

# PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 <b>H</b> Hydrogen 1.0																	
3 <b>Li</b> Lithium 6.9	4 <b>Be</b> Beryllium 9.0																
11 <b>Na</b> Sodium 23.0	12 <b>Mg</b> Magnesium 24.3																
19 <b>K</b> Potassium 39.1	20 <b>Ca</b> Calcium 40.1	21 <b>Sc</b> Scandium 45.0	22 <b>Ti</b> Titanium 47.9	23 <b>V</b> Vanadium 50.9	24 <b>Cr</b> Chromium 52.0	25 <b>Mn</b> Manganese 54.9	26 <b>Fe</b> Iron 55.8	27 <b>Co</b> Cobalt 58.9	28 <b>Ni</b> Nickel 58.7	29 <b>Cu</b> Copper 63.5	30 <b>Zn</b> Zinc 65.4	31 <b>Ga</b> Gallium 69.7	32 <b>Ge</b> Germanium 72.6	33 <b>As</b> Arsenic 74.9	34 <b>Se</b> Selenium 79.0	35 <b>Br</b> Bromine 79.9	36 <b>Kr</b> Krypton 83.8
37 <b>Rb</b> Rubidium 85.5	38 <b>Sr</b> Strontium 87.6	39 <b>Y</b> Yttrium 88.9	40 <b>Zr</b> Zirconium 91.2	41 <b>Nb</b> Niobium 92.9	42 <b>Mo</b> Molybdenum 95.9	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.1	45 <b>Rh</b> Rhodium 102.9	46 <b>Pd</b> Palladium 106.4	47 <b>Ag</b> Silver 107.9	48 <b>Cd</b> Cadmium 112.4	49 <b>In</b> Indium 114.8	50 <b>Sn</b> Tin 118.7	51 <b>Sb</b> Antimony 121.8	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.9	54 <b>Xe</b> Xenon 131.3
55 <b>Cs</b> Cesium 132.9	56 <b>Ba</b> Barium 137.3	57 <b>La</b> Lanthanum 138.9	72 <b>Hf</b> Hafnium 178.5	73 <b>Ta</b> Tantalum 180.9	74 <b>W</b> Tungsten 183.8	75 <b>Re</b> Rhenium 186.2	76 <b>Os</b> Osmium 190.2	77 <b>Ir</b> Iridium 192.2	78 <b>Pt</b> Platinum 195.1	79 <b>Au</b> Gold 197.0	80 <b>Hg</b> Mercury 200.6	81 <b>Tl</b> Thallium 204.4	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 209.0	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89 <b>Ac</b> Actinium (227)	104 <b>Rf</b> Rutherfordium (261)	105 <b>Db</b> Dubnium (262)	106 <b>Sg</b> Seaborgium (263)	107 <b>Bh</b> Bohrium (262)	108 <b>Hs</b> Hassium (265)	109 <b>Mt</b> Meitnerium (266)									

14

Si

Silicon

28.1

Atomic Number

Symbol

Name

Atomic Mass

Based on mass of C <sup>12</sup> at 12.00.																	
Values in parentheses																	
are the masses of the most																	
stable or best known isotopes for																	
elements which do not occur naturally.																	

58 <b>Ce</b> Cerium 140.1	59 <b>Pr</b> Praseodymium 140.9	60 <b>Nd</b> Neodymium 144.2	61 <b>Pm</b> Promethium (145)	62 <b>Sm</b> Samarium 150.4	63 <b>Eu</b> Europium 152.0	64 <b>Gd</b> Gadolinium 157.3	65 <b>Tb</b> Terbium 158.9	66 <b>Dy</b> Dysprosium 162.5	67 <b>Ho</b> Holmium 164.9	68 <b>Er</b> Erbium 167.3	69 <b>Tm</b> Thulium 168.9	70 <b>Yb</b> Ytterbium 173.0	71 <b>Lu</b> Lutetium 175.0
90 <b>Th</b> Thorium 232.0	91 <b>Pa</b> Protactinium 231.0	92 <b>U</b> Uranium 238.0	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (244)	95 <b>Am</b> Americium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkelium (247)	98 <b>Cf</b> Californium (251)	99 <b>Es</b> Einsteinium (252)	100 <b>Fm</b> Fermium (257)	101 <b>Md</b> Mendelevium (258)	102 <b>No</b> Nobelium (259)	103 <b>Lr</b> Lawrencium (262)

