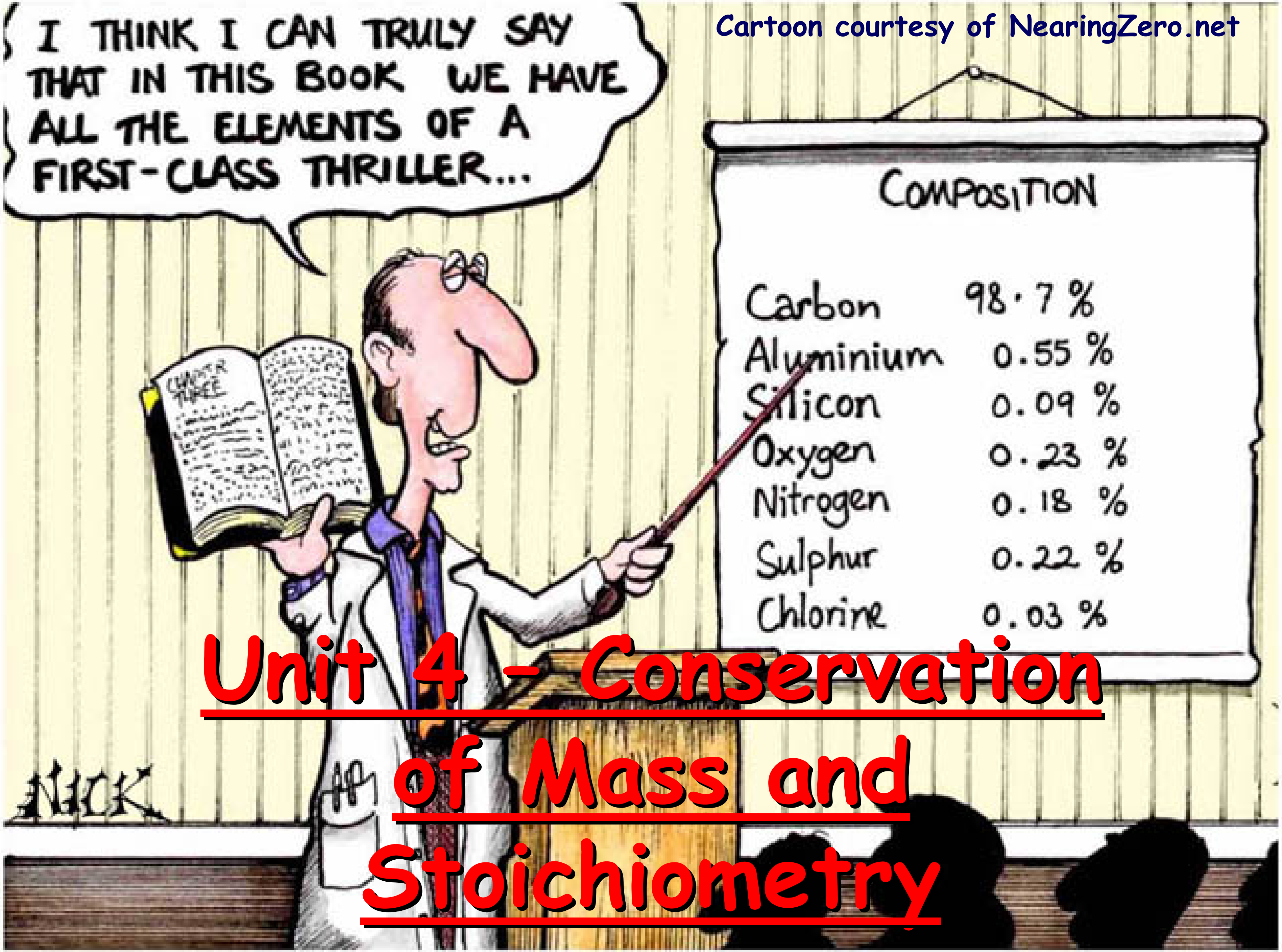

Cartoon courtesy of NearingZero.net

Unit 4 – Conservation of Mass and Stoichiometry

Ions

- **Cation**: A positive ion
  - Mg^{2+}, NH_4^+
- **Anion**: A negative ion
  - Cl^-, SO_4^{2-}
- **Ionic Bonding**: Force of attraction between oppositely charged ions.

