Names and Formulas in General Chemistry

Mastering names and formulas takes *practice* – the more you do, the more you remember and the easier it gets! This is a skill that will help to open up the subject of chemistry to you, because after all, chemical names are an integral part of the language of chemistry. The following notes are really intended to be more of reminders, as your textbook should have this information in much better detail and organization. The rules below pertain to the English names, but even so, there are variations, such as "sulfate" (American spelling) and "sulphate" (British spelling), and "aluminum" (American) and "aluminium" (British).

Memorize (some things in chemistry simply *have* to be memorized!) the names and charges of common ions such as chloride, nitrate, sulfate, sulfite, etc. This will happen automatically with practice. Use the periodic table to determine the charges of common single atom (monatomic) cations and anions: Group(charge) 1A(1+), 2A(2+), 3A(3+), 7A(1–), 6A(2–), 5A(3– for N, P, and As). You can many times easily deduce the charge of an ion that you're not sure about from another formula with the same ion in it. For example, what was the sulfate ion's charge? Luckily, I remember the formula of sodium sulfate: Na_2SO_4. Since Na ion is +1 (Group 1A) and there are two of them in the formula, SO_4 ion must therefore be –2, SO_4^{2-}. Easy! Incidentally, when you write the charge with the formula of an ion, the convention nowadays is like this: Na^+, Ca^{2+}, PO_4^{3-} rather than Na^{+1}, Ca^{+2} or PO_4^{-3}. *Oxidation numbers* of atoms (sometimes but not *necessarily* the actual charge of the atom), *are* normally written +1, +2, –3, etc.

Ionic Compounds
Formulas of ionic compounds are by their nature *empirical*, or *simplest*, formulas, which have the simplest whole numbers of positive and negative ions that give a charge-balanced formula. The formula of sodium chloride is always NaCl, never "Na_2Cl_2." If an equation has two sodium chlorides in it, we would use a *coefficient* of two: *2* NaCl. A case that looks like an exception, but is not, is mercurous chloride, or mercury(I) chloride, which has the formula Hg_2Cl_2 instead of HgCl. This is because the mercurous ion occurs as an unusual *diatomic* metal cation, Hg_2^{2+} with a *covalent bond* between the two Hg^+ ions. Remember that when naming ionic compounds (in English), *the positive ion is always named first*, and likewise with the formulas also. Sodium chloride, not "chloride sodium;" NaCl, not "ClNa." Note the "ide" ending of single atom negative ions: sodium chlor*ide* and not "sodium chlorine."

Binary Molecular Compounds
Names of *binary molecular* compounds (which contain only two different elements, normally nonmetals, and do not contain positive and negative ions) can contain the prefixes mono, di, tri, tetra, penta, etc. Normally, names of *ionic* compounds do *not* use these prefixes to indicate the number of positive or negative ions. $CaCl_2$ is calcium chloride, *not* "calcium dichloride". However, aluminum chloride, $AlCl_3$, is sometimes called aluminum trichloride which is not incorrect in this case because it actually *is* a molecular compound (it has very polar aluminum-chlorine covalent bonds) even though it looks like it should be ionic since it contains metal and nonmetal elements typical of ionic compounds. MnO_2 is often called manganese dioxide rather than manganese(IV) oxide for the same reason. Usually, it is best to play it safe with compounds like these and use the ionic names: $FeCl_3$ is ferric chloride or iron(III) chloride rather than "iron trichloride." PCl_3, a molecular compound (expected since only nonmetallic elements are present), is commonly called phosphorus trichloride, but is sometimes called "phosphorus(III) chloride." The "(III)" in the latter name, called the Stock name, would indicate the *oxidation state* rather than an actual charge of the phosphorus atom (see variable charges, below).

Acid Names
Acid names should be used when specified or usually when the acid is dissolved in water. For example, hydrogen chloride, HCl (g), which is a gaseous *molecular* compound, becomes *hydrochloric acid*, HCl (aq) a strong acid which exists as completely separated H^+ and Cl^- *ions* in aqueous solution. H_2SO_4 is normally always named by its acid name sulfuric acid, *not* "dihydrogen sulfate;" likewise HNO_3 is nitric acid and not "hydrogen nitrate." H_2S (g) is hydrogen sulfide or dihydrogen sulfide, a gaseous molecular compound. In aqueous solution, H_2S (aq), the acid name hydrosulfuric acid (a weak acid) will normally be

used, especially in the context of acid behavior. Another common weak acid is acetic acid, $HC_2H_3O_2$, which is found in vinegar. In this case, as with other common acids such as sulfuric acid, the acid name is always used; "hydrogen acetate" is *not* correct. (Acetic acid belongs to a class of organic compounds called *carboxylic acids*. These have their own special nomenclature rules as do the many other classes of organic compounds.)

