	4	900	1760	14800	21000
B	5	799	2420	3660	25000
C	6	1090	2350	4610	6220
N	7	1400	2860	4590	7480
O	8	1310	3390	5320	7450
F	9	1680	3370	6040	8410
Ne	10	2080	3950	6150	9290
Na	11	494	4560	6940	9540
Mg	12	736	1450	7740	10500
A*l*	13	577	1820	2740	11600
Si	14	786	1580	3230	4360
P	15	1060	1900	2920	4960
S	16	1000	2260	3390	4540
C*l*	17	1260	2300	3850	5150
Ar	18	1520	2660	3950	5770
K	19	418	3070	4600	5860
Ca	20	590	1150	4940	6480
Sc	21	632	1240	2390	7110
Ti	22	661	1310	2720	4170
V	23	648	1370	2870	4600
Cr	24	653	1590	2990	4770
Mn	25	716	1510	3250	5190
Fe	26	762	1560	2960	5400
Co	27	757	1640	3230	5100
Ni	28	736	1750	3390	5400
Cu	29	745	1960	3350	5690
Zn	30	908	1730	3828	5980
Ga	31	577	1980	2960	6190
Br	35	1140	2080	3460	4850
Rb	37	403	2632	3900	5080
Sr	38	548	1060	4120	5440
Ag	47	731	2074	3361	5000
I	53	1010	1840	3000	4030
Cs	55	376	2420	3300	4400
Ba	56	502	966	3390	4700

3 Bond Energies

3(a) Bond energies in diatomic molecules (these are exact values)

Homonuclear

Bond	Energy / kJ mol^{-1}
H—H	436
D—D	442
N≡N	944
O=O	496
P≡P	485
S=S	425
F—F	158
C*l*—C*l*	242
Br—Br	193
I—I	151

Heteronuclear

Bond	Energy / kJ mol^{-1}
H—F	562
H—C*l*	431
H—Br	366
H—I	299
C≡O	1077

3(b) Bond energies in polyatomic molecules (these are average values)

Homonuclear

Bond	**Energy / kJ mol^{-1}**
C—C	350
C=C	610
C≡C	840
C┈C (benzene)	520
N—N	160
N=N	410
O—O	150
Si—Si	225
P—P	200
S—S	265

Heteronuclear

Bond	**Energy / kJ mol^{-1}**
C—H	410
C—Cl	340
C—Br	280
C—I	240
C—N	305
C=N	610
C≡N	890
C—O	360
C=O	740
C=O in CO_2	805
N—H	390
N—Cl	310
O—H	460
Si—Cl	360
Si—H	320
Si—O (in SiO_2(s))	460
Si=O (in SiO_2(g))	640
P—H	320
P—Cl	330
P—O	340
P=O	540
S—H	340
S—Cl	250
S—O	360
S=O	500

4 Standard electrode potential and redox potentials, $E^\ominus$ at 298 K (25 °C)

For ease of reference, two tables are given:

(a) an extended list in alphabetical order;
(b) a shorter list in decreasing order of magnitude, i.e. a redox series.