Based on mass of  $C^{12}$  at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

# ATOMIC MASSES OF THE ELEMENTS

Based on mass of  $C^{12}$  at 12.00.  
Values in parentheses are the mass number of the most stable or best known isotopes for elements that do not occur naturally.

Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)
Aluminum	Al	13	27.0
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.9
Arsenic	As	33	74.9
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.0
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(251)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dubnium	Db	105	(262)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(252)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.0
Holmium	Ho	67	164.9
Hydrogen	H	1	1.0
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(262)
Lead	Pb	82	207.2
Lithium	Li	3	6.9
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(258)

Element	Symbol	Atomic Number	Atomic Mass
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	(237)
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulphur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(98)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2

# NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

\* Aqueous solutions are readily oxidized by air.  
 \*\* Not stable in aqueous solutions.

Positive Ions (Cations)			
$\text{Al}^{3+}$	Aluminum	$\text{Pb}^{4+}$	Lead(IV), plumbic
$\text{NH}_4^+$	Ammonium	$\text{Li}^+$	Lithium
$\text{Ba}^{2+}$	Barium	$\text{Mg}^{2+}$	Magnesium
$\text{Ca}^{2+}$	Calcium	$\text{Mn}^{2+}$	Manganese(II), manganous
$\text{Cr}^{2+}$	Chromium(II), chromous	$\text{Mn}^{4+}$	Manganese(IV)
$\text{Cr}^{3+}$	Chromium(III), chromic	$\text{Hg}_2^{2+}$	Mercury(I)*, mercurous
$\text{Cu}^+$	Copper(I)*, cuprous	$\text{Hg}^{2+}$	Mercury(II), mercuric
$\text{Cu}^{2+}$	Copper(II), cupric	$\text{K}^+$	Potassium
$\text{H}^+$	Hydrogen	$\text{Ag}^+$	Silver
$\text{H}_3\text{O}^+$	Hydronium	$\text{Na}^+$	Sodium
$\text{Fe}^{2+}$	Iron(II)*, ferrous	$\text{Sn}^{2+}$	Tin(II)*, stannous
$\text{Fe}^{3+}$	Iron(III), ferric	$\text{Sn}^{4+}$	Tin(IV), stannic
$\text{Pb}^{2+}$	Lead(II), plumbous	$\text{Zn}^{2+}$	Zinc
Negative Ions (Anions)			
$\text{Br}^-$	Bromide	$\text{OH}^-$	Hydroxide
$\text{CO}_3^{2-}$	Carbonate	$\text{ClO}^-$	Hypochlorite
$\text{ClO}_3^-$	Chlorate	$\text{I}^-$	Iodide
$\text{Cl}^-$	Chloride	$\text{HPO}_4^{2-}$	Monohydrogen phosphate
$\text{ClO}_2^-$	Chlorite	$\text{NO}_3^-$	Nitrate
$\text{CrO}_4^{2-}$	Chromate	$\text{NO}_2^-$	Nitrite
$\text{CN}^-$	Cyanide	$\text{C}_2\text{O}_4^{2-}$	Oxalate
$\text{Cr}_2\text{O}_7^{2-}$	Dichromate	$\text{O}^{2-}$	Oxide**
$\text{H}_2\text{PO}_4^-$	Dihydrogen phosphate	$\text{ClO}_4^-$	Perchlorate
$\text{CH}_3\text{COO}^-$	Ethanoate, acetate	$\text{MnO}_4^-$	Permanganate
$\text{F}^-$	Fluoride	$\text{PO}_4^{3-}$	Phosphate
$\text{HCO}_3^-$	Hydrogen carbonate, bicarbonate	$\text{SO}_4^{2-}$	Sulphate
$\text{HC}_2\text{O}_4^-$	Hydrogen oxalate, binoxalate	$\text{S}^{2-}$	Sulphide
$\text{HSO}_4^-$	Hydrogen sulphate, bisulphate	$\text{SO}_3^{2-}$	Sulphite
$\text{HS}^-$	Hydrogen sulphide, bisulphide	$\text{SCN}^-$	Thiocyanate
$\text{HSO}_3^-$	Hydrogen sulphite, bisulphite		

