

# CHEMISTRY

## *Data Booklet*

*revised 2009*

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### Table of Common Polyatomic Ions

acetate (ethanoate)	CH <sub>3</sub> COO <sup>-</sup>	chromate	CrO <sub>4</sub> <sup>2-</sup>	phosphate	PO <sub>4</sub> <sup>3-</sup>
ammonium	NH <sub>4</sub> <sup>+</sup>	dichromate	Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup>	hydrogen phosphate	HPO <sub>4</sub> <sup>2-</sup>
benzoate	C <sub>6</sub> H <sub>5</sub> COO <sup>-</sup>	cyanide	CN <sup>-</sup>	dihydrogen phosphate	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>
borate	BO <sub>3</sub> <sup>3-</sup>	hydroxide	OH <sup>-</sup>	silicate	SiO <sub>3</sub> <sup>2-</sup>
carbide	C <sub>2</sub> <sup>2-</sup>	iodate	IO <sub>3</sub> <sup>-</sup>	sulfate	SO <sub>4</sub> <sup>2-</sup>
carbonate	CO <sub>3</sub> <sup>2-</sup>	nitrate	NO <sub>3</sub> <sup>-</sup>	hydrogen sulfate	HSO <sub>4</sub> <sup>-</sup>
hydrogen carbonate	HCO <sub>3</sub> <sup>-</sup>	nitrite	NO <sub>2</sub> <sup>-</sup>	sulfite	SO <sub>3</sub> <sup>2-</sup>
perchlorate	ClO <sub>4</sub> <sup>-</sup>	oxalate	O <sub>2</sub> C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	hydrogen sulfite	HSO <sub>3</sub> <sup>-</sup>
chlorate	ClO <sub>3</sub> <sup>-</sup>	hydrogen oxalate	HO <sub>2</sub> C <sub>2</sub> O <sub>4</sub> <sup>-</sup>	hydrogen sulfide	HS <sup>-</sup>
chlorite	ClO <sub>2</sub> <sup>-</sup>	permanganate	MnO <sub>4</sub> <sup>-</sup>	thiocyanate	SCN <sup>-</sup>
hypochlorite	OCI <sup>-</sup> or ClO <sup>-</sup>	peroxide	O <sub>2</sub> <sup>2-</sup>	thiosulfate	S <sub>2</sub> O <sub>3</sub> <sup>2-</sup>
		persulfide	S <sub>2</sub> <sup>2-</sup>		

<b>1</b> 1.01 1+,1- <b>H</b> hydrogen	<b>3</b> 6.94 1+ <b>Li</b> lithium	<b>4</b> 9.01 2+ <b>Be</b> beryllium	<b>11</b> 22.99 1+ <b>Na</b> sodium	<b>12</b> 24.31 2+ <b>Mg</b> magnesium	<b>19</b> 39.10 1+ <b>K</b> potassium	<b>20</b> 40.08 2+ <b>Ca</b> calcium	<b>21</b> 44.96 3+ <b>Sc</b> scandium	<b>22</b> 47.87 4+, 3+ <b>Ti</b> titanium	<b>23</b> 50.94 5+, 4+ <b>V</b> vanadium	<b>24</b> 52.00 3+, 2+ <b>Cr</b> chromium	<b>25</b> 54.94 2+, 4+ <b>Mn</b> manganese	<b>26</b> 55.85 3+, 2+ <b>Fe</b> iron	<b>27</b> 58.93 2+, 3+ <b>Co</b> cobalt				
<b>37</b> 85.47 1+ <b>Rb</b> rubidium	<b>38</b> 87.62 2+ <b>Sr</b> strontium	<b>39</b> 88.91 3+ <b>Y</b> yttrium	<b>40</b> 91.22 4+ <b>Zr</b> zirconium	<b>41</b> 92.91 5+, 3+ <b>Nb</b> niobium	<b>42</b> 95.94 6+ <b>Mo</b> molybdenum	<b>43</b> (98) 7+ <b>Tc</b> technetium	<b>44</b> 101.07 3+ <b>Ru</b> ruthenium	<b>45</b> 102.91 3+ <b>Rh</b> rhodium	<b>55</b> 132.91 1+ <b>Cs</b> cesium	<b>56</b> 137.33 2+ <b>Ba</b> barium	<b>57</b> 138.91 3+ <b>La</b> lanthanum	<b>72</b> 178.49 4+ <b>Hf</b> hafnium	<b>73</b> 180.95 5+ <b>Ta</b> tantalum	<b>74</b> 183.84 6+ <b>W</b> tungsten	<b>75</b> 186.21 7+ <b>Re</b> rhenium	<b>76</b> 190.23 4+ <b>Os</b> osmium	<b>77</b> 192.22 4+ <b>Ir</b> iridium
<b>87</b> (223) 1+ <b>Fr</b> francium	<b>88</b> (226) 2+ <b>Ra</b> radium	<b>89</b> (227) 3+ <b>Ac</b> actinium	<b>104</b> (261) 4+ <b>Rf</b> rutherfordium	<b>105</b> (262) <b>Db</b> dubnium	<b>106</b> (266) <b>Sg</b> seaborgium	<b>107</b> (264) <b>Bh</b> bohrium	<b>108</b> (277) <b>Hs</b> hassium	<b>109</b> (268) <b>Mt</b> meitnerium									

lanthanide and actinide series begin

<b>58</b> 140.12 3+ <b>Ce</b> cerium	<b>59</b> 140.91 3+ <b>Pr</b> praseodymium	<b>60</b> 144.24 3+ <b>Nd</b> neodymium	<b>61</b> (145) 3+ <b>Pm</b> promethium	<b>62</b> 150.36 3+, 2+ <b>Sm</b> samarium
<b>90</b> 232.04 4+ <b>Th</b> thorium	<b>91</b> 231.04 5+, 4+ <b>Pa</b> protactinium	<b>92</b> 238.03 6+, 4+ <b>U</b> uranium	<b>93</b> (237) 5+ <b>Np</b> neptunium	<b>94</b> (244) 4+, 6+ <b>Pu</b> plutonium

#### References





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Speight, James G. 2005. *Lange's Handbook of Chemistry*. 16<sup>th</sup> ed. New York: McGraw-Hill, Inc.