(a) $E^\ominus$ in alphabetical order

Electrode reaction			$E^\ominus$/V
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+0.80
$Al^{3+} + 3e^-$	$\rightleftharpoons$	Al	–1.66
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	Ba	–2.90
$Br_2 + 2e^-$	$\rightleftharpoons$	$2Br^-$	+1.07
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	–2.87
$Cl_2 + 2e^-$	$\rightleftharpoons$	$2Cl^-$	+1.36
$2HOCl + 2H^+ + 2e^-$	$\rightleftharpoons$	$Cl_2 + 2H_2O$	+1.64
$ClO^- + H_2O + 2e^-$	$\rightleftharpoons$	$Cl^- + 2OH^-$	+0.89
$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	–0.28
$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+1.82
$[Co(NH_3)_6]^{2+} + 2e^-$	$\rightleftharpoons$	$Co + 6NH_3$	–0.43
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	–0.91
$Cr^{3+} + 3e^-$	$\rightleftharpoons$	Cr	–0.74
$Cr^{3+} + e^-$	$\rightleftharpoons$	Cr^{2+}	–0.41
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+1.33
$Cu^+ + e^-$	$\rightleftharpoons$	Cu	+0.52
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+0.34
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+0.15
$[Cu(NH_3)_4]^{2+} + 2e^-$	$\rightleftharpoons$	$Cu + 4NH_3$	–0.05
$F_2 + 2e^-$	$\rightleftharpoons$	$2F^-$	+2.87
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	–0.44
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	–0.04
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+0.77
$[Fe(CN)_6]^{3-} + e^-$	$\rightleftharpoons$	$[Fe(CN)_6]^{4-}$	+0.36
$Fe(OH)_3 + e^-$	$\rightleftharpoons$	$Fe(OH)_2 + OH^-$	–0.56
$2H^+ + 2e^-$	$\rightleftharpoons$	H_2	0.00
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2 + 2OH^-$	–0.83
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+0.54
$K^+ + e^-$	$\rightleftharpoons$	K	–2.92
$Li^+ + e^-$	$\rightleftharpoons$	Li	–3.04
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	–2.38
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	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
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2 + H_2O$	+0.81
$NO_3^- + 3H^+ + 2e^-$	$\rightleftharpoons$	$HNO_2 + H_2O$	+0.94
$NO_3^- + 10H^+ + 8e^-$	$\rightleftharpoons$	$NH_4^+ + 3H_2O$	+0.87

Electrode reaction			$E^{\ominus}$/V
$Na^+ + e^-$	$\rightleftharpoons$	Na	–2.71
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	–0.25
$[Ni(NH_3)_6]^{2+} + 2e^-$	$\rightleftharpoons$	$Ni + 6NH_3$	–0.51
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1.77
$HO_2^- + H_2O + 2e^-$	$\rightleftharpoons$	$3OH^-$	+0.88
$O_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+1.23
$O_2 + 2H_2O + 4e^-$	$\rightleftharpoons$	$4OH^-$	+0.40
$O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O_2	+0.68
$O_2 + H_2O + 2e^-$	$\rightleftharpoons$	$HO_2^- + OH^-$	–0.08
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	–0.13
$Pb^{4+} + 2e^-$	$\rightleftharpoons$	Pb^{2+}	+1.69
$PbO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Pb^{2+} + 2H_2O$	+1.47
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2 + 2H_2O$	+0.17
$S_2O_8^{2-} + 2e^-$	$\rightleftharpoons$	$2SO_4^{2-}$	+2.01
$S_4O_6^{2-} + 2e^-$	$\rightleftharpoons$	$2S_2O_3^{2-}$	+0.09
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	–0.14
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+0.15
$V^{2+} + 2e^-$	$\rightleftharpoons$	V	–1.20
$V^{3+} + e^-$	$\rightleftharpoons$	V^{2+}	–0.26
$VO^{2+} + 2H^+ + e^-$	$\rightleftharpoons$	$V^{3+} + H_2O$	+0.34
$VO_2^+ + 2H^+ + e^-$	$\rightleftharpoons$	$VO^{2+} + H_2O$	+1.00
$VO_3^- + 4H^+ + e^-$	$\rightleftharpoons$	$VO^{2+} + 2H_2O$	+1.00
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	–0.76

All ionic states refer to aqueous ions but other state symbols have been omitted.

