

# CHEMISTRY 12 DATA BOULET

## PERIODIC TABLE OF THE ELEMENTS

|                               |                               |                                |                                     |                               |                                  |                                     |                                    |                                    |                                |                             |                              |                               |                               |                               |                                |                               |                             |
|-------------------------------|-------------------------------|--------------------------------|-------------------------------------|-------------------------------|----------------------------------|-------------------------------------|------------------------------------|------------------------------------|--------------------------------|-----------------------------|------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|-----------------------------|
| 1<br>H<br>Hydrogen<br>1.0     |                               |                                |                                     |                               |                                  |                                     |                                    |                                    |                                |                             |                              |                               |                               |                               |                                |                               | 2<br>He<br>Helium<br>4.0    |
| 3<br>Li<br>Lithium<br>6.9     | 4<br>Be<br>Beryllium<br>9.0   |                                |                                     |                               |                                  |                                     |                                    |                                    |                                |                             |                              |                               |                               |                               |                                | 10<br>Ne<br>Neon<br>20.2      |                             |
| 11<br>Na<br>Sodium<br>23.0    | 12<br>Mg<br>Magnesium<br>24.3 |                                |                                     |                               |                                  |                                     |                                    |                                    |                                |                             |                              |                               |                               |                               |                                | 18<br>Ar<br>Argon<br>39.9     |                             |
| 19<br>K<br>Potassium<br>39.1  | 20<br>Ca<br>Calcium<br>40.1   | 21<br>Sc<br>Scandium<br>45.0   | 22<br>Ti<br>Titanium<br>47.9        | 23<br>V<br>Vanadium<br>50.9   | 24<br>Cr<br>Chromium<br>52.0     | 25<br>Mn<br>Manganese<br>54.9       | 26<br>Fe<br>Iron<br>55.8           | 27<br>Co<br>Cobalt<br>58.9         | 28<br>Ni<br>Nickel<br>58.7     | 29<br>Cu<br>Copper<br>63.5  | 30<br>Zn<br>Zinc<br>65.4     | 31<br>Ga<br>Gallium<br>69.7   | 32<br>Ge<br>Germanium<br>72.6 | 33<br>As<br>Arsenic<br>74.9   | 34<br>Se<br>Selenium<br>79.0   | 35<br>Br<br>Bromine<br>79.9   | 36<br>Kr<br>Krypton<br>83.8 |
| 37<br>Rb<br>Rubidium<br>85.5  | 38<br>Sr<br>Strontium<br>87.6 | 39<br>Y<br>Yttrium<br>88.9     | 40<br>Zr<br>Zirconium<br>91.2       | 41<br>Nb<br>Niobium<br>92.9   | 42<br>Mo<br>Molybdenum<br>95.9   | 43<br>Tc<br>Technetium<br>(98)      | 44<br>Ru<br>Ruthenium<br>101.1     | 45<br>Rh<br>Rhodium<br>102.9       | 46<br>Pd<br>Palladium<br>106.4 | 47<br>Ag<br>Silver<br>107.9 | 48<br>Cd<br>Cadmium<br>112.4 | 49<br>In<br>Indium<br>114.8   | 50<br>Sn<br>Tin<br>118.7      | 51<br>Sb<br>Antimony<br>121.8 | 52<br>Te<br>Tellurium<br>127.6 | 53<br>I<br>Iodine<br>126.9    | 54<br>Xe<br>Xenon<br>131.3  |
| 55<br>Cs<br>Cesium<br>132.9   | 56<br>Ba<br>Barium<br>137.3   | 57<br>La<br>Lanthanum<br>138.9 | 72<br>Hf<br>Hafnium<br>178.5        | 73<br>Ta<br>Tantalum<br>180.9 | 74<br>W<br>Tungsten<br>183.8     | 75<br>Re<br>Rhenium<br>186.2        | 76<br>Os<br>Osmium<br>190.2        | 77<br>Ir<br>Iridium<br>192.2       | 78<br>Pt<br>Platinum<br>195.1  | 79<br>Au<br>Gold<br>197.0   | 80<br>Hg<br>Mercury<br>200.6 | 81<br>Tl<br>Thallium<br>204.4 | 82<br>Pb<br>Lead<br>207.2     | 83<br>Bi<br>Bismuth<br>209.0  | 84<br>Po<br>Polonium<br>(209)  | 85<br>At<br>Astatine<br>(210) | 86<br>Rn<br>Radon<br>(222)  |
| 87<br>Fr<br>Francium<br>(223) | 88<br>Ra<br>Radium<br>(226)   | 89<br>Ac<br>Actinium<br>(227)  | 104<br>Rf<br>Rutherfordium<br>(261) | 105<br>Ha<br>Hahnium<br>(262) | 106<br>Sg<br>Seaborgium<br>(263) | 107<br>Uns<br>Unnilseptium<br>(262) | 108<br>Uno<br>Unniloctium<br>(265) | 109<br>Une<br>Unnilennium<br>(266) |                                |                             |                              |                               |                               |                               |                                |                               |                             |