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**Legend for Elements**

 Metallic solids	 Gases
 Non-metallic solids	 Liquids

**Note:** The legend denotes the physical state of the elements at exactly 101.325 kPa and 298.15 K.

**Key**

Atomic number →	<b>26</b>	<b>55.85</b>	Atomic molar mass (g/mol)*
Electronegativity →	<b>1.8</b>	<b>3+, 2+</b>	Most stable ion charges
Symbol →	<b>Fe</b>		
Name →	<b>iron</b>		

\* Based on  $^{12}_6\text{C}$   
( ) Indicates mass of the most stable isotope

										<b>2</b> 4.00 — <b>He</b> helium							
										<b>10</b> 20.18 — <b>Ne</b> neon							
										<b>18</b> 39.95 — <b>Ar</b> argon							
<b>5</b> 10.81 2.0 <b>B</b> boron	<b>6</b> 12.01 2.6 <b>C</b> carbon	<b>7</b> 14.01 3.0 <b>N</b> nitrogen	<b>8</b> 16.00 3.4 <b>O</b> oxygen	<b>9</b> 19.00 4.0 <b>F</b> fluorine	<b>13</b> 26.98 1.6 <b>Al</b> aluminium	<b>14</b> 28.09 1.9 <b>Si</b> silicon	<b>15</b> 30.97 2.2 <b>P</b> phosphorus	<b>16</b> 32.07 2.6 <b>S</b> sulfur	<b>17</b> 35.45 3.2 <b>Cl</b> chlorine	<b>36</b> 83.80 — <b>Kr</b> krypton							
<b>28</b> 58.69 2+, 3+ 1.9 <b>Ni</b> nickel	<b>29</b> 63.55 2+, 1+ 1.9 <b>Cu</b> copper	<b>30</b> 65.41 2+ 1.7 <b>Zn</b> zinc	<b>31</b> 69.72 3+ 1.8 <b>Ga</b> gallium	<b>32</b> 72.64 4+ 2.0 <b>Ge</b> germanium	<b>33</b> 74.92 — 2.2 <b>As</b> arsenic	<b>34</b> 78.96 — 2.6 <b>Se</b> selenium	<b>35</b> 79.90 — 3.0 <b>Br</b> bromine	<b>54</b> 131.29 — 2.6 <b>Xe</b> xenon	<b>46</b> 106.42 2+, 3+ 2.2 <b>Pd</b> palladium	<b>47</b> 107.87 1+ 1.9 <b>Ag</b> silver	<b>48</b> 112.41 2+ 1.7 <b>Cd</b> cadmium	<b>49</b> 114.82 3+ 1.8 <b>In</b> indium	<b>50</b> 118.71 4+, 2+ 2.0 <b>Sn</b> tin	<b>51</b> 121.76 3+, 5+ 2.1 <b>Sb</b> antimony	<b>52</b> 127.60 — 2.1 <b>Te</b> tellurium	<b>53</b> 126.90 — 2.7 <b>I</b> iodine	<b>86</b> (222) — — <b>Rn</b> radon
<b>78</b> 195.08 4+, 2+ 2.2 <b>Pt</b> platinum	<b>79</b> 196.97 3+, 1+ 2.4 <b>Au</b> gold	<b>80</b> 200.59 2+, 1+ 1.9 <b>Hg</b> mercury	<b>81</b> 204.38 1+, 3+ 1.8 <b>Tl</b> thallium	<b>82</b> 207.2* 2+, 4+ 1.8 <b>Pb</b> lead	<b>83</b> 208.98 3+, 5+ 1.9 <b>Bi</b> bismuth	<b>84</b> (209) 2+, 4+ 2.0 <b>Po</b> polonium	<b>85</b> (210) — 2.2 <b>At</b> astatine	<b>110</b> (271) — <b>Ds</b> darmstadtium	<b>111</b> (272) — <b>Rg</b> roentgenium	* The isotopic mix of naturally occurring lead is more variable than other elements, preventing precision to greater than tenths of a gram per mole.							

<b>63</b> 151.96 3+, 2+ — <b>Eu</b> europium	<b>64</b> 157.25 3+ 1.2 <b>Gd</b> gadolinium	<b>65</b> 158.93 3+ — <b>Tb</b> terbium	<b>66</b> 162.50 3+ 1.2 <b>Dy</b> dysprosium	<b>67</b> 164.93 3+ 1.2 <b>Ho</b> holmium	<b>68</b> 167.26 3+ 1.2 <b>Er</b> erbium	<b>69</b> 168.93 3+ 1.3 <b>Tm</b> thulium	<b>70</b> 173.04 3+, 2+ — <b>Yb</b> ytterbium	<b>71</b> 174.97 3+ 1.0 <b>Lu</b> lutetium
<b>95</b> (243) 3+, 4+ — <b>Am</b> americium	<b>96</b> (247) 3+ — <b>Cm</b> curium	<b>97</b> (247) 3+, 4+ — <b>Bk</b> berkelium	<b>98</b> (251) 3+ — <b>Cf</b> californium	<b>99</b> (252) 3+ — <b>Es</b> einsteinium	<b>100</b> (257) 3+ — <b>Fm</b> fermium	<b>101</b> (258) 2+, 3+ — <b>Md</b> mendelevium	<b>102</b> (259) 2+, 3+ — <b>No</b> nobelium	<b>103</b> (262) 3+ — <b>Lr</b> lawrencium

