

## Elements, their Atomic Number and Molar Mass

Element	Symbol	Atomic Number	Molar mass/ (g mol <sup>-1</sup> )
Actinium	Ac	89	227.03
Aluminium	Al	13	26.98
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	210
Barium	Ba	56	137.34
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	208.98
Bohrium	Bh	107	(264)
Boron	B	5	10.81
Bromine	Br	35	79.91
Cadmium	Cd	48	112.40
Caesium	Cs	55	132.91
Calcium	Ca	20	40.08
Californium	Cf	98	251.08
Carbon	C	6	12.01
Cerium	Ce	58	140.12
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copper	Cu	29	63.54
Curium	Cm	96	247.07
Dubnium	Db	105	(263)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(252)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(257.10)
Fluorine	F	9	19.00
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.61
Gold	Au	79	196.97
Hafnium	Hf	72	178.49
Hassium	Hs	108	(269)
Helium	He	2	4.00
Holmium	Ho	67	164.93
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.90
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(262.1)
Lead	Pb	82	207.19
Lithium	Li	3	6.94
Lutetium	Lu	71	174.96
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94
Meitneium	Mt	109	(268)
Mendelevium	Md	101	258.10

Element	Symbol	Atomic Number	Molar mass/ (g mol <sup>-1</sup> )
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.18
Neptunium	Np	93	(237.05)
Nickel	Ni	28	58.71
Niobium	Nb	41	92.91
Nitrogen	N	7	14.0067
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.00
Palladium	Pd	46	106.4
Phosphorus	P	15	30.97
Platinum	Pt	78	195.09
Plutonium	Pu	94	(244)
Polonium	Po	84	210
Potassium	K	19	39.10
Praseodymium	Pr	59	140.91
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.04
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.35
Scandium	Sc	21	44.96
Seaborgium	Sg	106	(266)
Selenium	Se	34	78.96
Silicon	Si	14	28.08
Silver	Ag	47	107.87
Sodium	Na	11	22.99
Strontium	Sr	38	87.62
Sulphur	S	16	32.06
Tantalum	Ta	73	180.95
Technetium	Tc	43	(98.91)
Tellurium	Te	52	127.60
Terbium	Tb	65	158.92
Thallium	Tl	81	204.37
Thorium	Th	90	232.04
Thulium	Tm	69	168.93
Tin	Sn	50	118.69
Titanium	Ti	22	47.88
Tungsten	W	74	183.85
Ununbium	Uub	112	(277)
Ununnilium	Uun	110	(269)
Ununonium	Uuu	111	(272)
Uranium	U	92	238.03
Vanadium	V	23	50.94
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.91
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

The value given in parenthesis is the molar mass of the isotope of largest known half-life.

## Some Useful Conversion Factors

### Common Unit of Mass and Weight

**1 pound = 453.59 grams**

1 pound = 453.59 grams = 0.45359 kilogram

1 kilogram = 1000 grams = 2.205 pounds

1 gram = 10 decigrams = 100 centigrams  
= 1000 milligrams

1 gram =  $6.022 \times 10^{23}$  atomic mass units or u

1 atomic mass unit =  $1.6606 \times 10^{-24}$  gram

1 metric tonne = 1000 kilograms  
= 2205 pounds

### Common Unit of Volume

**1 quart = 0.9463 litre**

**1 litre = 1.056 quarts**

1 litre = 1 cubic decimetre = 1000 cubic centimetres = 0.001 cubic metre

1 millilitre = 1 cubic centimetre = 0.001 litre  
=  $1.056 \times 10^{-3}$  quart

1 cubic foot = 28.316 litres = 29.902 quarts  
= 7.475 gallons

### Common Units of Energy

**1 joule =  $1 \times 10^7$  ergs**

1 thermochemical calorie\*\*

= 4.184 joules

=  $4.184 \times 10^7$  ergs

=  $4.129 \times 10^{-2}$  litre-atmospheres

=  $2.612 \times 10^{19}$  electron volts

1 ergs =  $1 \times 10^{-7}$  joule =  $2.3901 \times 10^{-8}$  calorie

1 electron volt =  $1.6022 \times 10^{-19}$  joule  
=  $1.6022 \times 10^{-12}$  erg  
= 96.487 kJ/mol†