(b) $E^{\ominus}$ in decreasing order of oxidising power

(a selection only – see also the extended alphabetical list on the previous pages)

Electrode reaction			$E^{\ominus}$/V
$F_2 + 2e^-$	⇌	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇌	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇌	$2H_2O$	+1.77
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	+1.52
$PbO_2 + 4H^+ + 2e^-$	⇌	$Pb^{2+} + 2H_2O$	+1.47
$Cl_2 + 2e^-$	⇌	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇌	$2Cr^{3+} + 7H_2O$	+1.33
$O_2 + 4H^+ + 4e^-$	⇌	$2H_2O$	+1.23
$Br_2 + 2e^-$	⇌	$2Br^-$	+1.07
$ClO^- + H_2O + 2e^-$	⇌	$Cl^- + 2OH^-$	+0.89
$NO_3^- + 10H^+ + 8e^-$	⇌	$NH_4^+ + 3H_2O$	+0.87
$NO_3^- + 2H^+ + e^-$	⇌	$NO_2 + H_2O$	+0.81
$Ag^+ + e^-$	⇌	Ag	+0.80
$Fe^{3+} + e^-$	⇌	Fe^{2+}	+0.77
$I_2 + 2e^-$	⇌	$2I^-$	+0.54
$O_2 + 2H_2O + 4e^-$	⇌	$4OH^-$	+0.40
$Cu^{2+} + 2e^-$	⇌	Cu	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2 + 2H_2O$	+0.17
$Sn^{4+} + 2e^-$	⇌	Sn^{2+}	+0.15
$S_4O_6^{2-} + 2e^-$	⇌	$2S_2O_3^{2-}$	+0.09
$2H^+ + 2e^-$	⇌	H_2	0.00
$Pb^{2+} + 2e^-$	⇌	Pb	–0.13
$Sn^{2+} + 2e^-$	⇌	Sn	–0.14
$Fe^{2+} + 2e^-$	⇌	Fe	–0.44
$Zn^{2+} + 2e^-$	⇌	Zn	–0.76
$2H_2O + 2e^-$	⇌	$H_2 + 2OH^-$	–0.83
$V^{2+} + 2e^-$	⇌	V	–1.20
$Mg^{2+} + 2e^-$	⇌	Mg	–2.38
$Ca^{2+} + 2e^-$	⇌	Ca	–2.87
$K^+ + e^-$	⇌	K	–2.92

5 Atomic and ionic radii

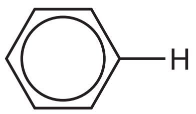
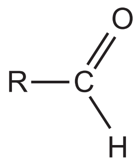
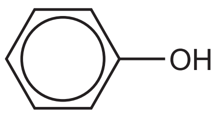
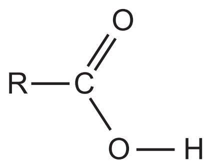
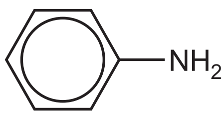
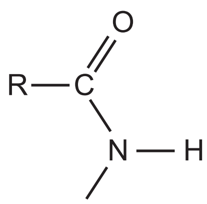
		atomic / nm		ionic / nm			
(a)	**Period 1**	**atomic / nm**		**ionic / nm**			
	single covalent	H	0.037	H^-	0.208		
	van der Waals	He	0.140				
(b)	**Period 2**	**atomic / nm**		**ionic / nm**			
	metallic	Li	0.152	Li^+	0.060		
		Be	0.112	Be^{2+}	0.031		
	single covalent	B	0.080	B^{3+}	0.020		
		C	0.077	C^{4+}	0.015	C^{4-}	0.260
		N	0.074			N^{3-}	0.171
		O	0.073			O^{2-}	0.140
		F	0.072			F^-	0.136
	van der Waals	Ne	0.160				
(c)	**Period 3**	**atomic / nm**		**ionic / nm**			
	metallic	Na	0.186	Na^+	0.095		
		Mg	0.160	Mg^{2+}	0.065		
		A*l*	0.143	Al^{3+}	0.050		
	single covalent	Si	0.117	Si^{4+}	0.041	Si^{4-}	0.271
		P	0.110			P^{3-}	0.212
		S	0.104			S^{2-}	0.184
		C*l*	0.099			Cl^-	0.181
	van der Waals	Ar	0.190				
(d)	**Group 2**	**atomic / nm**		**ionic / nm**			
	metallic	Be	0.112	Be^{2+}	0.031		
		Mg	0.160	Mg^{2+}	0.065		
		Ca	0.197	Ca^{2+}	0.099		
		Sr	0.215	Sr^{2+}	0.113		
		Ba	0.217	Ba^{2+}	0.135		
		Ra	0.220	Ra^{2+}	0.140		