## Chemistry Notation

Symbol	Term	Unit(s)
$c$	specific heat capacity	J/(g·°C) or J/(g·K)
$E$	electrical potential	V or J/C
$E_k$	kinetic energy	kJ
$E_p$	potential energy	kJ
$\Delta H$	enthalpy (heat)	kJ
$\Delta_f H^\circ$	standard molar enthalpy of formation	kJ/mol
$I$	current	A or C/s
$K_c$	equilibrium constant	—
$K_a$	acid ionization (dissociation) constant	—
$K_b$	base ionization (dissociation) constant	—
$M$	molar mass	g/mol
$m$	mass	g
$n$	amount of substance	mol
$P$	pressure	kPa
$Q$	charge	C
$T$	temperature (absolute)	K
$t$	temperature (Celsius)	°C
$t$	time	s
$V$	volume	L
$c$	amount concentration	mol/L

Symbol	Term
$\Delta$	delta (change in)
$^\circ$	standard
[ ]	amount concentration

## Miscellaneous

25.00 °C .....	equivalent to 298.15 K	
Specific heat capacity.....	$c_{\text{air}}$	= 1.01 J/(g·°C)
(at 298.15 K and 100.000 kPa)	$c_{\text{polystyrene foam cup}}$	= 1.01 J/(g·°C)
	$c_{\text{copper}}$	= 0.385 J/(g·°C)
	$c_{\text{aluminium}}$	= 0.897 J/(g·°C)
	$c_{\text{tin}}$	= 0.227 J/(g·°C)
	$c_{\text{water}}$	= 4.19 J/(g·°C)
Water autoionization constant..... (Dissociation constant)	$K_w = 1.0 \times 10^{-14}$ at 298.15 K (for ion concentrations in mol/L)	
Faraday constant .....	$F = 9.65 \times 10^4 \text{ C/mol e}^-$	
Quadratic formula .....	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	

## Selected SI Prefixes

Prefix	Exponential Symbol	Value
tera	T	$10^{12}$
giga	G	$10^9$
mega	M	$10^6$
kilo	k	$10^3$
milli	m	$10^{-3}$
micro	$\mu$	$10^{-6}$
nano	n	$10^{-9}$
pico	p	$10^{-12}$

## Standard Molar Enthalpies of Formation at 298.15 K

Name	Formula	$\Delta_f H^\circ$ (kJ/mol)
aluminium oxide	Al <sub>2</sub> O <sub>3</sub> (s)	-1 675.7
ammonia	NH <sub>3</sub> (g)	-45.9
ammonium chloride	NH <sub>4</sub> Cl(s)	-314.4
ammonium nitrate	NH <sub>4</sub> NO <sub>3</sub> (s)	-365.6
barium carbonate	BaCO <sub>3</sub> (s)	-1 213.0
barium chloride	BaCl <sub>2</sub> (s)	-855.0
barium hydroxide	Ba(OH) <sub>2</sub> (s)	-944.7
barium oxide	BaO(s)	-548.0
barium sulfate	BaSO <sub>4</sub> (s)	-1 473.2
benzene	C <sub>6</sub> H <sub>6</sub> (l)	+49.1
butane	C <sub>4</sub> H <sub>10</sub> (g)	-125.7
calcium carbonate	CaCO <sub>3</sub> (s)	-1 207.6
calcium chloride	CaCl <sub>2</sub> (s)	-795.4
calcium hydroxide	Ca(OH) <sub>2</sub> (s)	-985.2
calcium oxide	CaO(s)	-634.9
calcium sulfate	CaSO <sub>4</sub> (s)	-1 434.5
carbon dioxide	CO <sub>2</sub> (g)	-393.5
carbon monoxide	CO(g)	-110.5
chromium(III) oxide	Cr <sub>2</sub> O <sub>3</sub> (s)	-1 139.7
copper(I) oxide	Cu <sub>2</sub> O(s)	-168.6
copper(II) oxide	CuO(s)	-157.3
copper(II) sulfate	CuSO <sub>4</sub> (s)	-771.4
copper(I) sulfide	Cu <sub>2</sub> S(s)	-79.5
copper(II) sulfide	CuS(s)	-53.1
dinitrogen tetroxide	N <sub>2</sub> O <sub>4</sub> (g)	+11.1
ethane	C <sub>2</sub> H <sub>6</sub> (g)	-84.0
ethanoic acid (acetic acid)	CH <sub>3</sub> COOH(l)	-484.3
ethanol	C <sub>2</sub> H <sub>5</sub> OH(l)	-277.6
ethene (ethylene)	C <sub>2</sub> H <sub>4</sub> (g)	+52.4
ethyne (acetylene)	C <sub>2</sub> H <sub>2</sub> (g)	+227.4
glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> (s)	-1 273.3
hydrogen bromide	HBr(g)	-36.3
hydrogen chloride	HCl(g)	-92.3
hydrogen fluoride	HF(g)	-273.3
hydrogen iodide	HI(g)	+26.5
hydrogen perchlorate	HClO <sub>4</sub> (l)	-40.6
hydrogen peroxide	H <sub>2</sub> O <sub>2</sub> (l)	-187.8
hydrogen sulfide	H <sub>2</sub> S(g)	-20.6
iron(II) oxide	FeO(s)	-272.0
iron(III) oxide	Fe <sub>2</sub> O <sub>3</sub> (s)	-824.2
iron(II,III) oxide (magnetite)	Fe <sub>3</sub> O <sub>4</sub> (s)	-1 118.4
lead(II) bromide	PbBr <sub>2</sub> (s)	-278.7
lead(II) chloride	PbCl <sub>2</sub> (s)	-359.4
lead(II) oxide (red)	PbO(s)	-219.0
lead(IV) oxide	PbO <sub>2</sub> (s)	-277.4
magnesium carbonate	MgCO <sub>3</sub> (s)	-1 095.8
magnesium chloride	MgCl <sub>2</sub> (s)	-641.3