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

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

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|         |               |
|---------|---------------|
| 14      | Atomic number |
| Si      | Symbol        |
| Silicon | Name          |
| 28.1    | Atomic mass   |

### ATOMIC MASSES OF THE ELEMENTS

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

| Element     | Symbol | Atomic Number | Atomic Mass | Element       | Symbol | Atomic Number | Atomic Mass |
|-------------|--------|---------------|-------------|---------------|--------|---------------|-------------|
| Actinium    | Ac     | 89            | (227)       | Mercury       | Hg     | 80            | 200.6       |
| Aluminum    | Al     | 13            | 27.0        | Molybdenum    | Mo     | 42            | 95.9        |
| Americium   | Am     | 95            | (243)       | Neodymium     | Nd     | 60            | 144.2       |
| Antimony    | Sb     | 51            | 121.8       | Neon          | Ne     | 10            | 20.2        |
| Argon       | Ar     | 18            | 39.9        | Neptunium     | Np     | 93            | (237)       |
| Arsenic     | As     | 33            | 74.9        | Nickel        | Ni     | 28            | 58.7        |
| Astatine    | At     | 85            | (210)       | Niobium       | Nb     | 41            | 92.9        |
| Barium      | Ba     | 56            | 137.3       | Nitrogen      | N      | 7             | 14.0        |
| Berkelium   | Bk     | 97            | (247)       | Nobelium      | No     | 102           | (259)       |
| Beryllium   | Be     | 4             | 9.0         | Osmium        | Os     | 76            | 190.2       |
| Bismuth     | Bi     | 83            | 209.0       | Oxygen        | O      | 8             | 16.0        |
| Boron       | B      | 5             | 10.8        | Palladium     | Pd     | 46            | 106.4       |
| Bromine     | Br     | 35            | 79.9        | Phosphorus    | P      | 15            | 31.0        |
| Cadmium     | Cd     | 48            | 112.4       | Platinum      | Pt     | 78            | 195.1       |
| Calcium     | Ca     | 20            | 40.1        | Plutonium     | Pu     | 94            | (244)       |
| Californium | Cf     | 98            | (251)       | Polonium      | Po     | 84            | (209)       |
| Carbon      | C      | 6             | 12.0        | Potassium     | K      | 19            | 39.1        |
| Cerium      | Ce     | 58            | 140.1       | Praseodymium  | Pr     | 59            | 140.9       |
| Cesium      | Cs     | 55            | 132.9       | Promethium    | Pm     | 61            | (145)       |
| Chlorine    | Cl     | 17            | 35.5        | Protactinium  | Pa     | 91            | 231.0       |
| Chromium    | Cr     | 24            | 52.0        | Radium        | Ra     | 88            | (226)       |
| Cobalt      | Co     | 27            | 58.9        | Radon         | Rn     | 86            | (222)       |
| Copper      | Cu     | 29            | 63.5        | Rhenium       | Re     | 75            | 186.2       |
| Curium      | Cm     | 96            | (247)       | Rhodium       | Rh     | 45            | 102.9       |
| Dysprosium  | Dy     | 66            | 162.5       | Rubidium      | Rb     | 37            | 85.5        |
| Einsteinium | Es     | 99            | (252)       | Ruthenium     | Ru     | 44            | 101.1       |
| Erbium      | Er     | 68            | 167.3       | Rutherfordium | Rf     | 104           | (261)       |
| Europium    | Eu     | 63            | 152.0       | Samarium      | Sm     | 62            | 150.4       |
| Fermium     | Fm     | 100           | (257)       | Scandium      | Sc     | 21            | 45.0        |
| Fluorine    | F      | 9             | 19.0        | Selenium      | Se     | 34            | 79.0        |
| Francium    | Fr     | 87            | (223)       | Silicon       | Si     | 14            | 28.1        |
| Gadolinium  | Gd     | 64            | 157.3       | Silver        | Ag     | 47            | 107.9       |
| Gallium     | Ga     | 31            | 69.7        | Sodium        | Na     | 11            | 23.0        |
| Germanium   | Ge     | 32            | 72.6        | Strontium     | Sr     | 38            | 87.6        |
| Gold        | Au     | 79            | 197.0       | Sulphur       | S      | 16            | 32.1        |
| Hafnium     | Hf     | 72            | 178.5       | Tantalum      | Ta     | 73            | 180.9       |
| Hahnium     | Ha     | 105           | (262)       | Technetium    | Tc     | 43            | (98)        |
| Helium      | He     | 2             | 4.0         | Tellurium     | Te     | 52            | 127.6       |
| Holmium     | Ho     | 67            | 164.9       | Terbium       | Tb     | 65            | 158.9       |
| Hydrogen    | H      | 1             | 1.0         | Thallium      | Tl     | 81            | 204.4       |
| Indium      | In     | 49            | 114.8       | Thorium       | Th     | 90            | 232.0       |
| Iodine      | I      | 53            | 126.9       | Thulium       | Tm     | 69            | 168.9       |
| Iridium     | Ir     | 77            | 192.2       | Tin           | Sn     | 50            | 118.7       |
| Iron        | Fe     | 26            | 55.8        | Titanium      | Ti     | 22            | 47.9        |
| Krypton     | Kr     | 36            | 83.8        | Tungsten      | W      | 74            | 183.8       |
| Lanthanum   | La     | 57            | 138.9       | Uranium       | U      | 92            | 238.0       |
| Lawrencium  | Lr     | 103           | (262)       | Vanadium      | V      | 23            | 50.9        |
| Lead        | Pb     | 82            | 207.2       | Xenon         | Xe     | 54            | 131.3       |
| Lithium     | Li     | 3             | 6.9         | Ytterbium     | Yb     | 70            | 173.0       |
| Lutetium    | Lu     | 71            | 175.0       | Yttrium       | Y      | 39            | 88.9        |
| Magnesium   | Mg     | 12            | 24.3        | Zinc          | Zn     | 30            | 65.4        |
| Manganese   | Mn     | 25            | 54.9        | Zirconium     | Zr     | 40            | 91.2        |
| Mendelevium | Md     | 101           | (258)       |               |        |               |             |