Handling Variable Charges
Many positive ions can have more than one charge and in those cases the charge *must* be specified in the name. You can indicate the positive charge with a Roman numeral in parentheses (known as the Stock number after the German chemist Alfred Stock), or by using the common name endings *ous* (for the lower common charge) or *ic* (for the higher common charge). Since iron can form +2 or +3 ions commonly, the names of ionic iron compounds must be unambiguous in this regard. $FeCl_2$ is iron(II) chloride or ferrous chloride, *not* "iron chloride." On the other hand, since the calcium ion, for example, *always* has the *same* charge (+2), we call $CaCl_2$ simply calcium chloride and not "calcium(II) chloride" because we know automatically that the charge of calcium ion is +2.

Oxyanions
Remember, with the oxyanion (or "oxoanion") names that the "ite" ion simply has one less oxygen than the "ate" ion, the charge is still the same. Na_2SO_4 = sodium sulf*ate*, Na_2SO_3 = sodium sulf*ite*. These translate into the acid names sulfur*ic* acid, H_2SO_4, and sulfur*ous* acid, H_2SO_3. Also, if the oxyanion has one *more* oxygen than the "ate" ion, add the prefix *per* to the ate ion name, and if there is one *less* oxygen than the "ite" ion, add the prefix *hypo* to the ite name. You probably have the chlorate series in your textbook as an example:

ClO_4^- = *per*chlorate ion (one more oxygen than chlorate)
ClO_3^- = chlor*ate* ion
ClO_2^- = chlor*ite* ion
ClO^- = *hypo*chlorite ion (one less oxygen than chlorite)

And the corresponding acid names:

$HClO_4$ = *per*chloric acid
$HClO_3$ = chlor*ic* acid
$HClO_2$ = chlor*ous* acid
HClO = *hypo*chlorous acid

IUPAC Names
Systematic names from the IUPAC rules (International Union of Pure and Applied Chemistry) are sometimes used to name complex inorganic compounds (the IUPAC rules are the standard for organic compounds). Here are some examples:

$NaClO_4$ = sodium tetraoxochlorate(VII)
Na_2SO_4 = sodium tetraoxosulfate(VI)
Na_2SO_3 = sodium trioxosulfate(IV)
$NaAlCl_4$ = sodium tetrachloroaluminate(III)

While the last name is in common use, the other three compounds (and most other inorganic compounds) are almost always named according to the common rules outlined above - sodium perchlorate, sodium sulfate, and sodium sulfite. Other examples of IUPAC names of inorganic compounds may be found by searching the ChEBI (Chemical Entities of Biological Interest) database.

Exercises

Some excellent practice problems can be found here, from John L. Park's great ChemTeam site.

Naming: Name the following ionic, molecular, or acid compounds:

1. $NaNO_3$
2. KI
3. $BaCl_2$
4. PCl_3
5. $ZnSO_4$
6. Al_2O_3
7. $CaCO_3$
8. $(NH_4)_3PO_4$
9. H_2SO_4 (acid name)
10. $CuCl_2$
11. CsBr
12. $Fe(ClO_4)_3$
13. H_2S (molecular name)
14. H_2S (acid name)
15. Na_2CrO_4
16. FeS
17. P_4O_{10}
18. $HC_2H_3O_2$ or CH_3COOH (acid name)
19. $CuNO_2$
20. $HClO_3$ (acid name)
21. CrF_3
22. NaCN
23. $NiSO_3$
24. H_3PO_4 (acid name)
25. $AgNO_3$
26. Mg_3N_2
27. $K_2Cr_2O_7$
28. $AuBr_3$
29. $(NH_4)C_2H_3O_2$
30. HgO
31. $HBrO_4$ (acid name)
32. Na_2SeO_4
33. CdS
34. MnO_2
35. Hg_2Cl_2
36. $Sr_3(PO_3)_2$
37. HClO (acid name)
38. HNO_2 (acid name)
39. WCl_5
40. $SnBr_2$
41. $PbCl_4$
42. TiO_2
43. XeF_4
44. $KMnO_4$
45. HIO_4 (acid name)
46. HBr (molecular name)
47. HBr (acid name)
48. SF_6
49. $LiHCO_3$
50. $SiCl_4$

Formulas: Write the formula of the following compounds:

