Data Booklet for Chemistry (Advanced Level) 2019 for H1-3

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 = 22.7 dm^3 mol^{-1} at s.t.p. V_m = 24 dm^3 mol^{-1} at r.t.p. (where s.t.p. is expressed as 10^5 Pa [1 bar] and 273 K [0 °C], r.t.p. is expressed as 101325 Pa [1 atm] and 293 K [20 °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
Al	13	577	1820	2740	11600
Si	14	786	1580	3230	4360
P	15	1060	1900	2920	4960
S	16	1000	2260	3390	4540
Cl	17	1260	2300	3850	5150
Ar	18	1520	2660	3950	5770
K	19	418	3070	4600	5860
Ca	20	590	1150	4940	6480

	Proton Number	First	Second	Third	Fourth
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
Ge	32	762	1540	3300	4390
Br	35	1140	2080	3460	4850
Rb	37	403	2632	3900	5080
Sr	38	548	1060	4120	5440
Ag	47	731	2074	3361	–
Sn	50	707	1410	2940	3930
I	53	1010	1840	3200	4030
Cs	55	376	2420	3300	–
Ba	56	502	966	3390	–
Pb	82	716	1450	3080	4080

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

Bond	Energy/kJ mol^{-1}	Bond	Energy/kJ mol^{-1}
H-H	436	H-F	562
D-D	442	H-Cl	431
N≡N	944	H-Br	366
O=O	496	H-I	299
F-F	158	C≡O	1077
Cl-Cl	244		
Br-Br	193		

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

Bond	Energy/kJ mol^{-1}	Bond	Energy/kJ mol^{-1}	Bond	Energy/kJ mol^{-1}	Bond	Energy/kJ mol^{-1}
C-C	350	S-S	264	C-O	360	Si-O in SiO_2(g)	640
C=C	610	C-H	410	C=O	740	P-H	320
C≡C	840	C-F	485	C=O in CO_2	805	P-Cl	330
C⩦C (benzene)	520	C-Cl	340	N-H	390	P-O	340
N-N	160	C-Br	280	N-Cl	310	P=O	540
N=N	410	C-I	240	O-H	460	S-H	347
O-O	150	C-N	305	Si-Cl	359	S-Cl	250
Si-Si	222	C=N	610	Si-H	320	S-O	360
P-P	200	C≡N	890	Si-O in SiO_2(s)	460	S=O	500

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

4(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
$ClO^{-} + H_2O + 2e^{-} \rightleftharpoons Cl^{-} + 2OH^{-}$	+0.81
$Co^{2+} + 2e^{-} \rightleftharpoons Co$	–0.28
$Co^{3+} + e^{-} \rightleftharpoons Co^{2+}$	+1.89
$[Co(NH_3)_6]^{2+} + 2e^{-} \rightleftharpoons Co + 6NH_3$	–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

Electrode reaction	$E^{\ominus}$ / V
$Fe^{3+} + e^{-} \rightleftharpoons Fe^{2+}$	+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
$I_2 + 2e^{-} \rightleftharpoons 2I^{-}$	+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
$Mn^{3+} + e^{-} \rightleftharpoons Mn^{2+}$	+1.54
$MnO_2 + 4H^{+} + 2e^{-} \rightleftharpoons Mn^{2+} + 2H_2O$	+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
$Na^{+} + e^{-} \rightleftharpoons Na$	–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

Electrode reaction			$E^\ominus$ / V
$O_2 + H_2O + 2e^-$	⇌	$HO_2^- + OH^-$	–0.08
$2H_2O + 2e^-$	⇌	$H_2 + 2OH^-$	–0.83
$Pb^{2+} + 2e^-$	⇌	Pb	–0.13
$Pb^{4+} + 2e^-$	⇌	Pb^{2+}	+1.69
$PbO_2 + 4H^+ + 2e^-$	⇌	$Pb^{2+} + 2H_2O$	+1.47
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2 + 2H_2O$	+0.17
$S_2O_8^{2-} + 2e^-$	⇌	$2SO_4^{2-}$	+2.01
$S_4O_6^{2-} + 2e^-$	⇌	$2S_2O_3^{2-}$	+0.09
$Sn^{2+} + 2e^-$	⇌	Sn	–0.14
$Sn^{4+} + 2e^-$	⇌	Sn^{2+}	+0.15
$V^{2+} + 2e^-$	⇌	V	–1.20
$V^{3+} + e^-$	⇌	V^{2+}	–0.26
$VO^{2+} + 2H^+ + e^-$	⇌	$V^{3+} + H_2O$	+0.34
$VO_2^+ + 2H^+ + e^-$	⇌	$VO^{2+} + H_2O$	+1.00
$VO_3^- + 4H^+ + e^-$	⇌	$VO^{2+} + 2H_2O$	+1.00
$Zn^{2+} + 2e^-$	⇌	Zn	–0.76