(e)	Group 14	atomic / nm		ionic / nm	
	single covalent	C	0.077		
		Si	0.117	Si^{4+}	0.041
		Ge	0.122	Ge^{2+}	0.093
	metallic	Sn	0.162	Sn^{2+}	0.112
		Pb	0.175	Pb^{2+}	0.120

(f)	Group 17	atomic / nm		ionic / nm	
	single covalent	F	0.072	F^{-}	0.136
		C*l*	0.099	Cl^{-}	0.181
		Br	0.114	Br^{-}	0.195
		I	0.133	I^{-}	0.216
		At	0.140		

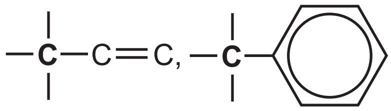
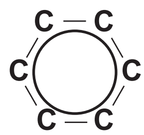
(g)	First row transition elements	atomic / nm		ionic / nm			
	metallic	Sc	0.164			Sc^{3+}	0.081
		Ti	0.146	Ti^{2+}	0.090	Ti^{3+}	0.067
		V	0.135	V^{2+}	0.079	V^{3+}	0.064
		Cr	0.129	Cr^{2+}	0.073	Cr^{3+}	0.062
		Mn	0.132	Mn^{2+}	0.067	Mn^{3+}	0.062
		Fe	0.126	Fe^{2+}	0.061	Fe^{3+}	0.055
		Co	0.125	Co^{2+}	0.078	Co^{2+}	0.053
		Ni	0.124	Ni^{2+}	0.070	Ni^{3+}	0.056
		Cu	0.128	Cu^{2+}	0.073		
		Zn	0.135	Zn^{2+}	0.075		

6 Typical proton (^1H) chemical shift values (δ) relative to TMS = 0

type of proton	environment of proton	example structures	chemical range (δ)
C–H	alkane	$–CH_3$, $–CH_2–$, >CH–	0.9–1.7
	alkyl next to C=O	$CH_3–C=O$, $–CH_2–C=O$, >CH–C=O	2.2–3.0
	alkyl next to aromatic ring	$CH_3–Ar$, $–CH_2–Ar$, >CH–Ar	2.3–3.0
	alkyl next to electronegative atom	$CH_3–O$, $–CH_2–O$, $–CH_2–Cl$, >CH–Br	3.2–4.0
	attached to alkyne	≡C–H	1.8–3.1
	attached to alkene	$=CH_2$, =CH–	4.5–6.0
	attached to aromatic ring		6.0–9.0
	aldehyde		9.3–10.5
O-H (see note below)	alcohol	RO–H	0.5–6.0
	phenol		4.5–7.0
	carboxylic acid		9.0–13.0
N-H (see note below)	alkyl amine	R–NH–	1.0–5.0
	aryl amine		3.0–6.0
	amide		5.0–12.0

Note: δ values for –O-H and –N-H protons can vary depending on solvent and concentration

