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Table of contents

Periodic table of the elements	3
Formulae	4
Units	4
Constants	4
Solubility rules for ionic solids in water	4
Colours of selected substances	5
α -amino acids	6–7
Standard reduction potentials at 25 °C	8

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Periodic table of the elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
¹ H hydrogen 1.008																	² He helium 4.003
³ Li lithium 6.94	⁴ Be beryllium 9.012																¹⁰ Ne neon 20.18
¹¹ Na sodium 22.99	¹² Mg magnesium 24.31																¹⁸ Ar argon 39.95
¹⁹ K potassium 39.10	²⁰ Ca calcium 40.08	²¹ Sc scandium 44.96	²² Ti titanium 47.87	²³ V vanadium 50.94	²⁴ Cr chromium 52.00	²⁵ Mn manganese 54.94	²⁶ Fe iron 55.85	²⁷ Co cobalt 58.93	²⁸ Ni nickel 58.69	²⁹ Cu copper 63.55	³⁰ Zn zinc 65.38	³¹ Ga gallium 69.72	³² Ge germanium 72.63	³³ As arsenic 74.92	³⁴ Se selenium 78.97	³⁵ Br bromine 79.90	³⁶ Kr krypton 83.80
³⁷ Rb rubidium 85.47	³⁸ Sr strontium 87.62	³⁹ Y yttrium 88.91	⁴⁰ Zr zirconium 91.22	⁴¹ Nb niobium 92.91	⁴² Mo molybdenum 95.95	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	¹¹³ Nh nihonium	¹¹⁴ Fl flerovium	¹¹⁵ Mc moscovium	¹¹⁶ Lv livermorium	¹¹⁷ Ts tennessine	¹¹⁸ Og oganeson

Key:

Atomic number
Symbol
Name
Standard atomic weight

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 173.0	⁷¹ Lu lutetium 175.0
⁸⁹ Ac actinium 232.0	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

[Data source: The International Union of Pure and Applied Chemistry Periodic Table of the Elements (2018)]

Formulae

Number of moles	n	$= \frac{m}{M} = \frac{\text{mass}}{\text{molar mass}}$
Number of moles of solute	n	$= cV$
Number of moles of a gas at STP	n	$= \frac{V}{22.71}$
Ideal gas law	PV	$= nRT$
Parts per million	ppm	$= \frac{\text{mass of solute (mg)}}{\text{mass of solution (kg)}}$
pH of a solution	pH	$= -\log_{10} [\text{H}^+]$

Units

Volumes are given in the units of litres (L), or millilitres (mL)

Temperatures are given in the units of degrees Celsius ($^{\circ}\text{C}$) or kelvin (K)

It may be assumed that $0.0^{\circ}\text{C} = 273.15\text{ K}$

Energy changes are given in kilojoules (kJ)

Pressures are given in kilopascals (kPa)

Solution concentrations are given in the units moles per litre (mol L^{-1}), grams per litre (g L^{-1}) or parts per million (ppm)

Constants

Universal gas constant, $R = 8.314\text{ J K}^{-1}\text{ mol}^{-1}$

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

Volume of 1.00 mol of an ideal gas at 0.0°C and 100.0 kPa is 22.71 L

STP is 0.0°C and 100.0 kPa

Equilibrium constant for water at 25°C , $K_w = 1.00 \times 10^{-14}$

Solubility rules for ionic solids in water

Soluble in water

Soluble	Exceptions	
	Insoluble	Slightly soluble
Most chlorides	AgCl	PbCl_2
Most bromides	AgBr	PbBr_2
Most iodides	AgI , PbI_2	
All nitrates	No exceptions	
All ethanoates		
Most sulfates	SrSO_4 , BaSO_4 , PbSO_4	CaSO_4 , Ag_2SO_4

Insoluble in water

Insoluble	Exceptions	
	Soluble	Slightly soluble
Most hydroxides	NaOH , KOH , $\text{Ba}(\text{OH})_2$ NH_4OH^* , AgOH^{**}	$\text{Ca}(\text{OH})_2$, $\text{Sr}(\text{OH})_2$
Most carbonates	Na_2CO_3 , K_2CO_3 , $(\text{NH}_4)_2\text{CO}_3$	
Most phosphates	Na_3PO_4 , K_3PO_4 , $(\text{NH}_4)_3\text{PO}_4$	
Most sulfides	Na_2S , K_2S , $(\text{NH}_4)_2\text{S}$	