### Standard Molar Enthalpies of Formation at 298.15 K cont'd

Name	Formula	$\Delta_f H^\circ$ (kJ/mol)
magnesium hydroxide	Mg(OH) <sub>2</sub> (s)	-924.5
magnesium oxide	MgO(s)	-601.6
magnesium sulfate	MgSO <sub>4</sub> (s)	-1 284.9
manganese(II) oxide	MnO(s)	-385.2
manganese(IV) oxide	MnO <sub>2</sub> (s)	-520.0
mercury(II) oxide (red)	HgO(s)	-90.8
mercury(II) sulfide (red)	HgS(s)	-58.2
methanal (formaldehyde)	CH <sub>2</sub> O(g)	-108.6
methane	CH <sub>4</sub> (g)	-74.6
methanoic acid (formic acid)	HCOOH(l)	-425.0
methanol	CH <sub>3</sub> OH(l)	-239.2
nickel(II) oxide	NiO(s)	-240.6
nitric acid	HNO <sub>3</sub> (l)	-174.1
nitrogen dioxide	NO <sub>2</sub> (g)	+33.2
nitrogen monoxide	NO(g)	+91.3
octane	C <sub>8</sub> H <sub>18</sub> (l)	-250.1
pentane	C <sub>5</sub> H <sub>12</sub> (l)	-173.5
phosphorus pentachloride	PCl <sub>5</sub> (s)	-443.5
phosphorus trichloride (liquid)	PCl <sub>3</sub> (l)	-319.7
phosphorus trichloride (vapour)	PCl <sub>3</sub> (g)	-287.0
potassium bromide	KBr(s)	-393.8
potassium chlorate	KClO <sub>3</sub> (s)	-397.7
potassium chloride	KCl(s)	-436.5
potassium hydroxide	KOH(s)	-424.6
propane	C <sub>3</sub> H <sub>8</sub> (g)	-103.8
silicon dioxide ( $\alpha$ -quartz)	SiO <sub>2</sub> (s)	-910.7
silver bromide	AgBr(s)	-100.4
silver chloride	AgCl(s)	-127.0
silver iodide	AgI(s)	-61.8
sodium bromide	NaBr(s)	-361.1
sodium chloride	NaCl(s)	-411.2
sodium hydroxide	NaOH(s)	-425.8
sodium iodide	NaI(s)	-287.8
sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> (s)	-2 226.1
sulfur dioxide	SO <sub>2</sub> (g)	-296.8
sulfuric acid	H <sub>2</sub> SO <sub>4</sub> (l)	-814.0
sulfur trioxide (liquid)	SO <sub>3</sub> (l)	-441.0
sulfur trioxide (vapour)	SO <sub>3</sub> (g)	-395.7
tin(II) chloride	SnCl <sub>2</sub> (s)	-325.1
tin(IV) chloride	SnCl <sub>4</sub> (l)	-511.3
tin(II) oxide	SnO(s)	-280.7
tin(IV) oxide	SnO <sub>2</sub> (s)	-577.6
water (liquid)	H <sub>2</sub> O(l)	-285.8
water (vapour)	H <sub>2</sub> O(g)	-241.8
zinc oxide	ZnO(s)	-350.5
zinc sulfide (sphalerite)	ZnS(s)	-206.0

## Solubility of Some Common Ionic Compounds in Water at 298.15 K

Ion	H <sup>+</sup> Na <sup>+</sup> , K <sup>+</sup> NH <sub>4</sub> <sup>+</sup> , NO <sub>3</sub> <sup>-</sup> ClO <sub>3</sub> <sup>-</sup> , ClO <sub>4</sub> <sup>-</sup> CH <sub>3</sub> COO <sup>-</sup>	F <sup>-</sup>	Cl <sup>-</sup> Br <sup>-</sup> I <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	CO <sub>3</sub> <sup>2-</sup> PO <sub>4</sub> <sup>3-</sup> SO <sub>3</sub> <sup>2-</sup>	IO <sub>3</sub> <sup>-</sup> OOC <sub>2</sub> COO <sup>2-</sup>	S <sup>2-</sup>	OH <sup>-</sup>
Solubility greater than or equal to 0.1 mol/L (very soluble)	most	most	most	most	H <sup>+</sup> Na <sup>+</sup> K <sup>+</sup> NH <sub>4</sub> <sup>+</sup>	Li <sup>+</sup> Co(IO <sub>3</sub> ) <sub>2</sub> Fe <sub>2</sub> (OOC <sub>2</sub> COO) <sub>3</sub>	Li <sup>+</sup> Mg <sup>2+</sup> Ca <sup>2+</sup>	Li <sup>+</sup> Sr <sup>2+</sup>
Solubility less than 0.1 mol/L (slightly soluble)	RbClO <sub>4</sub> CsClO <sub>4</sub> AgCH <sub>3</sub> COO Hg <sub>2</sub> (CH <sub>3</sub> COO) <sub>2</sub>	Li <sup>+</sup> Mg <sup>2+</sup> Ca <sup>2+</sup> Sr <sup>2+</sup> Ba <sup>2+</sup> Fe <sup>2+</sup> Hg <sub>2</sub> <sup>2+</sup> Pb <sup>2+</sup>	Cu <sup>+</sup> Ag <sup>+</sup> Hg <sub>2</sub> <sup>2+</sup> Hg <sup>2+</sup> Pb <sup>2+</sup>	Ca <sup>2+</sup> Sr <sup>2+</sup> Ba <sup>2+</sup> Ag <sup>+</sup> Hg <sub>2</sub> <sup>2+</sup> Pb <sup>2+</sup>	most	most	most	most