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

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

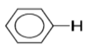
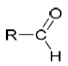
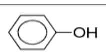
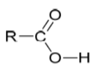
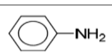
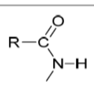
Electrode reaction			$E^\ominus$ / V
$F_2 + 2e^-$	⇌	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇌	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇌	$2H_2O$	+1.77
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	+1.52
$PbO_2 + 4H^+ + 2e^-$	⇌	$Pb^{2+} + 2H_2O$	+1.47
$Cl_2 + 2e^-$	⇌	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇌	$2Cr^{3+} + 7H_2O$	+1.33
$O_2 + 4H^+ + 4e^-$	⇌	$2H_2O$	+1.23
$Br_2 + 2e^-$	⇌	$2Br^-$	+1.07
$NO_3^- + 10H^+ + 8e^-$	⇌	$NH_4^+ + 3H_2O$	+0.87
$ClO^- + H_2O + 2e^-$	⇌	$Cl^- + 2OH^-$	+0.81
$NO_3^- + 2H^+ + e^-$	⇌	$NO_2 + H_2O$	+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
$Fe^{2+} + 2e^-$	⇌	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						
single covalent	H	0.037			H^-	0.208
van der Waals	He	0.140				
(b) Period 2						
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						
metallic	Na	0.186	Na^+	0.095		
	Mg	0.160	Mg^{2+}	0.065		
	Al	0.143	Al^{3+}	0.050		
single covalent	Si	0.117	Si^{4+}	0.041		
	P	0.110			P^{3-}	0.212
	S	0.104			S^{2-}	0.184
	Cl	0.099			Cl^-	0.181
van der Waals	Ar	0.190				
(d) Group 2						
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		

		atomic/nm	ionic/nm			
(e) Group 14						
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						
single covalent	F	0.072			F^-	0.136
	Cl	0.099			Cl^-	0.181
	Br	0.114			Br^-	0.195
	I	0.133			I^-	0.216
	At	0.140				
(g) First row d block elements						
metallic	Sc	0.164			Sc^{3+}	0.075
	Ti	0.146	Ti^{2+}	0.086	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+}	0.083	Mn^{3+}	0.058
	Fe	0.126	Fe^{2+}	0.061	Fe^{3+}	0.055
	Co	0.125	Co^{2+}	0.065	Co^{3+}	0.055
	Ni	0.124	Ni^{2+}	0.069	Ni^{3+}	0.056
	Cu	0.128	Cu^{2+}	0.073		
	Zn	0.135	Zn^{2+}	0.074		

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

Type of proton	Environment of proton	Example structures	Chemical Shift 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

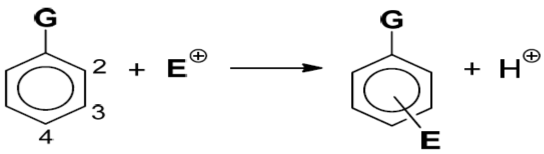
Note: δ values for –O–H and –N–H protons can vary depending on solvent and concentration.

7 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–C*l*	chloroalkanes	700–800	***s***
C–O	alcohol ether ester carboxylic acids	970–1260 1000–1310 1050–1330 1210–1440	***s*** ***s*** ***s*** ***s***
C=C	aromatic alkenes	1475–1625 1635–1690	***s*** ***w***
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 acid, RCO_2–H H-bonded alcohol/phenol, RO–H free alcohol, RO–H	2500–3000 3200–3600 3580–3650	***s*** and very broad ***s*** ***s*** and sharp

8 The orientating effect of groups in aromatic substitution reactions

The position of the incoming group, **E**, is determined by the nature of the group, **G**, already bonded to the ring, and not by the nature of the incoming group **E**.



G	–alkyl –OH or –OR $–NH_2$, –NHR or $–NR_2$ –NHCOR	–C*l*, –Br, –I	–CHO, –COR $–CO_2H$, $–CO_2R$ $–NH_3^+$ $–NO_2$, –CN
Reactivity of ring (compared to benzene)	Activated	Deactivated	Deactivated
Position of E (relative to position of G)	2- and/or 4-	2- and/or 4-	3-

9 Qualitative Analysis Notes *[ppt. = precipitate]*

9(a) Reactions of aqueous cations

cation	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+ (aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

9(b) Reactions of anions

anion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

9(c) Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

9(d) Colour of halogens

halogen	*colour of element*	*colour in aqueous solution*	*colour in hexane*
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple

10 The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0			**Key** atomic number atomic symbol name relative atomic mass								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 144.2	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 –