Predicting Ionic Charges

<u>Group 1</u>: Lose 1 electron to form 1+ ions

H^+ Li^+ Na^+ K^+

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Predicting Ionic Charges

Group 2: Loses 2 electrons to form 2+ ions

Be^{2+} Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+}

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 4.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
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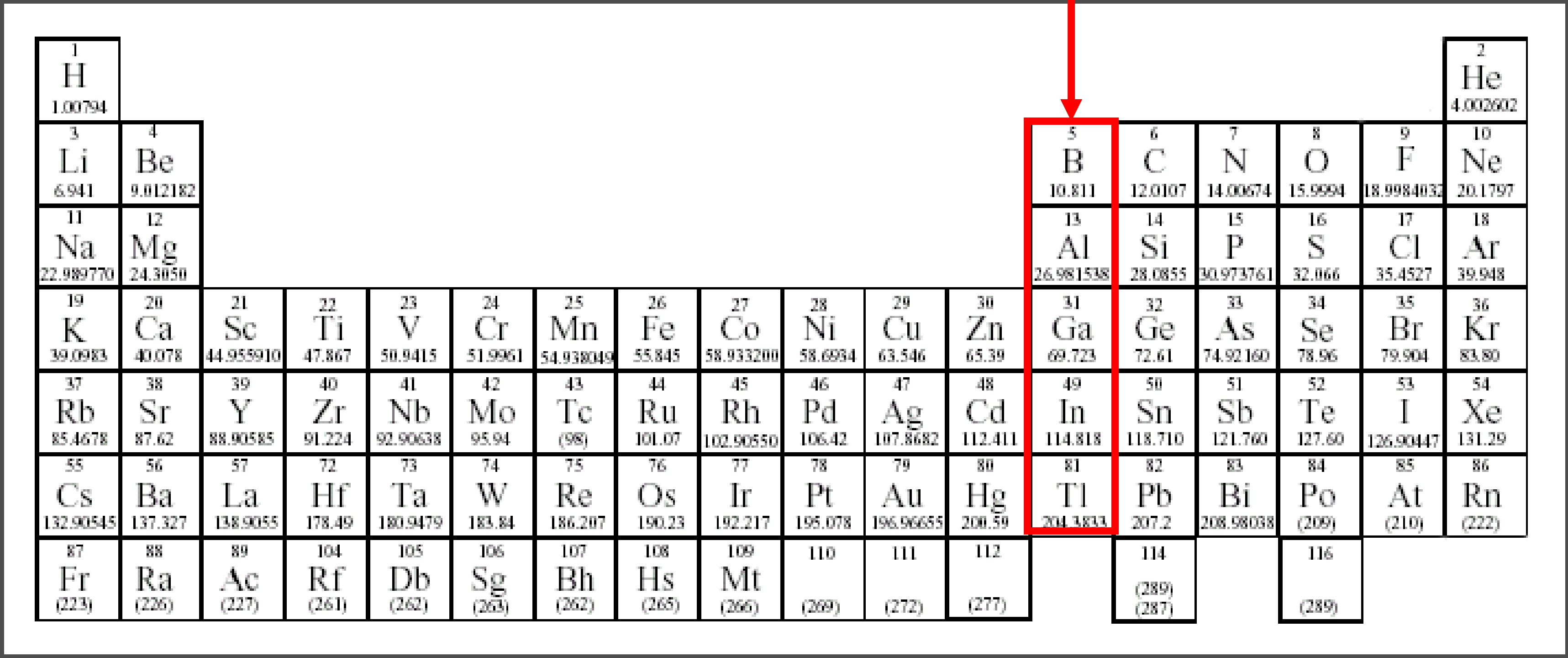
Predicting Ionic Charges

B^{3+} Al^{3+} Ga^{3+}

<u>Group 13</u>: Loses 3 electrons to form 3+ ions



Predicting Ionic Charges

Neither! Group 13 elements rarely form ions.

Group 14: Lose 4 electrons or gain 4 electrons?