### NAMES, FORMULAE AND CHARGES OF SOME COMMON IONS

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

\* Aqueous solutions are readily oxidized by air.

† Not stable in aqueous solutions.

## SOLUBILITY OF COMMON COMPOUNDS IN WATER



(A compound is listed as "soluble" if its solubility is  $> 0.1$  mol/L at  $25^{\circ}\text{C}$ )

| NEGATIVE IONS<br>(Anions)  | POSITIVE IONS<br>(Cations)  | SOLUBILITY OF<br>COMPOUNDS |
|--|---|----------------------------|
| All  | Alkali ions:<br>$\text{Li}^+$ , $\text{Na}^+$ , $\text{K}^+$ , $\text{Rb}^+$ , $\text{Cs}^+$ , $\text{Fr}^+$                                | Soluble                    |
| All  | Hydrogen ion, $\text{H}^+$  | Soluble                    |
| All  | Ammonium, $\text{NH}_4^+$   | Soluble                    |
| Nitrate, $\text{NO}_3^-$   | All   | Soluble                    |
| Chloride, $\text{Cl}^-$<br>or<br>Bromide, $\text{Br}^-$<br>or<br>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, $\text{H}^+$ , $\text{NH}_4^+$ , $\text{Be}^{2+}$<br>$\text{Mg}^{2+}$ , $\text{Ca}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Ba}^{2+}$ | Soluble                    |
|  | All others  | LOW SOLUBILITY             |
| Hydroxide, $\text{OH}^-$   | Alkali ions, $\text{H}^+$ , $\text{NH}_4^+$ , $\text{Sr}^{2+}$  | Soluble                    |
|  | All others  | LOW SOLUBILITY             |
| Phosphate, $\text{PO}_4^{3-}$<br>or<br>Carbonate, $\text{CO}_3^{2-}$<br>or<br>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