1 litre-atmosphere = 24.217 calories  
= 101.32 joules  
=  $1.0132 \times 10^9$  ergs

1 British thermal unit = 1055.06 joules  
=  $1.05506 \times 10^{10}$  ergs  
= 252.2 calories

### Common Units of Length

**1 inch = 2.54 centimetres (exactly)**

1 mile = 5280 feet = 1.609 kilometres

1 yard = 36 inches = 0.9144 metre

1 metre = 100 centimetres = 39.37 inches  
= 3.281 feet

= 1.094 yards

1 kilometre = 1000 metres = 1094 yards

= 0.6215 mile

1 Angstrom =  $1.0 \times 10^{-8}$  centimetre

= 0.10 nanometre

=  $1.0 \times 10^{-10}$  metre

=  $3.937 \times 10^{-9}$  inch

### Common Units of Force\* and Pressure

1 atmosphere = 760 millimetres of mercury

=  $1.013 \times 10^5$  pascals

= 14.70 pounds per square inch

1 bar =  $10^5$  pascals

1 torr = 1 millimetre of mercury

1 pascal =  $1 \text{ kg/ms}^2 = 1 \text{ N/m}^2$

### Temperature

**SI Base Unit: Kelvin (K)**

K =  $-273.15^\circ\text{C}$

K =  $^\circ\text{C} + 273.15$

$^\circ\text{F} = 1.8(^\circ\text{C}) + 32$

$^\circ\text{C} = \frac{^\circ\text{F} - 32}{1.8}$

\* Force: 1 newton (N) =  $1 \text{ kg m/s}^2$ , i.e., the force that, when applied for 1 second, gives a 1-kilogram mass a velocity of 1 metre per second.

\*\* The amount of heat required to raise the temperature of one gram of water from  $14.5^\circ\text{C}$  to  $15.5^\circ\text{C}$ .

† Note that the other units are per particle and must be multiplied by  $6.022 \times 10^{23}$  to be strictly comparable.