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

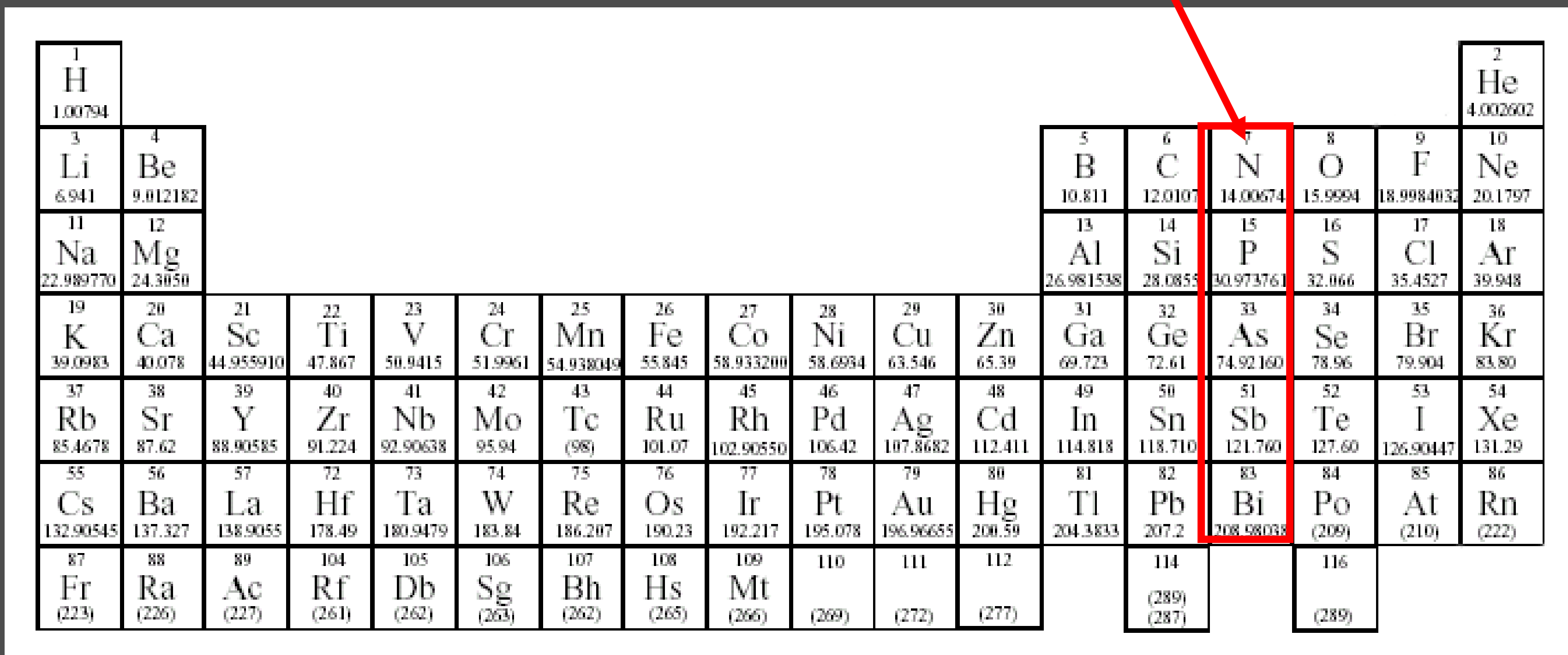
Predicting Ionic Charges

N^{3-} Nitride

P^{3-} Phosphide

As^{3-} Arsenide

Group 15: Gains 3 electrons to form **3-** ions



Predicting Ionic Charges

O^{2-} Oxide

S^{2-} Sulfide

Se^{2-} Selenide

Group 16: Gains 2 electrons to form 2- ions

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
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Predicting Ionic Charges