**Note:** This solubility table is only a guideline that is established using the  $K_{sp}$  values. A concentration of 0.1 mol/L corresponds to approximately 10 g/L to 30 g/L depending on molar mass.

### Flame Colour of Elements

Element	Symbol	Colour
lithium	Li	red
sodium	Na	yellow
potassium	K	violet
rubidium	Rb	violet
cesium	Cs	violet
calcium	Ca	yellowish red
strontium	Sr	scarlet red
barium	Ba	yellowish green
copper	Cu	blue to green
boron	B	yellowish green
lead	Pb	blue-white

**Note:** The flame test can be used to determine the identity of a metal or a metal ion. Blue to green indicates a range of colours that might appear.

**Table of Selected Standard Electrode Potentials\***

	<b>Reduction Half-Reaction</b>	<b>Electrical Potential <math>E^\circ</math> (V)</b>
	$F_2(g) + 2 e^- \rightleftharpoons 2 F^-(aq)$ .....	+ 2.87
$PbO_2(s) + SO_4^{2-}(aq) + 4 H^+(aq) + 2 e^-$	$\rightleftharpoons PbSO_4(s) + 2 H_2O(l)$ .....	+ 1.69
$MnO_4^-(aq) + 8 H^+(aq) + 5 e^-$	$\rightleftharpoons Mn^{2+}(aq) + 4 H_2O(l)$ .....	+ 1.51
	$Au^{3+}(aq) + 3 e^- \rightleftharpoons Au(s)$ .....	+ 1.50
$ClO_4^-(aq) + 8 H^+(aq) + 8 e^-$	$\rightleftharpoons Cl^-(aq) + 4 H_2O(l)$ .....	+ 1.39
	$Cl_2(g) + 2 e^- \rightleftharpoons 2 Cl^-(aq)$ .....	+ 1.36
$2 HNO_2(aq) + 4 H^+(aq) + 4 e^-$	$\rightleftharpoons N_2O(g) + 3 H_2O(l)$ .....	+ 1.30
$Cr_2O_7^{2-}(aq) + 14 H^+(aq) + 6 e^-$	$\rightleftharpoons 2 Cr^{3+}(aq) + 7 H_2O(l)$ .....	+ 1.23
$O_2(g) + 4 H^+(aq) + 4 e^-$	$\rightleftharpoons 2 H_2O(l)$ .....	+ 1.23
$MnO_2(s) + 4 H^+(aq) + 2 e^-$	$\rightleftharpoons Mn^{2+}(aq) + 2 H_2O(l)$ .....	+ 1.22
	$Br_2(l) + 2 e^- \rightleftharpoons 2 Br^-(aq)$ .....	+ 1.07
	$Hg^{2+}(aq) + 2 e^- \rightleftharpoons Hg(l)$ .....	+ 0.85
$OCl^-(aq) + H_2O(l) + 2 e^-$	$\rightleftharpoons Cl^-(aq) + 2 OH^-(aq)$ .....	+ 0.84
$2 NO_3^-(aq) + 4 H^+(aq) + 2 e^-$	$\rightleftharpoons N_2O_4(g) + 2 H_2O(l)$ .....	+ 0.80
	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ .....	+ 0.80
	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$ .....	+ 0.77
$O_2(g) + 2 H^+(aq) + 2 e^-$	$\rightleftharpoons H_2O_2(l)$ .....	+ 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
$SO_4^{2-}(aq) + 4 H^+(aq) + 2 e^-$	$\rightleftharpoons H_2SO_3(aq) + H_2O(l)$ .....	+ 0.17
	$Sn^{4+}(aq) + 2 e^- \rightleftharpoons Sn^{2+}(aq)$ .....	+ 0.15
$S(s) + 2 H^+(aq) + 2 e^-$	$\rightleftharpoons H_2S(aq)$ .....	+ 0.14
	$AgBr(s) + e^- \rightleftharpoons Ag(s) + Br^-(aq)$ .....	+ 0.07
	$2 H^+(aq) + 2 e^- \rightleftharpoons H_2(g)$ .....	0.00
	$Pb^{2+}(aq) + 2 e^- \rightleftharpoons Pb(s)$ .....	- 0.13
	$Sn^{2+}(aq) + 2 e^- \rightleftharpoons Sn(s)$ .....	- 0.14
	$AgI(s) + e^- \rightleftharpoons Ag(s) + I^-(aq)$ .....	- 0.15
	$Ni^{2+}(aq) + 2 e^- \rightleftharpoons Ni(s)$ .....	- 0.26
	$Co^{2+}(aq) + 2 e^- \rightleftharpoons Co(s)$ .....	- 0.28
	$PbSO_4(s) + 2 e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ .....	- 0.36
$Se(s) + 2 H^+(aq) + 2 e^-$	$\rightleftharpoons H_2Se(aq)$ .....	- 0.40
	$Cd^{2+}(aq) + 2 e^- \rightleftharpoons Cd(s)$ .....	- 0.40
	$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$ .....	- 0.41
	$Fe^{2+}(aq) + 2 e^- \rightleftharpoons Fe(s)$ .....	- 0.45
$NO_2^-(aq) + H_2O(l) + e^-$	$\rightleftharpoons NO(g) + 2 OH^-(aq)$ .....	- 0.46
	$Ag_2S(s) + 2 e^- \rightleftharpoons 2 Ag(s) + S^{2-}(aq)$ .....	- 0.69
	$Zn^{2+}(aq) + 2 e^- \rightleftharpoons Zn(s)$ .....	- 0.76
$2 H_2O(l) + 2 e^-$	$\rightleftharpoons H_2(g) + 2 OH^-(aq)$ .....	- 0.83
	$Cr^{2+}(aq) + 2 e^- \rightleftharpoons Cr(s)$ .....	- 0.91
	$Se(s) + 2 e^- \rightleftharpoons Se^{2-}(aq)$ .....	- 0.92
$SO_4^{2-}(aq) + H_2O(l) + 2 e^-$	$\rightleftharpoons SO_3^{2-}(aq) + 2 OH^-(aq)$ .....	- 0.93
	$Al^{3+}(aq) + 3 e^- \rightleftharpoons Al(s)$ .....	- 1.66
	$Mg^{2+}(aq) + 2 e^- \rightleftharpoons Mg(s)$ .....	- 2.37
	$Na^+(aq) + e^- \rightleftharpoons Na(s)$ .....	- 2.71
	$Ca^{2+}(aq) + 2 e^- \rightleftharpoons Ca(s)$ .....	- 2.87
	$Ba^{2+}(aq) + 2 e^- \rightleftharpoons Ba(s)$ .....	- 2.91
	$K^+(aq) + e^- \rightleftharpoons K(s)$ .....	- 2.93
	$Li^+(aq) + e^- \rightleftharpoons Li(s)$ .....	- 3.04

