Atoms, Molecules, Ions, and Inorganic Nomenclature

Brown, LeMay Ch 2 AP Chemistry Monta Vista High School

2.2: Evidence for the Atomic Theory

1. J.J. Thomson's cathode ray tube: discovery of electrons and the e- charge-to-mass ratio

☆ In a vacuum chamber, flow of high voltage (emitted from cathode to anode) is deflected by magnetic & electrical fields (animation:

http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::100%::100%::/sites/dl/free/ 0072512644/117354/01 Cathode Ray Tube.swf::Cathode%20Ray%20Tube)





2. Robert Millikan's oil drop: determines charge of e- (and thus the mass)

 "Atomized" drops of oil picked up small charges (integral numbers), and balanced oil drops in an electrical & gravitational field

http://cwx.prenhall.com/petrucci/medialib/media_portfolio/text_images/004_MILLIKANOIL.MOV







atom

nucleus

gold foil

 Alpha particles from radioactive source are deflected from positive gold atom nuclei



e cent

http://www.mhhe.com/physsci/ chemistry/animations/ chang_2e/ rutherfords_experiment.swf



2.3: Structure of the Atom

Figure 1: Subatomic particles (Table 2.1; 1 amu = $1.66054 \times 10^{-24} g$).

Subatomic particle	Charge	Location	Mass
Proton, p ⁺	+1.6 x 10 ⁻¹⁹ C	nucleus	1.0073 amu
Neutron, n	None	nucleus	1.0087 amu
Electron, e ⁻	-1.6 x 10 ⁻¹⁹ C	e- cloud	5.486 x 10 ⁻⁴ amu



- **Atomic number:** number of p⁺ (determines the element)
- Mass number: sum of p⁺ and n (determines the isotope)
- Isotopes: atoms of an element that differ in the number of neutrons
- **Isobars**: atoms of different elements with same atomic mass but different atomic number.
- Groups or families: columns on Periodic Table: alkali (1A), alkaline earth (2A), halogens (7A), noble or inert gases (8A); pnictogens (5A) and chalcogens (6A); have same number of valence e⁻
- Periods: rows on P.T.; indicates new shell of e⁻
- Cations: positively charged ions
- Anions: negatively charged ions

Naming Compounds Review

- Before naming a compound, it is important to know why type of compound it is because different types of compounds are named differently. For naming purposes, we classify compounds as ionic compounds, molecular compounds, and acids.
- **Ionic Compounds** can be identified by the presence of a metal in it. (generally solids) Ex. NaCl, K₂SO₄, PbSO₄
- Molecular compounds are made up of all non metals. (generally liquids and gases) Ex. H₂O, N₂O₅
- Acids begin with H (generally present as aq solutions or gases) Ex. HCl, H₂SO₄, HClO₃

To name an ionic compound

Name the metal first, followed by a roman numeral specifying its charge (ONLY if variable valency), then name the anion (monoatomic ending in –ide, and polyatomic named as such). Ex. MgO (Magnesium Oxide), Na₂S (Sodium Sulfide), Fe₂O₃ (Iron (III) Oxide), (NH₄)₂SO₄ (Ammonium Sulfate)

Common Cations with Variable Valencies

Cuprous, Cupric	Copper	Cu	Cu ⁺	Cu ²⁺
Cobaltous, Cobatic	Cobalt	Со	Co ²⁺	Co ³⁺
Chromous, Chromic	Chromium	Cr	Cr ²⁺	Cr ³⁺
Ferrous, Ferric	Iron	Fe	Fe ²⁺	Fe ³⁺
Plumbous, Plumbic	Lead	Pb	Pb ²⁺	Pb ⁴⁺
Mercurous, Mercuric	Mercury	Hg	Hg ₂ ²⁺	Hg ²⁺
Stannous, Stannic	Tin	Sn	Sn ²⁺	Sn ⁴⁺

