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School Curriculum and Standards Authority

CHEMISTRY
ATAR COURSE

DATA BOOKLET

2019

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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											5 B boron 10.82	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
11 Na sodium 22.99	12 Mg magnesium 24.31											13 Aℓ aluminium 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.07	17 Cℓ chlorine 35.45	18 Ar argon 39.95
19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.88	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 72.59	33 As arsenic 74.92	34 Se selenium 78.96	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 95.94	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 *La lanthanum 138.9	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.9	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.08	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 226.0	89–103 **Ac actinium	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 oganesson

Key:

Atomic number
Symbol
Name
Standard atomic weight

* Lanthanide series	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
** Actinide series	90 Th thorium 232.0	91 Pa protactinium	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 (2016)]

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	=	$-\log_{10}[H^+]$

Units

Volumes are given in the units of litres (L), or millilitres (mL)
Temperatures are given in the units of degrees Celsius (°C) or kelvin (K)
It may be assumed that 0.0 °C = 273.15 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 J K^{-1} mol^{-1}
Avogadro constant, N = 6.022×10^{23} 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, $Ba(OH)_2$ NH_4OH*, AgOH**	$Ca(OH)_2$, $Sr(OH)_2$
Most carbonates	Na_2CO_3, K_2CO_3, $(NH_4)_2CO_3$	
Most phosphates	Na_3PO_4, K_3PO_4, $(NH_4)_3PO_4$	
Most sulfides	Na_2S, K_2S, $(NH_4)_2S$	

* NH_3 dissolves in water to form both NH_3 (aq) and NH_4^+(aq)/OH^-(aq)
** Ag^+(aq) reacts with OH^-(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
$C\ell_2(g)$	greenish-yellow
$Br_2(\ell)$	red
$I_2(g)$	purple

Halogen	Colour of halogen in aqueous solution
$C\ell_2(aq)$	pale yellow
$Br_2(aq)$	orange
$I_2(aq)$	brown

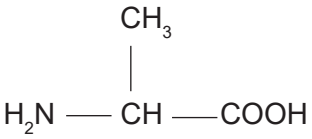
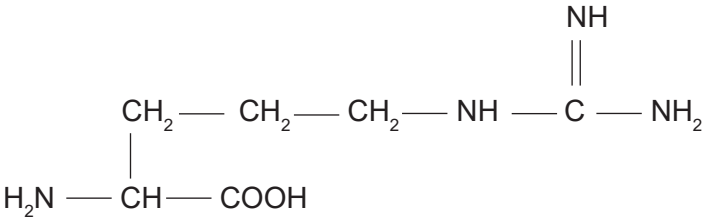
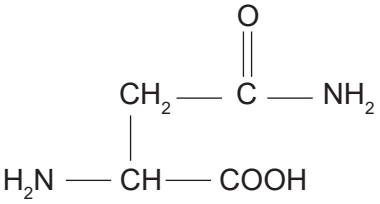
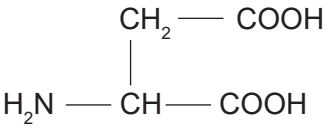
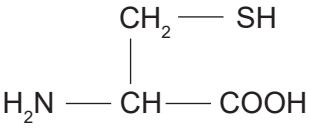
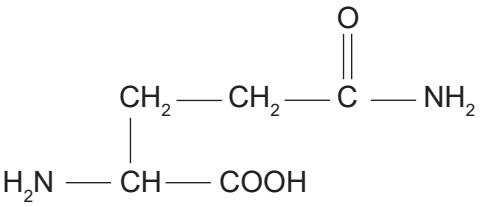
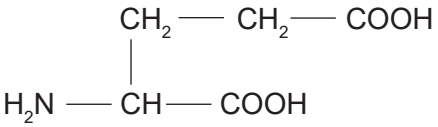
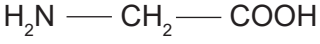
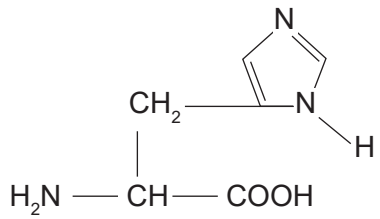
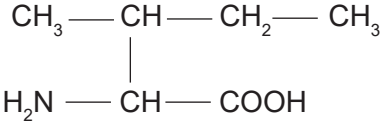
Halogen	Colour of halogen in organic solvent
Br_2	red
I_2	purple