## SOLUBILITY OF COMMON COMPOUNDS IN WATER

*The term soluble here means  $> 0.1 \text{ mol/L}$  at  $25^\circ\text{C}$ .*

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: $\text{Li}^+$ , $\text{Na}^+$ , $\text{K}^+$ , $\text{Rb}^+$ , $\text{Cs}^+$ , $\text{Fr}^+$	Soluble
All	Hydrogen ion: $\text{H}^+$	Soluble
All	Ammonium ion: $\text{NH}_4^+$	Soluble
Nitrate, $\text{NO}_3^-$	All	Soluble
Chloride, $\text{Cl}^-$ or Bromide, $\text{Br}^-$ or Iodide, $\text{I}^-$	All others	Soluble
	$\text{Ag}^+$ , $\text{Pb}^{2+}$ , $\text{Cu}^+$	Low Solubility
Sulphate, $\text{SO}_4^{2-}$	All others	Soluble
	$\text{Ag}^+$ , $\text{Ca}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Ba}^{2+}$ , $\text{Pb}^{2+}$	Low Solubility
Sulphide, $\text{S}^{2-}$	Alkali ions, $\text{H}^+$ , $\text{NH}_4^+$ , $\text{Be}^{2+}$ , $\text{Mg}^{2+}$ , $\text{Ca}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Ba}^{2+}$	Soluble
	All others	Low Solubility
Hydroxide, $\text{OH}^-$	Alkali ions, $\text{H}^+$ , $\text{NH}_4^+$ , $\text{Sr}^{2+}$	Soluble
	All others	Low Solubility
Phosphate, $\text{PO}_4^{3-}$ or Carbonate, $\text{CO}_3^{2-}$ or Sulphite, $\text{SO}_3^{2-}$	Alkali ions, $\text{H}^+$ , $\text{NH}_4^+$	Soluble
	All others	Low Solubility

## SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	$K_{sp}$
Barium carbonate	BaCO <sub>3</sub>	$2.6 \times 10^{-9}$
Barium chromate	BaCrO <sub>4</sub>	$1.2 \times 10^{-10}$
Barium sulphate	BaSO <sub>4</sub>	$1.1 \times 10^{-10}$
Calcium carbonate	CaCO <sub>3</sub>	$5.0 \times 10^{-9}$
Calcium oxalate	CaC <sub>2</sub> O <sub>4</sub>	$2.3 \times 10^{-9}$
Calcium sulphate	CaSO <sub>4</sub>	$7.1 \times 10^{-5}$
Copper(I) iodide	CuI	$1.3 \times 10^{-12}$
Copper(II) iodate	Cu(IO <sub>3</sub> ) <sub>2</sub>	$6.9 \times 10^{-8}$
Copper(II) sulphide	CuS	$6.0 \times 10^{-37}$
Iron(II) hydroxide	Fe(OH) <sub>2</sub>	$4.9 \times 10^{-17}$
Iron(II) sulphide	FeS	$6.0 \times 10^{-19}$
Iron(III) hydroxide	Fe(OH) <sub>3</sub>	$2.6 \times 10^{-39}$
Lead(II) bromide	PbBr <sub>2</sub>	$6.6 \times 10^{-6}$
Lead(II) chloride	PbCl <sub>2</sub>	$1.2 \times 10^{-5}$
Lead(II) iodate	Pb(IO <sub>3</sub> ) <sub>2</sub>	$3.7 \times 10^{-13}$
Lead(II) iodide	PbI <sub>2</sub>	$8.5 \times 10^{-9}$
Lead(II) sulphate	PbSO <sub>4</sub>	$1.8 \times 10^{-8}$
Magnesium carbonate	MgCO <sub>3</sub>	$6.8 \times 10^{-6}$
Magnesium hydroxide	Mg(OH) <sub>2</sub>	$5.6 \times 10^{-12}$
Silver bromate	AgBrO <sub>3</sub>	$5.3 \times 10^{-5}$
Silver bromide	AgBr	$5.4 \times 10^{-13}$
Silver carbonate	Ag <sub>2</sub> CO <sub>3</sub>	$8.5 \times 10^{-12}$
Silver chloride	AgCl	$1.8 \times 10^{-10}$
Silver chromate	Ag <sub>2</sub> CrO <sub>4</sub>	$1.1 \times 10^{-12}$
Silver iodate	AgIO <sub>3</sub>	$3.2 \times 10^{-8}$
Silver iodide	AgI	$8.5 \times 10^{-17}$
Strontium carbonate	SrCO <sub>3</sub>	$5.6 \times 10^{-10}$
Strontium fluoride	SrF <sub>2</sub>	$4.3 \times 10^{-9}$
Strontium sulphate	SrSO <sub>4</sub>	$3.4 \times 10^{-7}$
Zinc sulphide	ZnS	$2.0 \times 10^{-25}$

# RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

Name of Acid	Acid	Base	K <sub>a</sub>
Perchloric	HClO <sub>4</sub>	→ H <sup>+</sup> + ClO <sub>4</sub> <sup>-</sup>	very large
Hydriodic	HI	→ H <sup>+</sup> + I <sup>-</sup>	very large
Hydrobromic	HBr	→ H <sup>+</sup> + Br <sup>-</sup>	very large
Hydrochloric	HCl	→ H <sup>+</sup> + Cl <sup>-</sup>	very large
Nitric	HNO <sub>3</sub>	→ H <sup>+</sup> + NO <sub>3</sub> <sup>-</sup>	very large
Sulphuric	H <sub>2</sub> SO <sub>4</sub>	→ H <sup>+</sup> + HSO <sub>4</sub> <sup>-</sup>	very large
Hydronium Ion	H <sub>3</sub> O <sup>+</sup>	⇌ H <sup>+</sup> + H <sub>2</sub> O	1.0
Iodic	HIO <sub>3</sub>	⇌ H <sup>+</sup> + IO <sub>3</sub> <sup>-</sup>	1.7 × 10 <sup>-1</sup>
Oxalic	H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	⇌ H <sup>+</sup> + HC <sub>2</sub> O <sub>4</sub> <sup>-</sup>	5.9 × 10 <sup>-2</sup>
Sulphurous (SO <sub>2</sub> + H <sub>2</sub> O)	H <sub>2</sub> SO <sub>3</sub>	⇌ H <sup>+</sup> + HSO <sub>3</sub> <sup>-</sup>	1.5 × 10 <sup>-2</sup>
Hydrogen sulphate ion	HSO <sub>4</sub> <sup>-</sup>	⇌ H <sup>+</sup> + SO <sub>4</sub> <sup>2-</sup>	1.2 × 10 <sup>-2</sup>
Phosphoric	H <sub>3</sub> PO <sub>4</sub>	⇌ H <sup>+</sup> + H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	7.5 × 10 <sup>-3</sup>
Hexaaquoiron ion, iron(III) ion	Fe(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	⇌ H <sup>+</sup> + Fe(H <sub>2</sub> O) <sub>5</sub> (OH) <sup>2+</sup>	6.0 × 10 <sup>-3</sup>
Citric	H <sub>3</sub> C <sub>6</sub> H <sub>5</sub> O <sub>7</sub>	⇌ H <sup>+</sup> + H <sub>2</sub> C <sub>6</sub> H <sub>5</sub> O <sub>7</sub> <sup>-</sup>	7.1 × 10 <sup>-4</sup>
Nitrous	HNO <sub>2</sub>	⇌ H <sup>+</sup> + NO <sub>2</sub> <sup>-</sup>	4.6 × 10 <sup>-4</sup>
Hydrofluoric	HF	⇌ H <sup>+</sup> + F <sup>-</sup>	3.5 × 10 <sup>-4</sup>
Methanoic, formic	HCOOH	⇌ H <sup>+</sup> + HCOO <sup>-</sup>	1.8 × 10 <sup>-4</sup>
Hexaaquochromium ion, chromium(III) ion	Cr(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	⇌ H <sup>+</sup> + Cr(H <sub>2</sub> O) <sub>5</sub> (OH) <sup>2+</sup>	1.5 × 10 <sup>-4</sup>
Benzoic	C <sub>6</sub> H <sub>5</sub> COOH	⇌ H <sup>+</sup> + C <sub>6</sub> H <sub>5</sub> COO <sup>-</sup>	6.5 × 10 <sup>-5</sup>
Hydrogen oxalate ion	HC <sub>2</sub> O <sub>4</sub> <sup>-</sup>	⇌ H <sup>+</sup> + C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	6.4 × 10 <sup>-5</sup>
