PERIODICITY AND NOMENCLATURE Chapter 3

"...I have tried to base a system on the magnitudes of the atomic weights of the elements. My first attempt in this respect was the following: I chose the smallest atomic weights and arranged them according to the sizes of their atomic weights. This showed that there existed a periodicity in the properties of these simple substances and that even according to their atomicity [valence] the elements followed one another in the arithmetical sequence of their atomic weights." Dimitri Ivanovich Mendeleyev (Mendeleev), 1869

"The periodicity in the properties of the elements is connected with the continuing build up and completion of the various electron groups that takes place with increasing atomic number." Niels Henrik David Bohr, 1923 (Nobel Prize in Physics in 1922 "for his services in the investigation of the structure of atoms and of the radiation emanating from them".)

1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	(8)	8B (9)	(10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.64	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.789
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	71 **Lu** 174.97	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	103 **Lr** (262)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 (285)	113 (284)	114 (289)	115 (288)	116 (292)		

Lanthanides	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04
Actinides	89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)

Major Classification

- metals
- nonmetalloids
- metalloids

Periods

Groups

- main group
- transition
- lanthanides
- actinides

Main Group Elements

- alkali metals
- alkaline earth metals
- chalcogens
- halogens
- noble gases

Electronegativity

Nomenclature of Typical Ions

fluoride	F^-	hydroxide	OH^-
chloride	Cl^-	hydride	H^-
bromide	Br^-	sulfide	S^{2-}
iodide	I^-	nitride	N^{3-}
oxide	O^{2-}	azide	N_3^-
peroxide	O_2^{2-}	cyanide	CN^-
superoxide	O_2^-		
carbonate	CO_3^{2-}	sulfate	SO_4^{2-}
hydrogen carbonate	HCO_3^-	hydrogen sulfate	HSO_4^-
nitrite	NO_2^-	thiocyanate	SCN^-
nitrate	NO_3^-	chromate	CrO_4^{2-}
phosphate	PO_4^{3-}	dichromate	$Cr_2O_7^{2-}$
hydrogen phosphate	HPO_4^{2-}	permanganate	MnO_4^-
dihydrogen phosphate	$H_2PO_4^-$	hypochlorite	ClO^-
arsenate	AsO_4^{3-}	chlorite	ClO_2^-
sulfite	SO_3^{2-}	chlorate	ClO_3^-
hydrogen sulfite	HSO_3^-	perchlorate	ClO_4^-
hydronium	H_3O^+	mercury(I)	Hg_2^{2+}
ammonium	NH_4^+		

Positive Ions (Cations)[1]

Monatomic		Polyatomic
Only One Ion Possible	More Than One Ion Possible	
Rule: Name of element + "ion". **Examples:** Na^+ sodium ion Mg^{2+} magnesium ion H^+ hydrogen ion Al^{3+} aluminum ion Ag^+ silver ion Zn^{2+} zinc ion Cd^{2+} cadmium ion **Comment:** The number of positive charges is *not* indicated in the name because it is not necessary, *e.g.*, Group I elements (1+) and Group II elements (2+).	**Rule:** (a) Newer rule: positive charges indicated by a roman numeral. **Examples:** Fe^{2+} iron(II) ion Fe^{3+} iron(III) ion Cu^+ copper(I) ion Cu^{2+} copper(II) ion (b) Older rule (but still used): Latin stem for the element + "ous" for the lesser charge and + "ic" for the greater charge. (We will use newer rule.) **Examples:** Fe^{2+} ferrous ion Fe^{3+} ferric ion	**Rule:** Special cases. **Examples:** NH_4^+ ammonium ion H_3O^+ hydronium ion Hg_2^{2+} mercury(I) ion **Comment:** Hg_2^{2+} is $Hg^+ - Hg^+$ but Hg^+ does not exist, therefore mercury(I) ion is Hg_2^{2+}. ($Hg^{2+}$is mercury(II) ion, but that is a monatomic ion.)