* NH_3 dissolves in water to form both $\text{NH}_3(\text{aq})$ and $\text{NH}_4^+(\text{aq})/\text{OH}^-(\text{aq})$

** $\text{Ag}^+(\text{aq})$ reacts with $\text{OH}^-(\text{aq})$ to form insoluble Ag_2O

Soluble = more than 0.1 mole dissolves per litre

Slightly soluble = between 0.01 and 0.1 mole dissolves per litre

Insoluble = less than 0.01 mole dissolves per litre

Colours of selected substances

In general, ionic solids have the same colour as that of any coloured ion they contain. Two colourless ions in general produce a white solid. Selected exceptions to these two basic rules are noted below.

Ionic Solid	Colour
copper(II) carbonate	green
copper(II) chloride	green
copper(II) oxide	black
copper(II) sulfide	black
lead(II) iodide	yellow
lead(II) sulfide	grey
manganese(IV) oxide	black
silver carbonate	yellow
silver iodide	pale yellow
silver oxide	brown
silver sulfide	black

Other coloured substances

Most gases and liquids are colourless, and most metals are silvery or grey. Selected exceptions to these basic rules are noted below.

Substance	Colour
copper(s)	salmon pink
gold(s)	yellow
nitrogen dioxide(g)	brown
sulfur(s)	yellow

Coloured halogens

Halogen	Colour of free element
F ₂ (g)	yellow
Cl ₂ (g)	greenish-yellow
Br ₂ (l)	red
I ₂ (g)	purple

Halogen	Colour of halogen in aqueous solution
Cl ₂ (aq)	pale yellow
Br ₂ (aq)	orange
I ₂ (aq)	brown

Halogen	Colour of halogen in organic solvent
Br ₂	red
I ₂	purple

Coloured ions in aqueous solution

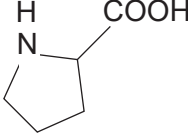
Cation	Colour
Cr ³⁺	deep green
Co ²⁺	pink
Cu ²⁺	blue
Fe ²⁺	pale green
Fe ³⁺	pale brown
Mn ²⁺	pale pink
Ni ²⁺	green

Anion	Colour
CrO ₄ ²⁻	yellow
Cr ₂ O ₇ ²⁻	orange
MnO ₄ ⁻	purple

α -amino acids

Name	Symbol	Structure
alanine	Ala	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
arginine	Arg	$\begin{array}{c} \text{NH} \\ \\ \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH} - \text{C} - \text{NH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
asparagine	Asn	$\begin{array}{c} \text{O} \\ \\ \text{CH}_2 - \text{C} - \text{NH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
aspartic acid	Asp	$\begin{array}{c} \text{CH}_2 - \text{COOH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
cysteine	Cys	$\begin{array}{c} \text{CH}_2 - \text{SH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
glutamine	Gln	$\begin{array}{c} \text{O} \\ \\ \text{CH}_2 - \text{CH}_2 - \text{C} - \text{NH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
glutamic acid	Glu	$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{COOH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
glycine	Gly	$\text{H}_2\text{N} - \text{CH}_2 - \text{COOH}$
histidine	His	$\begin{array}{c} \text{N} \\ // \quad \backslash \\ \text{CH}_2 - \text{C} \quad \text{N} - \text{H} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
isoleucine	Ile	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_2 - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$

α -amino acids

Name	Symbol	Structure
leucine	Leu	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{CH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
lysine	Lys	$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
methionine	Met	$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{S} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
phenylalanine	Phe	$\begin{array}{c} \text{CH}_2 - \text{C}_6\text{H}_5 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
proline	Pro	
serine	Ser	$\begin{array}{c} \text{CH}_2 - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
threonine	Thr	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
tryptophan	Trp	$\begin{array}{c} \text{H} \\ \\ \text{CH} \\ \\ \text{CH}_2 - \text{C}_8\text{H}_6\text{N} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
tyrosine	Tyr	$\begin{array}{c} \text{CH}_2 - \text{C}_6\text{H}_4 - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
valine	Val	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$