\*For 1.0 mol/L solutions at 298.15 K (25.00 °C) and a pressure of 101.325 kPa

## Relative Strengths of Acids and Bases at 298.15 K

Common Name IUPAC / Systematic Name	Acid Formula	Conjugate Base Formula	$K_a$
perchloric acid aqueous hydrogen perchlorate	$\text{HClO}_4(\text{aq})$	$\text{ClO}_4^-(\text{aq})$	very large
hydroiodic acid aqueous hydrogen iodide	$\text{HI}(\text{aq})$	$\text{I}^-(\text{aq})$	very large
hydrobromic acid aqueous hydrogen bromide	$\text{HBr}(\text{aq})$	$\text{Br}^-(\text{aq})$	very large
hydrochloric acid aqueous hydrogen chloride	$\text{HCl}(\text{aq})$	$\text{Cl}^-(\text{aq})$	very large
sulfuric acid aqueous hydrogen sulfate	$\text{H}_2\text{SO}_4(\text{aq})$	$\text{HSO}_4^-(\text{aq})$	very large
nitric acid aqueous hydrogen nitrate	$\text{HNO}_3(\text{aq})$	$\text{NO}_3^-(\text{aq})$	very large
hydronium ion	$\text{H}_3\text{O}^+(\text{aq})$	$\text{H}_2\text{O}(\text{l})$	1
oxalic acid	$\text{HOOC-COOH}(\text{aq})$	$\text{HOOC-COO}^-(\text{aq})$	$5.6 \times 10^{-2}$
sulfurous acid aqueous hydrogen sulfite	$\text{H}_2\text{SO}_3(\text{aq})$	$\text{HSO}_3^-(\text{aq})$	$1.4 \times 10^{-2}$
hydrogen sulfate ion	$\text{HSO}_4^-(\text{aq})$	$\text{SO}_4^{2-}(\text{aq})$	$1.0 \times 10^{-2}$
phosphoric acid aqueous hydrogen phosphate	$\text{H}_3\text{PO}_4(\text{aq})$	$\text{H}_2\text{PO}_4^-(\text{aq})$	$6.9 \times 10^{-3}$
citric acid 2-hydroxy-1,2,3-propanetricarboxylic acid	$\text{C}_3\text{H}_5\text{O}(\text{COOH})_3(\text{aq})$	$\text{C}_3\text{H}_5\text{O}(\text{COOH})_2\text{COO}^-(\text{aq})$	$7.4 \times 10^{-4}$
hydrofluoric acid aqueous hydrogen fluoride	$\text{HF}(\text{aq})$	$\text{F}^-(\text{aq})$	$6.3 \times 10^{-4}$
nitrous acid aqueous hydrogen nitrite	$\text{HNO}_2(\text{aq})$	$\text{NO}_2^-(\text{aq})$	$5.6 \times 10^{-4}$
formic acid methanoic acid	$\text{HCOOH}(\text{aq})$	$\text{HCOO}^-(\text{aq})$	$1.8 \times 10^{-4}$
hydrogen oxalate ion	$\text{HOOC-COO}^-(\text{aq})$	$\text{OOC-COO}^{2-}(\text{aq})$	$1.5 \times 10^{-4}$
lactic acid 2-hydroxypropanoic acid	$\text{C}_2\text{H}_5\text{O-COOH}(\text{aq})$	$\text{C}_2\text{H}_5\text{O-COO}^-(\text{aq})$	$1.4 \times 10^{-4}$
ascorbic acid 2(1,2-dihydroxyethyl) -4,5-dihydroxy-furan-3-one	$\text{H}_2\text{C}_6\text{H}_6\text{O}_6(\text{aq})$	$\text{HC}_6\text{H}_6\text{O}_6^-(\text{aq})$	$9.1 \times 10^{-5}$