Negative Ions (Anions)[1]

Monatomic	Oxoanions (Containing Oxygen)	Others and Exceptions	Oxoanions Containing Hydrogen
Rule: Stem of the element name + "ide". **Examples:** H^- hydride ion F^- fluoride ion O^{2-} oxide ion N^{3-} nitride ion	**Rule:** least oxygen: hypo_ite ion less oxygen: _ite ion more oxygen: _ate ion most oxygen: per_ate ion **Examples:** ClO^- hypochlorite ion ClO_2^- chlorite ion ClO_3^- chlorate ion ClO_4^- perchlorate ion SO_3^{2-} sulfite ion SO_4^{2-} sulfate ion **Comment:** Halogens (except F) form all four ions. When only two of the four ions exist, they are the -ite and the -ate ions.	**Rule:** These items do not follow any rules: they must be memorized. **Examples:** OH^- hydroxide ion O_2^{2-} peroxide ion O_2^- superoxide ion CN^- cyanide ion N_3^- azide ion SCN^- thiocyanate ion AsO_4^{3-} arsenate ion MnO_4^- permanganate ion CrO_4^{2-} chromate ion $Cr_2O_7^{2-}$ dichromate ion	**Rule:** H - oxoanion: "hydrogen" + name of oxoanion or "bi" + oxoanion H_2 - oxoanion: "dihydrogen" + name of oxoanion **Examples:** HCO_3^- hydrogen carbonate (or bicarbonate) ion HSO_4^- hydrogen sulfate (or bisulfate) ion HPO_4^{2-} hydrogen phosphate $H_2PO_4^-$ dihydrogen phosphate ion **Comment:** H_2CO_3 is not named according to this rule because it is a compound and not an ion.

[1]adapted from Gerhard Lind, *Journal of Chemical Education*, **69**, 613 (1992)

Compounds (Metalloid Can Be Substituted for Nonmetal)[1]

Ionic (Cation-Anion)			Covalent (Nonmetal-Nonmetal)
Compounds Containing Hydrogen			
H-Metal	H-Nonmetal	H-Oxoanion	
Rule: Name of cation + name of anion (word "ion" dropped). **Examples:** $ZnSO_4$ zinc sulfate $NaNO_2$ sodium nitrite $CaCl_2$ calcium chloride Fe_3N_2 iron(II) nitride Li_2CO_3 lithium carbonate NH_4I ammonium iodide $Cu(IO_3)_2$ copper(II) iodate BaH_2 barium hydride **Comment:** The name does not indicate the numbers of cations and anions because there is only one possibility for the ions to combine to form a compound.	**Rule 1:** (without the presence of H_2O) hydrogen _ide **Examples:** HCl hydrogen chloride HF hydrogen fluoride H_2S hydrogen sulfide H_2Se hydrogen selenide **Rule 2:** (H acids) (when dissolved in H_2O) hydro_ic acid **Examples:** HCl hydrochloric acid HF hydrofluoric acid H_2S hydrosulfuric acid H_2Se hydroselenic acid **Comment:** (a) These H-containing compounds are named as if they were ionic. (b) Often the (*aq*) in the formulas of the acids is omitted when it is obvious from the context that they are acids.	**Rule 1:** (without the presence of H_2O) like ionic compounds: cation + anion hydrogen hypo_ite hydrogen _ite hydrogen _ate hydrogen per_ate **Rule 2:** (HO acids) (when dissolved in H_2O) hypo_ous acid _ous acid _ic acid per_ic acid **Examples:** HClO hypochlorous acid $HClO_2$ chlorous acid $HClO_3$ chloric acid $HClO_4$ perchloric acid HNO_2 nitrous acid HNO_3 nitric acid H_2SO_3 sulfurous acid H_2SO_4 sulfuric acid H_3PO_4 phosphoric acid **Comment:** The (*aq*) is usually omitted.	**Rule:** (a) Less electronegative element first[2] (exceptions: when one of the elements is hydrogen). (b) Greekprefixes specify number of atoms of each kind. (c) Prefix mono at beginning is dropped. **Prefixes:** 1 = mono 6 = hexa 2 = di 7 = hepta 3 = tri 8 = octa 4 = tetra 9 = nona 5 = penta 10 = deca **Examples:** SCl_6 sulfur hexachloride N_2O_4 dinitrogen tetroxide CO carbon monoxide CO_2 carbon dioxide NO_2 nitrogen dioxide N_2O dinitrogen monoxide **Comment:** Tetraoxide becomes tetroxide, monooxide becomes monoxide, etc., so that the name sounds better.

[1] adapted from Gerhard Lind, *Journal of Chemical Education*, **69**, 613 (1992)

[2] ordering of elements in formula of binary molecular compounds: order according to Group number, bottom to top, H, O need to be memorized:

	B	Si	C	Sb	As	P	N	H	Te	Se	S	I	Br	Cl	O	F
Group #:	3A	4A		5A					6A			7A				