## Standard potentials at 298 K in electrochemical order

Reduction half-reaction	$E^\circ / V$	Reduction half-reaction	$E^\circ / V$
$H_4XeO_6 + 2H^+ + 2e^- \longrightarrow XeO_3 + 3H_2O$	+3.0	$Cu^+ + e^- \longrightarrow Cu$	+0.52
$F_2 + 2e^- \longrightarrow 2F^-$	+2.87	$NiOOH + H_2O + e^- \longrightarrow Ni(OH)_2 + OH^-$	+0.49
$O_3 + 2H^+ + 2e^- \longrightarrow O_2 + H_2O$	+2.07	$Ag_2CrO_4 + 2e^- \longrightarrow 2Ag + CrO_4^{2-}$	+0.45
$S_2O_8^{2-} + 2e^- \longrightarrow 2SO_4^{2-}$	+2.05	$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$	+0.40
$Ag^+ + e^- \longrightarrow Ag^+$	+1.98	$ClO_4^- + H_2O + 2e^- \longrightarrow ClO_3^- + 2OH^-$	+0.36
$Co^{3+} + e^- \longrightarrow Co^{2+}$	+1.81	$[Fe(CN)_6]^{3-} + e^- \longrightarrow [Fe(CN)_6]^{4-}$	+0.36
$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$	+1.78	$Cu^{2+} + 2e^- \longrightarrow Cu$	+0.34
$Au^+ + e^- \longrightarrow Au$	+1.69	$Hg_2Cl_2 + 2e^- \longrightarrow 2Hg + 2Cl^-$	+0.27
$Pb^{4+} + 2e^- \longrightarrow Pb^{2+}$	+1.67	$AgCl + e^- \longrightarrow Ag + Cl^-$	+0.27
$2HClO + 2H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$	+1.63	$Bi^{3+} + 3e^- \longrightarrow Bi$	+0.20
$Ce^{4+} + e^- \longrightarrow Ce^{3+}$	+1.61	$SO_4^{2-} + 4H^+ + 2e^- \longrightarrow H_2SO_3 + H_2O$	+0.17
$2HBrO + 2H^+ + 2e^- \longrightarrow Br_2 + 2H_2O$	+1.60	$Cu^{2+} + e^- \longrightarrow Cu^+$	+0.16
$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$	+1.51	$Sn^{4+} + 2e^- \longrightarrow Sn^{2+}$	+0.15
$Mn^{3+} + e^- \longrightarrow Mn^{2+}$	+1.51	$AgBr + e^- \longrightarrow Ag + Br^-$	+0.07
$Au^{3+} + 3e^- \longrightarrow Au$	+1.40	$Ti^{4+} + e^- \longrightarrow Ti^{3+}$	0.00
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36	$2H^+ + 2e^- \longrightarrow H_2$	0.0 by definition
$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$	+1.33	$Fe^{3+} + 3e^- \longrightarrow Fe$	-0.04
$O_3 + H_2O + 2e^- \longrightarrow O_2 + 2OH^-$	+1.24	$O_2 + H_2O + 2e^- \longrightarrow HO_2^- + OH^-$	-0.08
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23	$Pb^{2+} + 2e^- \longrightarrow Pb$	-0.13
$ClO_4^- + 2H^+ + 2e^- \longrightarrow ClO_3^- + 2H_2O$	+1.23	$In^+ + e^- \longrightarrow In$	-0.14
$MnO_2 + 4H^+ + 2e^- \longrightarrow Mn^{2+} + 2H_2O$	+1.23	$Sn^{2+} + 2e^- \longrightarrow Sn$	-0.14
$Pt^{2+} + 2e^- \longrightarrow Pt$	+1.20	$AgI + e^- \longrightarrow Ag + I^-$	-0.15
$Br_2 + 2e^- \longrightarrow 2Br^-$	+1.09	$Ni^{2+} + 2e^- \longrightarrow Ni$	-0.23
$Pu^{4+} + e^- \longrightarrow Pu^{3+}$	+0.97	$V^{3+} + e^- \longrightarrow V^{2+}$	-0.26
$NO_3^- + 4H^+ + 3e^- \longrightarrow NO + 2H_2O$	+0.96	$Co^{2+} + 2e^- \longrightarrow Co$	-0.28
$2Hg^{2+} + 2e^- \longrightarrow Hg_2^{2+}$	+0.92	$In^{3+} + 3e^- \longrightarrow In$	-0.34
$ClO^- + H_2O + 2e^- \longrightarrow Cl^- + 2OH^-$	+0.89	$Tl^+ + e^- \longrightarrow Tl$	-0.34
$Hg^{2+} + 2e^- \longrightarrow Hg$	+0.86	$PbSO_4 + 2e^- \longrightarrow Pb + SO_4^{2-}$	-0.36
$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$	+0.80	$Ti^{3+} + e^- \longrightarrow Ti^{2+}$	-0.37
$Ag^+ + e^- \longrightarrow Ag$	+0.80	$Cd^{2+} + 2e^- \longrightarrow Cd$	-0.40
$Hg_2^{2+} + 2e^- \longrightarrow 2Hg$	+0.79	$In^{2+} + e^- \longrightarrow In^+$	-0.40
$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77	$Cr^{3+} + e^- \longrightarrow Cr^{2+}$	-0.41
$BrO^- + H_2O + 2e^- \longrightarrow Br^- + 2OH^-$	+0.76	$Fe^{2+} + 2e^- \longrightarrow Fe$	-0.44
$Hg_2SO_4 + 2e^- \longrightarrow 2Hg + SO_4^{2-}$	+0.62	$In^{3+} + 2e^- \longrightarrow In^+$	-0.44
$MnO_4^{2-} + 2H_2O + 2e^- \longrightarrow MnO_2 + 4OH^-$	+0.60	$S + 2e^- \longrightarrow S^{2-}$	-0.48
$MnO_4^- + e^- \longrightarrow MnO_4^{2-}$	+0.56	$In^{3+} + e^- \longrightarrow In^{2+}$	-0.49
$I_2 + 2e^- \longrightarrow 2I^-$	+0.54	$U^{4+} + e^- \longrightarrow U^{3+}$	-0.61
$I_3^- + 2e^- \longrightarrow 3I^-$	+0.53	$Cr^{3+} + 3e^- \longrightarrow Cr$	-0.74
		$Zn^{2+} + 2e^- \longrightarrow Zn$	-0.76

(continued)