benzoic acid benzenecarboxylic acid	$C_6H_5COOH(aq)$	$C_6H_5COO^-(aq)$	$6.3 \times 10^{-5}$
acetic acid ethanoic acid	$CH_3COOH(aq)$	$CH_3COO^-(aq)$	$1.8 \times 10^{-5}$
dihydrogen citrate ion	$C_3H_5O(COOH)_2COO^-(aq)$	$C_3H_5O(COOH)(COO)_2^{2-}(aq)$	$1.7 \times 10^{-5}$
butanoic acid	$C_3H_7COOH(aq)$	$C_3H_7COO^-(aq)$	$1.5 \times 10^{-5}$
propanoic acid	$C_2H_5COOH(aq)$	$C_2H_5COO^-(aq)$	$1.3 \times 10^{-5}$
carbonic acid ( $CO_2 + H_2O$ ) aqueous hydrogen carbonate	$H_2CO_3(aq)$	$HCO_3^-(aq)$	$4.5 \times 10^{-7}$
hydrogen citrate ion	$C_3H_5O(COOH)(COO)_2^{2-}(aq)$	$C_3H_5O(COO)_3^{3-}(aq)$	$4.0 \times 10^{-7}$
hydrosulfuric acid aqueous hydrogen sulfide	$H_2S(aq)$	$HS^-(aq)$	$8.9 \times 10^{-8}$
hydrogen sulfite ion	$HSO_3^-(aq)$	$SO_3^{2-}(aq)$	$6.3 \times 10^{-8}$
dihydrogen phosphate ion	$H_2PO_4^-(aq)$	$HPO_4^{2-}(aq)$	$6.2 \times 10^{-8}$
hypochlorous acid aqueous hydrogen hypochlorite	$HOCl(aq)$	$OCl^-(aq)$	$4.0 \times 10^{-8}$
hydrocyanic acid aqueous hydrogen cyanide	$HCN(aq)$	$CN^-(aq)$	$6.2 \times 10^{-10}$
ammonium ion	$NH_4^+(aq)$	$NH_3(aq)$	$5.6 \times 10^{-10}$
hydrogen carbonate ion	$HCO_3^-(aq)$	$CO_3^{2-}(aq)$	$4.7 \times 10^{-11}$
hydrogen ascorbate ion	$HC_6H_6O_6^-(aq)$	$C_6H_6O_6^{2-}(aq)$	$2.0 \times 10^{-12}$
hydrogen phosphate ion	$HPO_4^{2-}(aq)$	$PO_4^{3-}(aq)$	$4.8 \times 10^{-13}$
water	$H_2O(l)$	$OH^-(aq)$	$1.0 \times 10^{-14}$

**Note:** An approximation may be used instead of the quadratic formula when the concentration of  $H_3O^+$  produced is less than 5% of the original acid concentration (or the concentration of the acid is 1 000 times greater than the  $K_a$ ). The same approximation can also be used for weak bases. The formula of the carboxylic acids have been written so that the COOH group can be easily recognized. Either the common or IUPAC name is acceptable.