Ethanoic, acetic	CH <sub>3</sub> COOH	⇌ H <sup>+</sup> + CH <sub>3</sub> COO <sup>-</sup>	1.8 × 10 <sup>-5</sup>
Dihydrogen citrate ion	H <sub>2</sub> C <sub>6</sub> H <sub>5</sub> O <sub>7</sub> <sup>-</sup>	⇌ H <sup>+</sup> + HC <sub>6</sub> H <sub>5</sub> O <sub>7</sub> <sup>2-</sup>	1.7 × 10 <sup>-5</sup>
Hexaaquoaluminum ion, aluminum ion	Al(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	⇌ H <sup>+</sup> + Al(H <sub>2</sub> O) <sub>5</sub> (OH) <sup>2+</sup>	1.4 × 10 <sup>-5</sup>
Carbonic (CO <sub>2</sub> + H <sub>2</sub> O)	H <sub>2</sub> CO <sub>3</sub>	⇌ H <sup>+</sup> + HCO <sub>3</sub> <sup>-</sup>	4.3 × 10 <sup>-7</sup>
Monohydrogen citrate ion	HC <sub>6</sub> H <sub>5</sub> O <sub>7</sub> <sup>2-</sup>	⇌ H <sup>+</sup> + C <sub>6</sub> H <sub>5</sub> O <sub>7</sub> <sup>3-</sup>	4.1 × 10 <sup>-7</sup>
Hydrogen sulphite ion	HSO <sub>3</sub> <sup>-</sup>	⇌ H <sup>+</sup> + SO <sub>3</sub> <sup>2-</sup>	1.0 × 10 <sup>-7</sup>
Hydrogen sulphide	H <sub>2</sub> S	⇌ H <sup>+</sup> + HS <sup>-</sup>	9.1 × 10 <sup>-8</sup>
Dihydrogen phosphate ion	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	⇌ H <sup>+</sup> + HPO <sub>4</sub> <sup>2-</sup>	6.2 × 10 <sup>-8</sup>
Boric	H <sub>3</sub> BO <sub>3</sub>	⇌ H <sup>+</sup> + H <sub>2</sub> BO <sub>3</sub> <sup>-</sup>	7.3 × 10 <sup>-10</sup>
Ammonium ion	NH <sub>4</sub> <sup>+</sup>	⇌ H <sup>+</sup> + NH <sub>3</sub>	5.6 × 10 <sup>-10</sup>
Hydrocyanic	HCN	⇌ H <sup>+</sup> + CN <sup>-</sup>	4.9 × 10 <sup>-10</sup>
Phenol	C <sub>6</sub> H <sub>5</sub> OH	⇌ H <sup>+</sup> + C <sub>6</sub> H <sub>5</sub> O <sup>-</sup>	1.3 × 10 <sup>-10</sup>
Hydrogen carbonate ion	HCO <sub>3</sub> <sup>-</sup>	⇌ H <sup>+</sup> + CO <sub>3</sub> <sup>2-</sup>	5.6 × 10 <sup>-11</sup>
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub>	⇌ H <sup>+</sup> + HO <sub>2</sub> <sup>-</sup>	2.4 × 10 <sup>-12</sup>
Monohydrogen phosphate ion	HPO <sub>4</sub> <sup>2-</sup>	⇌ H <sup>+</sup> + PO <sub>4</sub> <sup>3-</sup>	2.2 × 10 <sup>-13</sup>
Water	H <sub>2</sub> O	⇌ H <sup>+</sup> + OH <sup>-</sup>	1.0 × 10 <sup>-14</sup>
Hydroxide ion	OH <sup>-</sup>	← H <sup>+</sup> + O <sup>2-</sup>	very small
Ammonia	NH <sub>3</sub>	← H <sup>+</sup> + NH <sub>2</sub> <sup>-</sup>	very small

## ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

# STANDARD REDUCTION POTENTIALS OF HALF-CELLS

*Ionic concentrations are at 1M in water at 25°C.*

	Oxidizing Agents	Reducing Agents	E° (Volts)	
↑ STRONG	$F_2(g) + 2e^-$	$\rightleftharpoons 2F^-$	+2.87	WEAK
	$S_2O_8^{2-} + 2e^-$	$\rightleftharpoons 2SO_4^{2-}$	+2.01	
	$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons 2H_2O$	+1.78	
	$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons Mn^{2+} + 4H_2O$	+1.51	
	$Au^{3+} + 3e^-$	$\rightleftharpoons Au(s)$	+1.50	
	$BrO_3^- + 6H^+ + 5e^-$	$\rightleftharpoons \frac{1}{2}Br_2(l) + 3H_2O$	+1.48	
	$ClO_4^- + 8H^+ + 8e^-$	$\rightleftharpoons Cl^- + 4H_2O$	+1.39	
	$Cl_2(g) + 2e^-$	$\rightleftharpoons 2Cl^-$	+1.36	
	$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.23	
	$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons H_2O$	+1.23	
	$MnO_2(s) + 4H^+ + 2e^-$	$\rightleftharpoons Mn^{2+} + 2H_2O$	+1.22	
	$IO_3^- + 6H^+ + 5e^-$	$\rightleftharpoons \frac{1}{2}I_2(s) + 3H_2O$	+1.20	
	$Br_2(l) + 2e^-$	$\rightleftharpoons 2Br^-$	+1.09	
	$AuCl_4^- + 3e^-$	$\rightleftharpoons Au(s) + 4Cl^-$	+1.00	
	$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons NO(g) + 2H_2O$	+0.96	
	$Hg^{2+} + 2e^-$	$\rightleftharpoons Hg(l)$	+0.85	
	$\frac{1}{2}O_2(g) + 2H^+(10^{-7}M) + 2e^-$	$\rightleftharpoons H_2O$	+0.82	
	$2NO_3^- + 4H^+ + 2e^-$	$\rightleftharpoons N_2O_4 + 2H_2O$	+0.80	
	$Ag^+ + e^-$	$\rightleftharpoons Ag(s)$	+0.80	
	$\frac{1}{2}Hg_2^{2+} + e^-$	$\rightleftharpoons Hg(l)$	+0.80	
↑ STRENGTH OF OXIDIZING AGENT	$Fe^{3+} + e^-$	$\rightleftharpoons Fe^{2+}$	+0.77	STRENGTH OF REDUCING AGENT
	$O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons H_2O_2$	+0.70	
	$MnO_4^- + 2H_2O + 3e^-$	$\rightleftharpoons MnO_2(s) + 4OH^-$	+0.60	
	$I_2(s) + 2e^-$	$\rightleftharpoons 2I^-$	+0.54	
	$Cu^+ + e^-$	$\rightleftharpoons Cu(s)$	+0.52	
	$H_2SO_3 + 4H^+ + 4e^-$	$\rightleftharpoons S(s) + 3H_2O$	+0.45	
	$Cu^{2+} + 2e^-$	$\rightleftharpoons Cu(s)$	+0.34	
	$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons H_2SO_3 + H_2O$	+0.17	
	$Cu^{2+} + e^-$	$\rightleftharpoons Cu^+$	+0.15	
	$Sn^{4+} + 2e^-$	$\rightleftharpoons Sn^{2+}$	+0.15	
	$S(s) + 2H^+ + 2e^-$	$\rightleftharpoons H_2S(g)$	+0.14	
	$2H^+ + 2e^-$	$\rightleftharpoons H_2(g)$	+0.00	
	$Pb^{2+} + 2e^-$	$\rightleftharpoons Pb(s)$	-0.13	
	$Sn^{2+} + 2e^-$	$\rightleftharpoons Sn(s)$	-0.14	
	$Ni^{2+} + 2e^-$	$\rightleftharpoons Ni(s)$	-0.26	
	$H_3PO_4 + 2H^+ + 2e^-$	$\rightleftharpoons H_3PO_3 + H_2O$	-0.28	
	$Co^{2+} + 2e^-$	$\rightleftharpoons Co(s)$	-0.28	
	$Se(s) + 2H^+ + 2e^-$	$\rightleftharpoons H_2Se$	-0.40	
	$Cr^{3+} + e^-$	$\rightleftharpoons Cr^{2+}$	-0.41	
	$2H_2O + 2e^-$	$\rightleftharpoons H_2 + 2OH^-(10^{-7}M)$	-0.41	
↑ WEAK	$Fe^{2+} + 2e^-$	$\rightleftharpoons Fe(s)$	-0.45	↓ STRONG
	$Ag_2S(s) + 2e^-$	$\rightleftharpoons 2Ag(s) + S^{2-}$	-0.69	
	$Cr^{3+} + 3e^-$	$\rightleftharpoons Cr(s)$	-0.74	
	$Zn^{2+} + 2e^-$	$\rightleftharpoons Zn(s)$	-0.76	
	$Te(s) + 2H^+ + 2e^-$	$\rightleftharpoons H_2Te$	-0.79	
	$2H_2O + 2e^-$	$\rightleftharpoons H_2(g) + 2OH^-$	-0.83	
	$Mn^{2+} + 2e^-$	$\rightleftharpoons Mn(s)$	-1.19	
	$Al^{3+} + 3e^-$	$\rightleftharpoons Al(s)$	-1.66	
	$Mg^{2+} + 2e^-$	$\rightleftharpoons Mg(s)$	-2.37	
	$Na^+ + e^-$	$\rightleftharpoons Na(s)$	-2.71	
	$Ca^{2+} + 2e^-$	$\rightleftharpoons Ca(s)$	-2.87	
	$Sr^{2+} + 2e^-$	$\rightleftharpoons Sr(s)$	-2.89	
	$Ba^{2+} + 2e^-$	$\rightleftharpoons Ba(s)$	-2.91	
	$K^+ + e^-$	$\rightleftharpoons K(s)$	-2.93	
	$Rb^+ + e^-$	$\rightleftharpoons Rb(s)$	-2.98	
	$Cs^+ + e^-$	$\rightleftharpoons Cs(s)$	-3.03	
	$Li^+ + e^-$	$\rightleftharpoons Li(s)$	-3.04	

Overpotential Effect

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