**APPENDIX III CONTINUED**

Reduction half-reaction	$E^\circ/V$	Reduction half-reaction	$E^\circ/V$
$\text{Cd}(\text{OH})_2 + 2e^- \longrightarrow \text{Cd} + 2\text{OH}^-$	-0.81	$\text{La}^{3+} + 3e^- \longrightarrow \text{La}$	-2.52
$2\text{H}_2\text{O} + 2e^- \longrightarrow \text{H}_2 + 2\text{OH}^-$	-0.83	$\text{Na}^+ + e^- \longrightarrow \text{Na}$	-2.71
$\text{Cr}^{2+} + 2e^- \longrightarrow \text{Cr}$	-0.91	$\text{Ca}^{2+} + 2e^- \longrightarrow \text{Ca}$	-2.87
$\text{Mn}^{2+} + 2e^- \longrightarrow \text{Mn}$	-1.18	$\text{Sr}^{2+} + 2e^- \longrightarrow \text{Sr}$	-2.89
$\text{V}^{2+} + 2e^- \longrightarrow \text{V}$	-1.19	$\text{Ba}^{2+} + 2e^- \longrightarrow \text{Ba}$	-2.91
$\text{Ti}^{2+} + 2e^- \longrightarrow \text{Ti}$	-1.63	$\text{Ra}^{2+} + 2e^- \longrightarrow \text{Ra}$	-2.92
$\text{Al}^{3+} + 3e^- \longrightarrow \text{Al}$	-1.66	$\text{Cs}^+ + e^- \longrightarrow \text{Cs}$	-2.92
$\text{U}^{3+} + 3e^- \longrightarrow \text{U}$	-1.79	$\text{Rb}^+ + e^- \longrightarrow \text{Rb}$	-2.93
$\text{Sc}^{3+} + 3e^- \longrightarrow \text{Sc}$	-2.09	$\text{K}^+ + e^- \longrightarrow \text{K}$	-2.93
$\text{Mg}^{2+} + 2e^- \longrightarrow \text{Mg}$	-2.36	$\text{Li}^+ + e^- \longrightarrow \text{Li}$	-3.05
$\text{Ce}^{3+} + 3e^- \longrightarrow \text{Ce}$	-2.48		

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## Logarithms

Sometimes, a numerical expression may involve multiplication, division or rational powers of large numbers. For such calculations, logarithms are very useful. They help us in making difficult calculations easy. In Chemistry, logarithm values are required in solving problems of chemical kinetics, thermodynamics, electrochemistry, etc. We shall first introduce this concept, and discuss the laws, which will have to be followed in working with logarithms, and then apply this technique to a number of problems to show how it makes difficult calculations simple.

We know that

$$2^3 = 8, 3^2 = 9, 5^3 = 125, 7^0 = 1$$

In general, for a positive real number  $a$ , and a rational number  $m$ , let  $a^m = b$ , where  $b$  is a real number. In other words

the  $m^{\text{th}}$  power of base  $a$  is  $b$ .

Another way of stating the same fact is logarithm of  $b$  to base  $a$  is  $m$ .

If for a positive real number  $a$ ,  $a \neq 1$

$$a^m = b,$$

we say that  $m$  is the logarithm of  $b$  to the base  $a$ .

We write this as  $\log_a^b = m$ ,

“log” being the abbreviation of the word “logarithm”.

Thus, we have

$$\log_2 8 = 3, \quad \text{Since } 2^3 = 8$$

$$\log_3 9 = 2, \quad \text{Since } 3^2 = 9$$

$$\log_5 125 = 3, \quad \text{Since } 5^3 = 125$$

$$\log_7 1 = 0, \quad \text{Since } 7^0 = 1$$

### Laws of Logarithms

In the following discussion, we shall take logarithms to any base  $a$ , ( $a > 0$  and  $a \neq 1$ )

**First Law:**  $\log_a(mn) = \log_a m + \log_a n$

**Proof:** Suppose that  $\log_a m = x$  and  $\log_a n = y$

Then  $a^x = m$ ,  $a^y = n$

$$\text{Hence } mn = a^x \cdot a^y = a^{x+y}$$

It now follows from the definition of logarithms that

$$\log_a(mn) = x + y = \log_a m + \log_a n$$

**Second Law:**  $\log_a \left( \frac{m}{n} \right) = \log_a m - \log_a n$

**Proof:** Let  $\log_a m = x$ ,  $\log_a n = y$