Standard Reduction Potentials at 25 °C

Half-reaction	E°(volts)
$F_2(g) + 2 e^- \rightleftharpoons 2 F^-(aq)$	+ 2.89
$H_2O_2(aq) + 2 H^+(aq) + 2 e^- \rightleftharpoons 2 H_2O(l)$	+ 1.76
$PbO_2(s) + SO_4^{2-}(aq) + 4 H^+(aq) + 2 e^- \rightleftharpoons PbSO_4(s) + 2 H_2O(l)$	+ 1.69
$2 HClO(aq) + 2 H^+(aq) + 2 e^- \rightleftharpoons Cl_2(g) + 2 H_2O(l)$	+ 1.63
$MnO_4^-(aq) + 8 H^+(aq) + 5 e^- \rightleftharpoons Mn^{2+}(aq) + 4 H_2O(l)$	+ 1.51
$Au^{3+}(aq) + 3 e^- \rightleftharpoons Au(s)$	+ 1.50
$HClO(aq) + H^+(aq) + 2 e^- \rightleftharpoons Cl^-(aq) + H_2O(l)$	+ 1.49
$PbO_2(s) + 4 H^+(aq) + 2 e^- \rightleftharpoons Pb^{2+}(aq) + 2 H_2O(l)$	+ 1.46
$Cl_2(g) + 2 e^- \rightleftharpoons 2 Cl^-(aq)$	+ 1.36
$Cr_2O_7^{2-}(aq) + 14 H^+(aq) + 6 e^- \rightleftharpoons 2 Cr^{3+}(aq) + 7 H_2O(l)$	+ 1.36
$O_2(g) + 4 H^+(aq) + 4 e^- \rightleftharpoons 2 H_2O(l)$	+ 1.23
$Br_2(l) + 2 e^- \rightleftharpoons 2 Br^-(aq)$	+ 1.08
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+ 0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+ 0.77
$O_2(g) + 2 H^+(aq) + 2 e^- \rightleftharpoons H_2O_2(aq)$	+ 0.70
$I_2(s) + 2 e^- \rightleftharpoons 2 I^-(aq)$	+ 0.54
$O_2(g) + 2 H_2O(l) + 4 e^- \rightleftharpoons 4 OH^-(aq)$	+ 0.40
$Cu^{2+}(aq) + 2 e^- \rightleftharpoons Cu(s)$	+ 0.34
$S(s) + 2 H^+(aq) + 2 e^- \rightleftharpoons H_2S(aq)$	+ 0.17
$2 H^+(aq) + 2 e^- \rightleftharpoons H_2(g)$	0 exactly
$Pb^{2+}(aq) + 2 e^- \rightleftharpoons Pb(s)$	- 0.13
$Sn^{2+}(aq) + 2 e^- \rightleftharpoons Sn(s)$	- 0.14
$Ni^{2+}(aq) + 2 e^- \rightleftharpoons Ni(s)$	- 0.24
$Co^{2+}(aq) + 2 e^- \rightleftharpoons Co(s)$	- 0.28
$PbSO_4(s) + 2 e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	- 0.36
$Cd^{2+}(aq) + 2 e^- \rightleftharpoons Cd(s)$	- 0.40
$2 CO_2(g) + 2 H^+(aq) + 2 e^- \rightleftharpoons H_2C_2O_4(aq)$	- 0.43
$Fe^{2+}(aq) + 2 e^- \rightleftharpoons Fe(s)$	- 0.44
$Cr^{3+}(aq) + 3 e^- \rightleftharpoons Cr(s)$	- 0.74
$Zn^{2+}(aq) + 2 e^- \rightleftharpoons Zn(s)$	- 0.76
$2 H_2O(l) + 2 e^- \rightleftharpoons H_2(g) + 2 OH^-(aq)$	- 0.83
$Mn^{2+}(aq) + 2 e^- \rightleftharpoons Mn(s)$	- 1.18
$Al^{3+}(aq) + 3 e^- \rightleftharpoons Al(s)$	- 1.68
$Mg^{2+}(aq) + 2 e^- \rightleftharpoons Mg(s)$	- 2.36
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	- 2.71
$Ca^{2+}(aq) + 2 e^- \rightleftharpoons Ca(s)$	- 2.87
$Sr^{2+}(aq) + 2 e^- \rightleftharpoons Sr(s)$	- 2.90
$Ba^{2+}(aq) + 2 e^- \rightleftharpoons Ba(s)$	- 2.91
$K^+(aq) + e^- \rightleftharpoons K(s)$	- 2.94

[Data source: Aylward, G.H., & Findlay, T. (2014). *SI Chemical Data* (7th ed.). Queensland: John Wiley & Sons Australia, Ltd.]