51. sulfur trioxide
52. oxygen (as found in our atmosphere)
53. sodium chlorite
54. iron(II) nitrate
55. potassium hydroxide
56. lithium sulfite
57. arsenic acid
58. antimony(III) bromide or antimony tribromide
59. oxygen difluoride
60. hydroiodic acid
61. copper(II) arsenide or cupric arsenide
62. zinc hydroxide
63. hydrogen peroxide
64. ammonium sulfide
65. cobalt(III) iodide or cobaltic iodide
66. iron(III) phosphate or ferric phosphate
67. hydrocyanic acid
68. calcium hypochlorite
69. sodium dihydrogenphosphate
70. carbon monoxide
71. hydrogen (in its normal state)
72. nickel(II) chloride hexahydrate
73. aluminum sulfate
74. tin(IV) bromide or stannic bromide
75. sodium hypophosphite
76. magnesium selenate
77. sodium hydride
78. chromium(II) oxalate or chromous oxalate
79. sulfurous acid
80. dinitrogen tetroxide
81. manganese(II) acetate
82. sodium hydrosulfide
83. gallium(III) bromide
84. nitric acid
85. methane
86. ammonia
87. boron nitride
88. silver carbonate
89. aluminum sulfide
90. lead(IV) oxide or plumbic oxide
91. iodine (in its normal state)
92. sulfur (in its normal state)
93. barium chromate
94. perchloric acid
95. bromine trifluoride
96. helium
97. copper(I) acetate or cuprous acetate
98. vanadium(III) bromide
99. osmium(II) sulfite
100. selenious acid

Answers

1. sodium nitrate
2. potassium iodide
3. barium chloride
4. phosphorus trichloride
5. zinc sulfate
6. aluminum oxide
7. calcium carbonate
8. ammonium phosphate
9. sulfuric acid
10. copper(II) chloride or cupric chloride
11. cesium bromide
12. iron(III) perchlorate or ferric perchlorate
13. dihydrogen sulfide (or simply hydrogen sulfide)
14. hydrosulfuric acid
15. sodium chromate
16. iron(II) sulfide or ferrous sulfide
17. tetraphosphorus decoxide
18. acetic acid (or ethanoic acid)
19. copper(I) nitrite or cuprous nitrite
20. chloric acid
21. chromium(III) fluoride or chromic fluoride
22. sodium cyanide
23. nickel(II) sulfite or nickelous sulfite or simply nickel sulfite
24. phosphoric acid
25. silver nitrate
26. magnesium nitride
27. potassium dichromate
28. gold(III) bromide or auric bromide
29. ammonium acetate
30. mercury(II) oxide or mercuric oxide
31. perbromic acid
32. sodium selenate
33. cadmium sulfide
34. manganese(IV) oxide (usually called manganese dioxide)
35. mercury(I) chloride or mercurous chloride
36. strontium phosphite
37. hypochlorous acid
38. nitrous acid
39. tungsten(V) chloride (also called tungsten pentachloride)
40. tin(II) bromide or stannous bromide
41. lead(IV) chloride or plumbic chloride
42. titanium(IV) oxide (commonly called titanium dioxide)
43. xenon tetrafluoride
44. potassium permanganate
45. periodic acid
46. hydrogen bromide
47. hydrobromic acid
48. sulfur hexafluoride
49. lithium hydrogencarbonate or lithium bicarbonate
50. silicon tetrachloride
51. SO_3
52. O_2 (also called dioxygen)
53. $NaClO_2$
54. $Fe(NO_3)_2$
55. KOH
56. Li_2SO_3
57. H_3AsO_4 (compare to phosphoric acid)
58. $SbBr_3$
59. OF_2
60. HI
61. Cu_3As_2
62. $Zn(OH)_2$
63. H_2O_2
64. $(NH_4)_2S$
65. CoI_3
66. $FePO_4$
67. HCN
68. $Ca(ClO)_2$
69. NaH_2PO_4
70. CO
71. H_2
72. $NiCl_2 \cdot 6\ H_2O$
73. $Al_2(SO_4)_3$
74. $SnBr_4$
75. Na_3PO_2
76. $MgSeO_4$ (compare to magnesium sulfate)
77. NaH
78. CrC_2O_4
79. H_2SO_3

80. N_2O_4
81. $Mn(C_2H_3O_2)_2$
82. NaHS
83. $GaBr_3$
84. HNO_3
85. CH_4
86. NH_3
87. BN
88. Ag_2CO_3
89. Al_2S_3
90. PbO_2
91. I_2
92. S_8
93. $BaCrO_4$
94. $HClO_4$
95. BrF_3
96. He
97. $CuC_2H_3O_2$
98. VBr_3
99. $OsSO_3$
100. H_2SeO_3 (compare to sulfurous acid)