7 Typical carbon (^{13}C) chemical shift values (δ) relative to TMS = 0

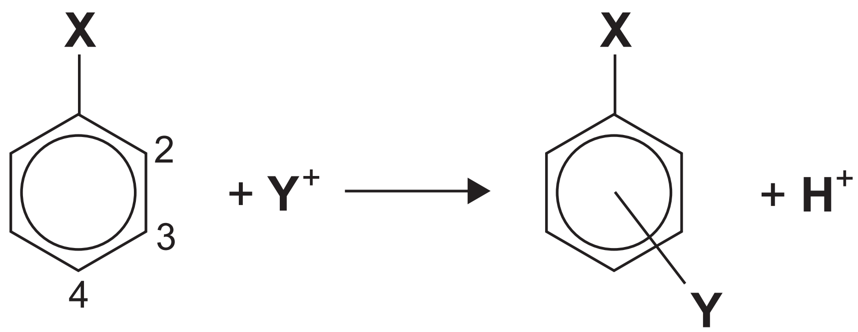
hybridisation of the carbon atom	environment of carbon atom	example structures	chemical shift range (δ)
sp^3	alkyl	**C**H_3–, –**C**H_2–, –**C**H<, >**C**<	0–50
sp^3	next to alkene/arene		10–40
sp^3	next to carbonyl/carboxyl	–**C**–COR, –**C**–CO_2R,	25–50
sp^3	next to nitrogen	–**C**–NH_2, –**C**–NR_2, –**C**–NHCO	30–65
sp^3	next to chlorine (-CH_2-Br and -CH_2-I are in the same range as alkyl)	–**C**–Cl	30–60
sp^3	next to oxygen	–**C**–OH, –**C**–O–CO–	50–70
sp^2	alkene or arene	>**C**=**C**<, 	110–160
sp^2	carboxyl	R–**C**O_2H, R–**C**O_2R	160–185
sp^2	carbonyl	R–**C**HO, R–**C**O–R	190–220
sp	alkyne	R–**C**≡**C**–	65–85
sp	nitrile	R–**C**≡N	100–125

8 Characteristic infra-red absorption frequencies for some selected bonds

bond	**functional groups containing the bond**	**absorption range (in wavenumbers) /cm^{-1}**	**appearance of peak (*s* = strong, *w* = weak)**
C–O	alcohols, ethers, esters	1040–1300	***s***
C=C	aromatic compounds, alkenes	1500–1680	***w*** unless conjugated
C=O	amides, ketones and aldehydes, carboxylic acids, esters	1640–1690 1670–1740 1680–1730 1710–1750	***s*** ***s*** ***s*** ***s***
C≡C	alkynes	2150–2250	***w*** unless conjugated
C≡N	nitriles	2200–2250	***w***
C–H	alkanes, CH_2–H alkenes/arenes, =C–H	2850–2950 3000–3100	***s*** ***w***
N–H	amines, amides	3300–3500	***w***
O–H	carboxylic acids, RCO_2–H H–bonded alcohol, RO–H free alcohol, RO–H	2500–3000 3200–3600 3580–3650	***s*** and very broad ***s*** ***s*** and sharp

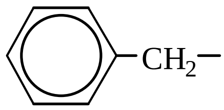
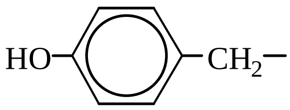
9 The orientating effect of groups in aromatic substitution reactions.

The position of the incoming group, **Y**, is determined by the nature of the group, **X**, already to the ring, and not by the nature of the incoming group **Y**.



X- groups that direct the incoming **Y** group to the 2- or 4- positions	**X**- groups that direct the incoming **Y** group to the 3- position
$–NH_2$, –NHR or $–NR_2$	$–NO_2$
–OH or –OR	$–NH_3^+$
–NHCOR	–CN
$–CH_3$, –alkyl	–CHO, –COR
–C*l*	$–CO_2H$, $–CO_2R$

10 Names, structures and abbreviations of some amino acids

name	3-letter abbreviation	1-letter symbol	structure of side chain R- in $R-CH(NH_2)CO_2H$
alanine	Ala	A	CH_3-
aspartic acid	Asp	D	HO_2CCH_2-
cysteine	Cys	C	$HSCH_2-$
glutamic acid	Glu	E	$HO_2CCH_2CH_2-$
glycine	Gly	G	H–
lysine	Lys	K	$H_2NCH_2CH_2CH_2CH_2-$
phenylalanine	Phe	F	
serine	Ser	S	$HOCH_2-$
tyrosine	Tyr	Y	
valine	Val	V	$(CH_3)_2CH-$

The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group																	
1	2											13	14	15	16	1	
							1 H hydrogen 1.0										he 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											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 –		114 Fl flerovium –		116 Lv livermorium –		

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 –

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