### Acid–Base Indicators at 298.15 K

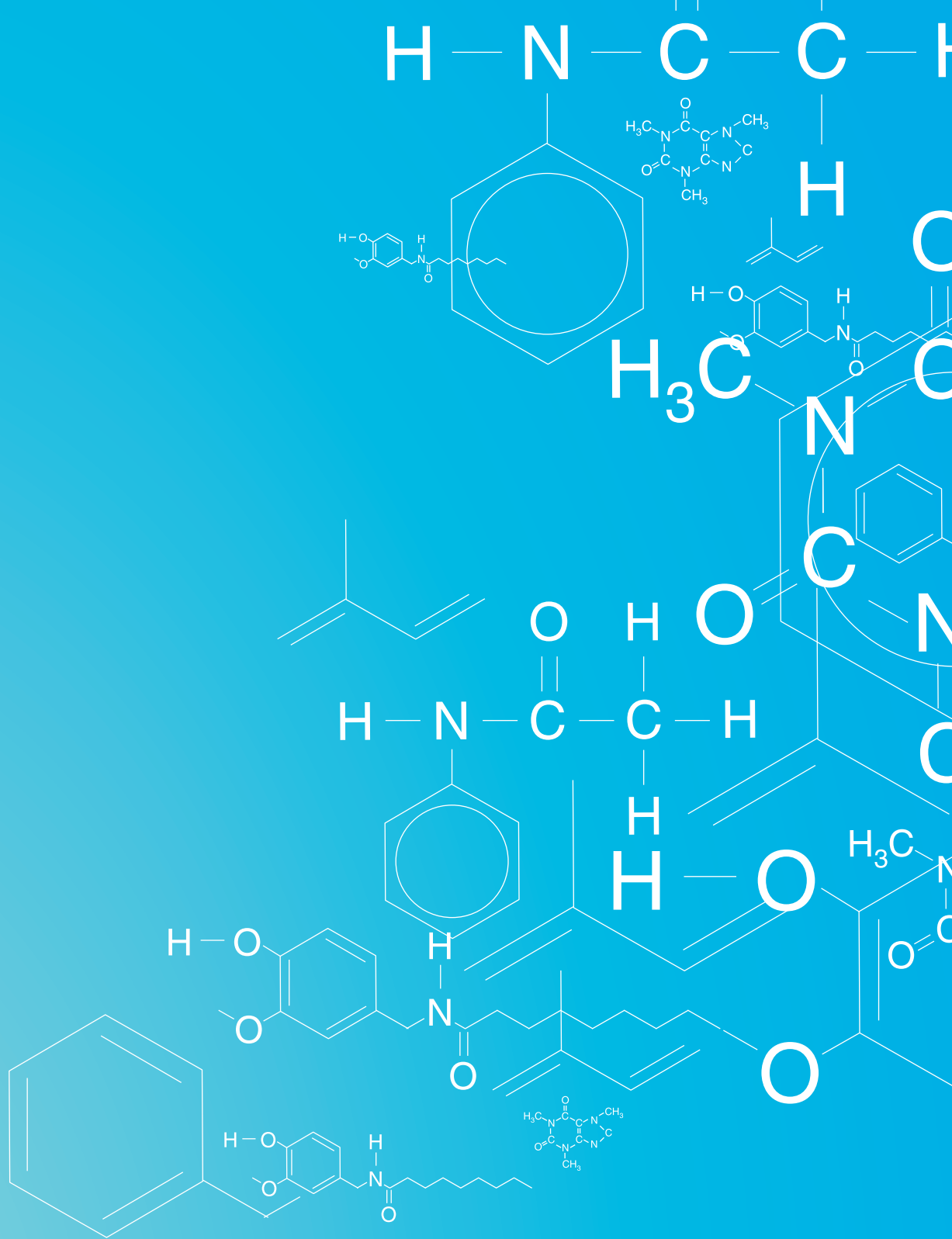
Indicator	Suggested Abbreviation(s)	pH Range	Colour Change as pH Increases	$K_a$
methyl violet	HMv(aq) / Mv <sup>-</sup> (aq)	0.0 – 1.6	yellow to blue	$\sim 2 \times 10^{-1}$
cresol red	H <sub>2</sub> Cr(aq) / HCr <sup>-</sup> (aq)	0.0 – 1.0	red to yellow	$\sim 3 \times 10^{-1}$
	HCr <sup>-</sup> (aq) / Cr <sup>2-</sup> (aq)	7.0 – 8.8	yellow to red	$3.5 \times 10^{-9}$
thymol blue	H <sub>2</sub> Tb(aq) / HTb <sup>-</sup> (aq)	1.2 – 2.8	red to yellow	$2.2 \times 10^{-2}$
	HTb <sup>-</sup> (aq) / Tb <sup>2-</sup> (aq)	8.0 – 9.6	yellow to blue	$6.3 \times 10^{-10}$
orange IV	HOr(aq) / Or <sup>-</sup> (aq)	1.4 – 2.8	red to yellow	$\sim 1 \times 10^{-2}$
methyl orange	HMo(aq) / Mo <sup>-</sup> (aq)	3.2 – 4.4	red to yellow	$3.5 \times 10^{-4}$
bromocresol green	HBg(aq) / Bg <sup>-</sup> (aq)	3.8 – 5.4	yellow to blue	$1.3 \times 10^{-5}$
methyl red	HMr(aq) / Mr <sup>-</sup> (aq)	4.8 – 6.0	red to yellow	$1.0 \times 10^{-5}$
chlorophenol red	HCh(aq) / Ch <sup>-</sup> (aq)	5.2 – 6.8	yellow to red	$5.6 \times 10^{-7}$
bromothymol blue	HBb(aq) / Bb <sup>-</sup> (aq)	6.0 – 7.6	yellow to blue	$5.0 \times 10^{-8}$
phenol red	HPr(aq) / Pr <sup>-</sup> (aq)	6.6 – 8.0	yellow to red	$1.0 \times 10^{-8}$
phenolphthalein	HPh(aq) / Ph <sup>-</sup> (aq)	8.2 – 10.0	colourless to pink	$3.2 \times 10^{-10}$
thymolphthalein	HTh(aq) / Th <sup>-</sup> (aq)	9.4 – 10.6	colourless to blue	$1.0 \times 10^{-10}$
alizarin yellow R	HAY(aq) / AY <sup>-</sup> (aq)	10.1 – 12.0	yellow to red	$6.9 \times 10^{-12}$
indigo carmine	HIc(aq) / Ic <sup>-</sup> (aq)	11.4 – 13.0	blue to yellow	$\sim 6 \times 10^{-12}$
1,3,5–trinitrobenzene	HNb(aq) / Nb <sup>-</sup> (aq)	12.0 – 14.0	colourless to orange	$\sim 1 \times 10^{-13}$

### Colours of Common Aqueous Ions

Ionic Species	Solution Concentration	
	1.0 mol/L	0.010 mol/L
chromate	yellow	pale yellow
chromium(III)	blue-green	green
chromium(II)	dark blue	pale blue
cobalt(II)	red	pink
copper(I)	blue-green	pale blue-green
copper(II)	blue	pale blue
dichromate	orange	pale orange
iron(II)	lime green	colourless
iron(III)	orange-yellow	pale yellow
manganese(II)	pale pink	colourless
nickel(II)	blue-green	pale blue-green
permanganate	deep purple	purple-pink







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