Polyatomic Ions List

Ammonium	NH ₄ ⁺	Chlorate	ClO ₃ -	Thiosulfate	$S_2O_3^2$ -
Nitrate	NO ₃ -	Perchlorate	ClO ₄ -	Thiocynate	SCN-
Phosphate	PO_4^{3} -	Chlorite	ClO ₂ -	Peroxide	O ₂ ² -
Phosphite	PO_{3}^{3} -	Hypochlorite	ClO-	Sulfite	SO_{3}^{2} -
Phosphide	P ³ -	Permanganate	MnO ₄ -	Nitrite	NO ₂ -
Carbonate	CO ₃ ² -	Acetate	C ₂ H ₃ O ₂ - CH ₃ COO-	Hydroxide	OH-
Chromate	CrO ₄ ² -	Bicarbonate (hydrogen carbonate	HCO ₃ -	Bisulfate (hydrogen sulfate)	HSO ₄ -
Dichromate	$Cr_2O_7^2-$	Cynide	CN-	Sulfate	SO ₄ ² -



To write the formula of an ionic compound:

Use **criss-cross method** (bring valency of one element down as a subscript next to the other element). Write the formulas of the following: Sodium Sulfide (Na₂S), Potassium Nitrate (KNO₃), Ferrous Sulfate Fe (SO₄), Ammonium Chloride (NH₄Cl)

To name a molecular compound:

Write name of the first element followed by its oxidation state in parenthesis- Stock Way or you can use older Prefix Way. Naming Stock Way: CO₂ – Carbon (IV) Oxide Prefix Way: Carbon dioxide Note: Mono is not used before first element. Ex. CO is Carbon Monoxide and NOT Mono Carbon Monoxide. Please go over Oxidation Numbers.

Review of Oxidation Numbers (O.N.)

- 1. O.N of an ion is equal to the charge on that ion.
- 2. O.N. of a pure element is 0.
- 3. Sum of all oxidation numbers in a compound is equal to 0.
- 4. O.N. of H is generally +1, except in hydrides, where it is -1.
- 5. O.N. of O is generally -2, except in peroxides, where it is -1.
- 6. O.N. of halides is -1.

Now some practice problems:

- i. What is the O.N. of P in PO₄3- ion?
- ii. What is the O.N. of C in CO?
- iii. What is the O.N. of Fe in Fe(NO3)3?

Note: O.N. for an element can vary in different compounds. Ex. C can have different O.N. in CO and CO2.



Naming Acids

To name an acid without oxygen:

Starts with Hydro-followed by the name of anion ending in -ic Acid. Ex. HCl \rightarrow Hydrochloric acid

To name an acid with Oxygen (Oxyacids):

Anion ending decides the name of the acid. If anion ends in –ate, then acid is –ic acid, if anion ends in –its, then acid is –ous acid.

Ex. $HClO_4 \rightarrow$ Perchloric Acid (anion perchlorate) $HClO_3 \rightarrow$ Chloric Acid (anion Chlorate)



Naming Oxyacids & Oxyanions

• **Oxyacid:** polyatomic acid that contains a nonmetal bonded to one or more oxygen atoms

Figure 4: The "standard" oxyacids (ic acids)					
H ₃ BO ₃	H ₂ CO ₃	HNO ₃	X	X	
	Х	H ₃ PO ₄	H ₂ SO ₄	HCIO ₃	
		H ₃ AsO ₄	H ₂ SeO ₄	HBrO ₃	
			Х	HIO ₃	

Also: H_2CrO_4 = chromic acid

 Oxyanions: polyatomic anions that contain a nonmetal bonded to one or more oxygen atoms.