| Strength of Acid   | Name of Acid                                    | Acid  | Base   | K <sub>a</sub>        | Strength of Base   |
|--|---|---|--|-----------------------|--|
| <b>EQUALLY STRONG ACIDS</b>  | Perchloric                                      | $\text{HClO}_4 \rightarrow$                                     | $\text{H}^+ + \text{ClO}_4^-$                                  |                       | <b>DO NOT ACT AS BASES</b>   |
|  | Hydriodic                                       | $\text{HI} \rightarrow$   | $\text{H}^+ + \text{I}^-$                                      |                       |  |
|  | Hydrobromic                                     | $\text{HBr} \rightarrow$  | $\text{H}^+ + \text{Br}^-$                                     |                       |  |
|  | Hydrochloric                                    | $\text{HCl} \rightarrow$  | $\text{H}^+ + \text{Cl}^-$                                     |                       |  |
|  | Nitric  | $\text{HNO}_3 \rightarrow$                                      | $\text{H}^+ + \text{NO}_3^-$                                   |                       |  |
|  | Sulphuric                                       | $\text{H}_2\text{SO}_4 \rightarrow$                             | $\text{H}^+ + \text{HSO}_4^-$                                  |                       |  |
| <b>Strong</b>  | Hydronium ion                                   | $\text{H}_3\text{O}^+ \rightleftharpoons$                       | $\text{H}^+ + \text{H}_2\text{O}$                              | 1.0                   | <b>Weak</b>  |
|  | Iodic   | $\text{HIO}_3 \rightleftharpoons$                               | $\text{H}^+ + \text{IO}_3^-$                                   | $1.7 \times 10^{-1}$  |  |
|  | Oxalic  | $\text{H}_2\text{C}_2\text{O}_4 \rightleftharpoons$             | $\text{H}^+ + \text{HC}_2\text{O}_4^-$                         | $5.9 \times 10^{-2}$  |  |
|  | Sulphurous (SO <sub>2</sub> + H <sub>2</sub> O) | $\text{H}_2\text{SO}_3 \rightleftharpoons$                      | $\text{H}^+ + \text{HSO}_3^-$                                  | $1.5 \times 10^{-2}$  |  |
|  | Hydrogen sulphate ion                           | $\text{HSO}_4^- \rightleftharpoons$                             | $\text{H}^+ + \text{SO}_4^{2-}$                                | $1.2 \times 10^{-2}$  |  |
|  | Phosphoric                                      | $\text{H}_3\text{PO}_4 \rightleftharpoons$                      | $\text{H}^+ + \text{H}_2\text{PO}_4^-$                         | $7.5 \times 10^{-3}$  |  |
|  | Iron(III), hexaquoiron(III) ion                 | $\text{Fe}(\text{H}_2\text{O})_6^{3+} \rightleftharpoons$       | $\text{H}^+ + \text{Fe}(\text{H}_2\text{O})_5(\text{OH})^{2+}$ | $6.0 \times 10^{-3}$  |  |
|  | Citric  | $\text{H}_3\text{C}_6\text{H}_5\text{O}_7 \rightleftharpoons$   | $\text{H}^+ + \text{H}_2\text{C}_6\text{H}_5\text{O}_7^-$      | $7.1 \times 10^{-4}$  |  |
|  | Nitrous   | $\text{HNO}_2 \rightleftharpoons$                               | $\text{H}^+ + \text{NO}_2^-$                                   | $4.6 \times 10^{-4}$  |  |
|  | Hydrofluoric                                    | $\text{HF} \rightleftharpoons$                                  | $\text{H}^+ + \text{F}^-$                                      | $3.5 \times 10^{-4}$  |  |
|  | Methanoic, formic                               | $\text{HCOOH} \rightleftharpoons$                               | $\text{H}^+ + \text{HCOO}^-$                                   | $1.8 \times 10^{-4}$  |  |
|  | Chromium(III), hexaquo chromium(III) ion        | $\text{Cr}(\text{H}_2\text{O})_6^{3+} \rightleftharpoons$       | $\text{H}^+ + \text{Cr}(\text{H}_2\text{O})_5(\text{OH})^{2+}$ | $1.5 \times 10^{-4}$  |  |
|  | Benzoic   | $\text{C}_6\text{H}_5\text{COOH} \rightleftharpoons$            | $\text{H}^+ + \text{C}_6\text{H}_5\text{COO}^-$                | $6.5 \times 10^{-5}$  |  |