Coloured ions in aqueous solution

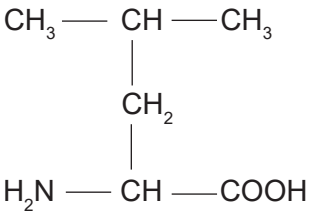
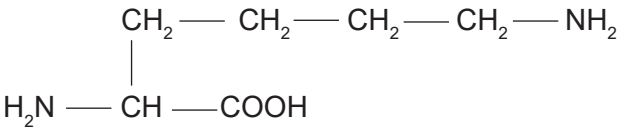
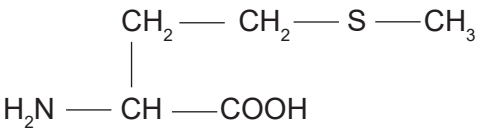
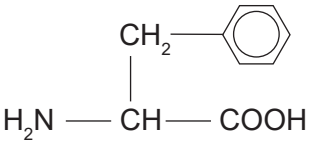
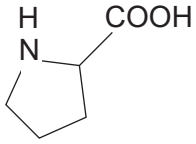
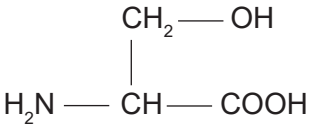
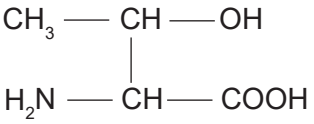
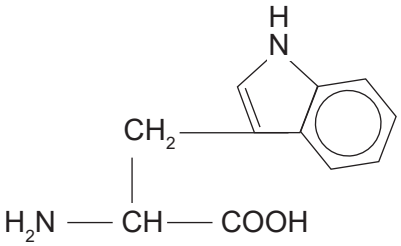
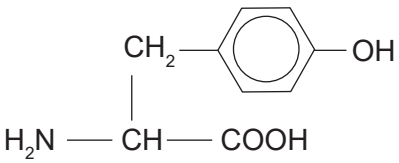
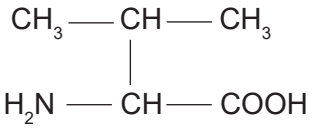
Cation	Colour
Cr^{3+}	deep green
Co^{2+}	pink
Cu^{2+}	blue
Fe^{2+}	pale green
Fe^{3+}	pale brown
Mn^{2+}	pale pink
Ni^{2+}	green

Anion	Colour
CrO_4^{2-}	yellow
$Cr_2O_7^{2-}$	orange
MnO_4^-	purple

α–amino acids

Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	
histidine	His	
isoleucine	Ile	

α–amino acids

Name	Symbol	Structure
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

Standard Reduction Potentials at 25 °C

Half-reaction	E°(volts)
$F_2(g) + 2\ e^- \rightleftharpoons 2\ F^-(aq)$	+ 2.89
$H_2O_2(aq) + 2\ H^+(aq) + 2\ e^- \rightleftharpoons 2\ H_2O(\ell)$	+ 1.76
$PbO_2(s) + SO_4^{2-}(aq) + 4\ H^+(aq) + 2\ e^- \rightleftharpoons PbSO_4(s) + 2\ H_2O(\ell)$	+ 1.69
$2\ HC\ell O(aq) + 2\ H^+(aq) + 2\ e^- \rightleftharpoons C\ell_2(g) + 2\ H_2O(\ell)$	+ 1.63
$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightleftharpoons Mn^{2+}(aq) + 4\ H_2O(\ell)$	+ 1.51
$Au^{3+}(aq) + 3\ e^- \rightleftharpoons Au(s)$	+ 1.50
$HC\ell O(aq) + H^+(aq) + 2\ e^- \rightleftharpoons C\ell^-(aq) + H_2O(\ell)$	+ 1.49
$PbO_2(s) + 4\ H^+(aq) + 2\ e^- \rightleftharpoons Pb^{2+}(aq) + 2\ H_2O(\ell)$	+ 1.46
$C\ell_2(g) + 2\ e^- \rightleftharpoons 2\ C\ell^-(aq)$	+ 1.36
$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^- \rightleftharpoons 2\ Cr^{3+}(aq) + 7\ H_2O(\ell)$	+ 1.36
$O_2(g) + 4\ H^+(aq) + 4\ e^- \rightleftharpoons 2\ H_2O(\ell)$	+ 1.23
$Br_2(\ell) + 2\ e^- \rightleftharpoons 2\ Br^-(aq)$	+ 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
$O_2(g) + 2\ H_2O(\ell) + 4\ e^- \rightleftharpoons 4\ OH^-(aq)$	+ 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
$2\ H_2O(\ell) + 2\ e^- \rightleftharpoons H_2(g) + 2\ OH^-(aq)$	– 0.83
$Mn^{2+}(aq) + 2\ e^- \rightleftharpoons Mn(s)$	– 1.18
$A\ell^{3+}(aq) + 3\ e^- \rightleftharpoons A\ell(s)$	– 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. (2008). *SI Chemical Data* (6th ed.). Queensland: John Wiley & Sons Australia, Ltd.]