Figure 5: Naming oxyacids and oxyanions

Oxyacids Example Format		Oxyani Example	Oxida -tion #	
Perchloric acid, HClO ₄	Peric acid	Perchlorate, ClO ₄ -	perate	+7
Chloric acid, HClO ₃	ic acid	Chlorate, ClO ₃ -	ate	+5
Chlorous acid, HClO ₂	ous acid	Chlorite, ClO ₂ -	ite	+3
Hypochlorous acid. HClO	Hypoous acid	Hypochlorite, ClO ⁻	hypoite	+1

Figure 6: Complete for sulfur oxyacids & oxyanions.					
Oxyacid	Oxyan	Oxidation #			
(Persulfuric acid)	(H ₂ S ₂ O ₈)	(Persulfate)	(S ₂ O ₈ ²⁻)	(+7)	
Sulfuric acid	H ₂ SO ₄	Sulfate	SO ₄ ²⁻	+6	
Sulfurous acid	H ₂ SO ₃	Sulfite	SO ₃ ²⁻	+4	
Hyposulfurous acid	H ₂ SO ₂	Hyposulfite	SO ₂ ²⁻	+2	



Other Oxyacids Patterns

- H₃PO₄ phosphoric acid
- H₂PO₄¹⁻ dihydrogen phosphate
- HPO₄²⁻ hydrogen (or monohydrogen) phosphate
- PO₄³⁻ phosphate

H₂CO₃ carbonic acid

- HCO₃¹⁻ hydrogen carbonate or bicarbonate
- CO₃²⁻ carbonate



Naming Hydrates

Name the compound, then the Greek prefix, and then add -hydrate.

Ex:

CuSO₄ · 5 H₂O copper (II) sulfate pentahydrate Or Cupric Sulfate pentahydrate



<u>Chemistry of</u> <u>Coordination Compounds</u>

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24.1: Structure of Complexes

Complex: species in which a central metal ion (usually a transition metal) is bonded to a group of surrounding molecules or ions

Ex. $[Cu(NH_3)_4]^{2+}$

Coordination compound: compound that contains a complex ion or ions. Ex. [Cu(NH₃)₄]Cl₂



A coordination compound, or complex, consists of: Metal ion

Ligand or **complexing agent:** molecule or ion with a lone pair of e⁻ that bonds to a metal ion. Ex. NH_3 , CN^- , $S_2O_3^{2,}$ SCN⁻, H_2O



Naming Complexes

- 1. Name **cation** before **anion**; one or both may be a complex. (Follow standard nomenclature for non-complexes.)
- 2. Within each complex (neutral or ion), name **all ligands** before the **metal**.
 - Name ligands in alphabetical order
 - If more than one of the same ligand is present, use a numerical prefix: *di, tri, tetra, penta, hexa, ...*
 - Ignore numerical prefixes when alphabetizing.



Neutral ligands: use the name of the molecule (with some exceptions)

 NH_3 ammine- H_2O aqua-

Anionic ligand: use suffix –o
Br⁻ bromo- CN⁻ cyano Cl⁻ chloro- OH⁻ hydroxo-

B. If the complex is an anion, use *—ate suffix*

 Record the oxidation number of the metal in parentheses (if appropriate).

Ex: [Co(NH₃)₅Cl]Cl₂ pentamminechlorocobalt (III) chloride



Nomenclature practice 1. K₄[Fe(CN)₆] potassium hexacyanoferrate

2. $[Cr(NH_3)_4(H_2O)CN]Cl_2$

tetrammineaquacyanochromium (III) chloride

3. Na[Al(OH)₄] sodium tetrahydroxoaluminate

Naming Compounds Flow Chart





Practice Websites for Naming

http://quizlet.com/526633/polyatomic-ions-flash-cards/ http://quizlet.com/206265/polyatomic-ion-quiz-flash-cards/ http://www.sciencegeek.net/Concentration/Anions/anions.html http://www.sciencegeek.net/Concentration/Monatomics/ monatomic.html http://www.sciencegeek.net/APchemistry/APtaters/directory.shtml http://www.syvum.com/cgi/online/serve.cgi/contrib/chem/ Polyatoms.tdf?0