|  | Hydrogen oxalate ion                            | $\text{HC}_2\text{O}_4^- \rightleftharpoons$                    | $\text{H}^+ + \text{C}_2\text{O}_4^{2-}$                       | $6.4 \times 10^{-5}$  |  |
|  | Ethanoic, acetic                                | $\text{CH}_3\text{COOH} \rightleftharpoons$                     | $\text{H}^+ + \text{CH}_3\text{COO}^-$                         | $1.8 \times 10^{-5}$  |  |
|  | Dihydrogen citrate ion                          | $\text{H}_2\text{C}_6\text{H}_5\text{O}_7^- \rightleftharpoons$ | $\text{H}^+ + \text{HC}_6\text{H}_5\text{O}_7^{2-}$            | $1.7 \times 10^{-5}$  |  |
|  | Aluminum ion, hexaquoaluminum ion               | $\text{Al}(\text{H}_2\text{O})_6^{3+} \rightleftharpoons$       | $\text{H}^+ + \text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+}$ | $1.4 \times 10^{-5}$  |  |
|  | Carbonic (CO <sub>2</sub> + H <sub>2</sub> O)   | $\text{H}_2\text{CO}_3 \rightleftharpoons$                      | $\text{H}^+ + \text{HCO}_3^-$                                  | $4.3 \times 10^{-7}$  |  |
|  | Monohydrogen citrate ion                        | $\text{HC}_6\text{H}_5\text{O}_7^{2-} \rightleftharpoons$       | $\text{H}^+ + \text{C}_6\text{H}_5\text{O}_7^{3-}$             | $4.1 \times 10^{-7}$  |  |
|  | Hydrogen sulphite ion                           | $\text{HSO}_3^- \rightleftharpoons$                             | $\text{H}^+ + \text{SO}_3^{2-}$                                | $1.0 \times 10^{-7}$  |  |
|  | Hydrogen sulphide                               | $\text{H}_2\text{S} \rightleftharpoons$                         | $\text{H}^+ + \text{HS}^-$                                     | $9.1 \times 10^{-8}$  |  |
|  | Dihydrogen phosphate ion                        | $\text{H}_2\text{PO}_4^- \rightleftharpoons$                    | $\text{H}^+ + \text{HPO}_4^{2-}$                               | $6.2 \times 10^{-8}$  |  |
|  | Boric   | $\text{H}_3\text{BO}_3 \rightleftharpoons$                      | $\text{H}^+ + \text{H}_2\text{BO}_3^-$                         | $7.3 \times 10^{-10}$ |  |
|  | Ammonium ion                                    | $\text{NH}_4^+ \rightleftharpoons$                              | $\text{H}^+ + \text{NH}_3$                                     | $5.6 \times 10^{-10}$ |  |
|  | Hydrocyanic                                     | $\text{HCN} \rightleftharpoons$                                 | $\text{H}^+ + \text{CN}^-$                                     | $4.9 \times 10^{-10}$ |  |
|  | Phenol  | $\text{C}_6\text{H}_5\text{OH} \rightleftharpoons$              | $\text{H}^+ + \text{C}_6\text{H}_5\text{O}^-$                  | $1.3 \times 10^{-10}$ |  |
|  | Hydrogen carbonate ion                          | $\text{HCO}_3^- \rightleftharpoons$                             | $\text{H}^+ + \text{CO}_3^{2-}$                                | $5.6 \times 10^{-11}$ |  |
| Hydrogen peroxide  | $\text{H}_2\text{O}_2 \rightleftharpoons$       | $\text{H}^+ + \text{HO}_2^-$                                    | $2.4 \times 10^{-12}$  |                       |  |
| Monohydrogen phosphate ion   | $\text{HPO}_4^{2-} \rightleftharpoons$          | $\text{H}^+ + \text{PO}_4^{3-}$                                 | $2.2 \times 10^{-13}$  |                       |  |
| <b>Weak</b>  | Water   | $\text{H}_2\text{O} \rightleftharpoons$                         | $\text{H}^+ + \text{OH}^-$                                     | $1.0 \times 10^{-14}$ | <b>Strong</b>  |
| <b>DO NOT ACT AS ACIDS</b>   |   | $\text{OH}^- \leftarrow$  | $\text{H}^+ + \text{O}^{2-}$                                   | Oxide                 | <b>EQUALLY STRONG BASES</b>  |
|  |   | $\text{NH}_3 \leftarrow$  | $\text{H}^+ + \text{NH}_2^-$                                   | Amide                 |  |

## ACID-BASE INDICATORS

| INDICATOR        | pH RANGE IN WHICH<br>COLOUR CHANGE OCCURS | COLOUR CHANGE AS pH<br>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 1 M in Water at 25°C.

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

weak

strong