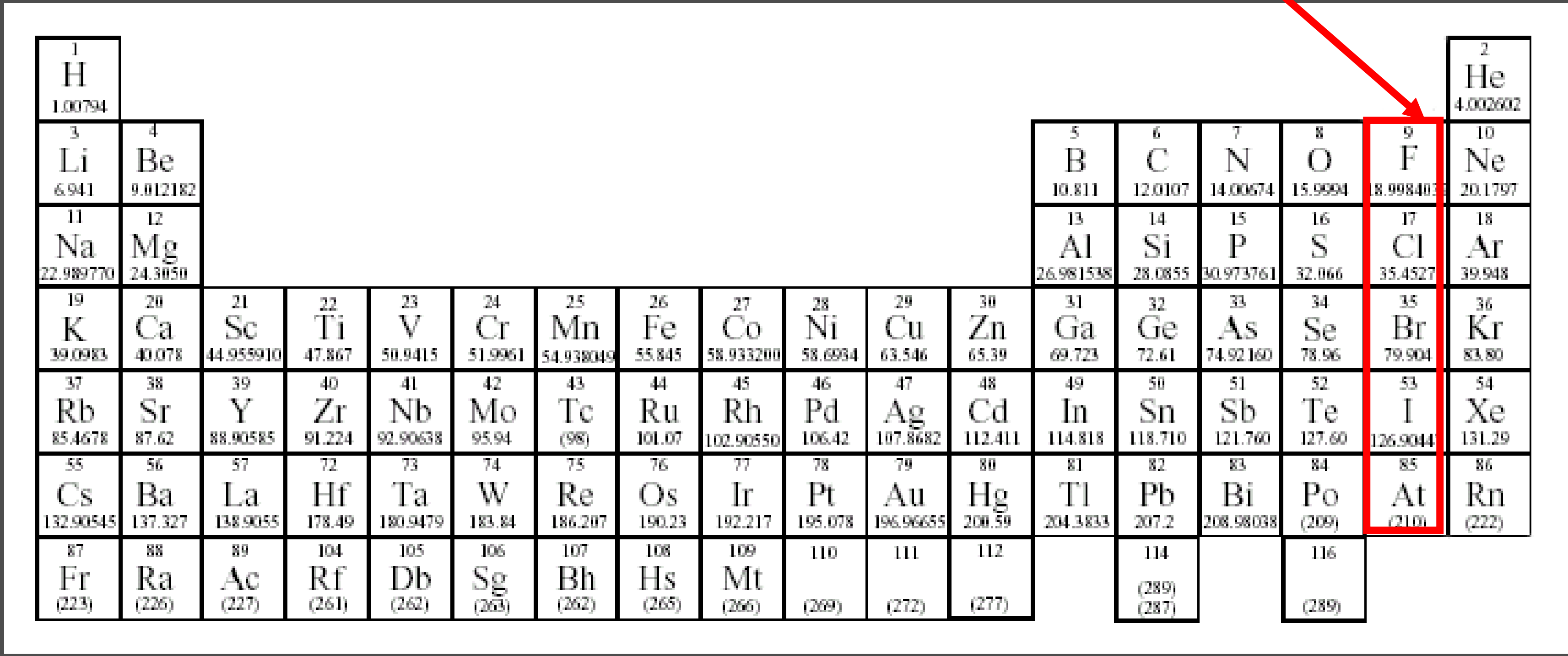
F^{1-} Fluoride

Br^{1-} Bromide

Cl^{1-} Chloride

I^{1-} Iodide

Group 17: Gains 1 electron to form 1- ions



Predicting Ionic Charges

Group 18: Stable

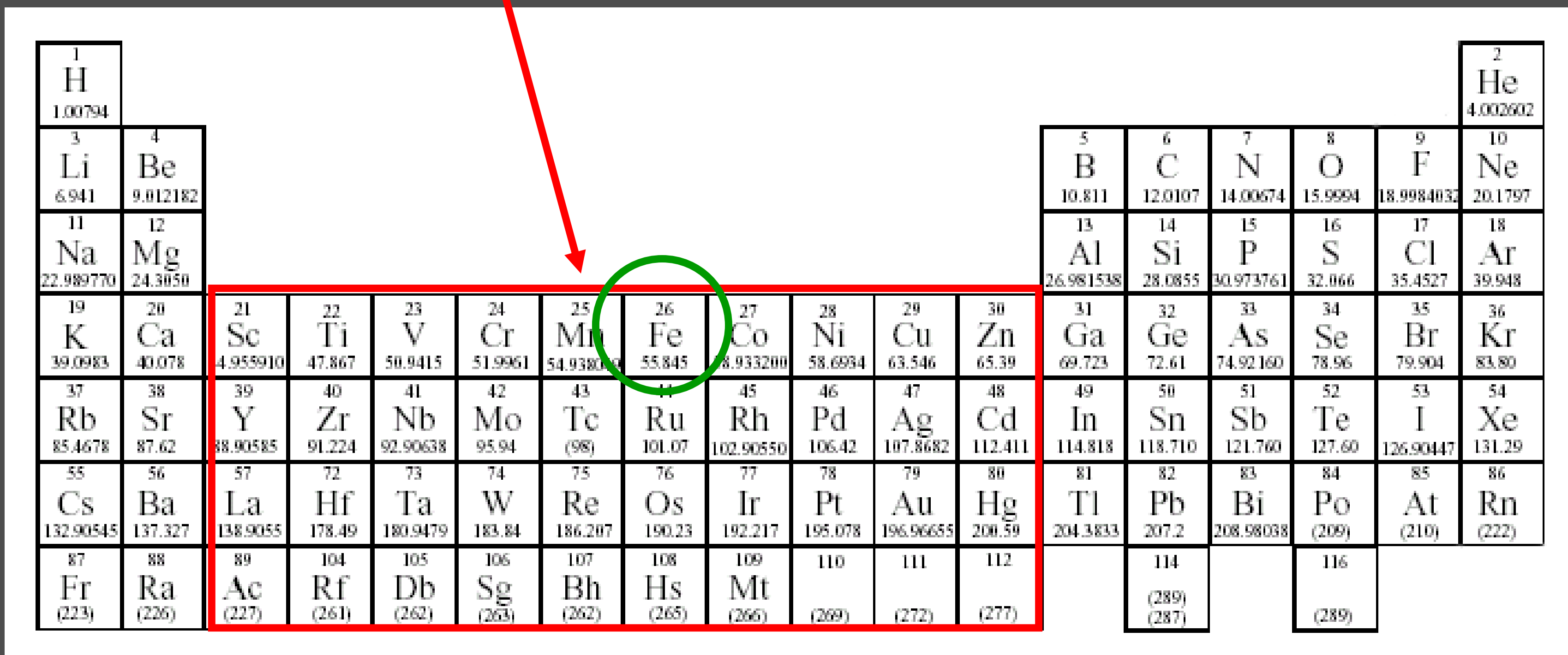
Noble gases **do not** form ions!

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.9044	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Predicting Ionic Charges

Groups 3 - 12: Many transition elements have more than one possible oxidation state.

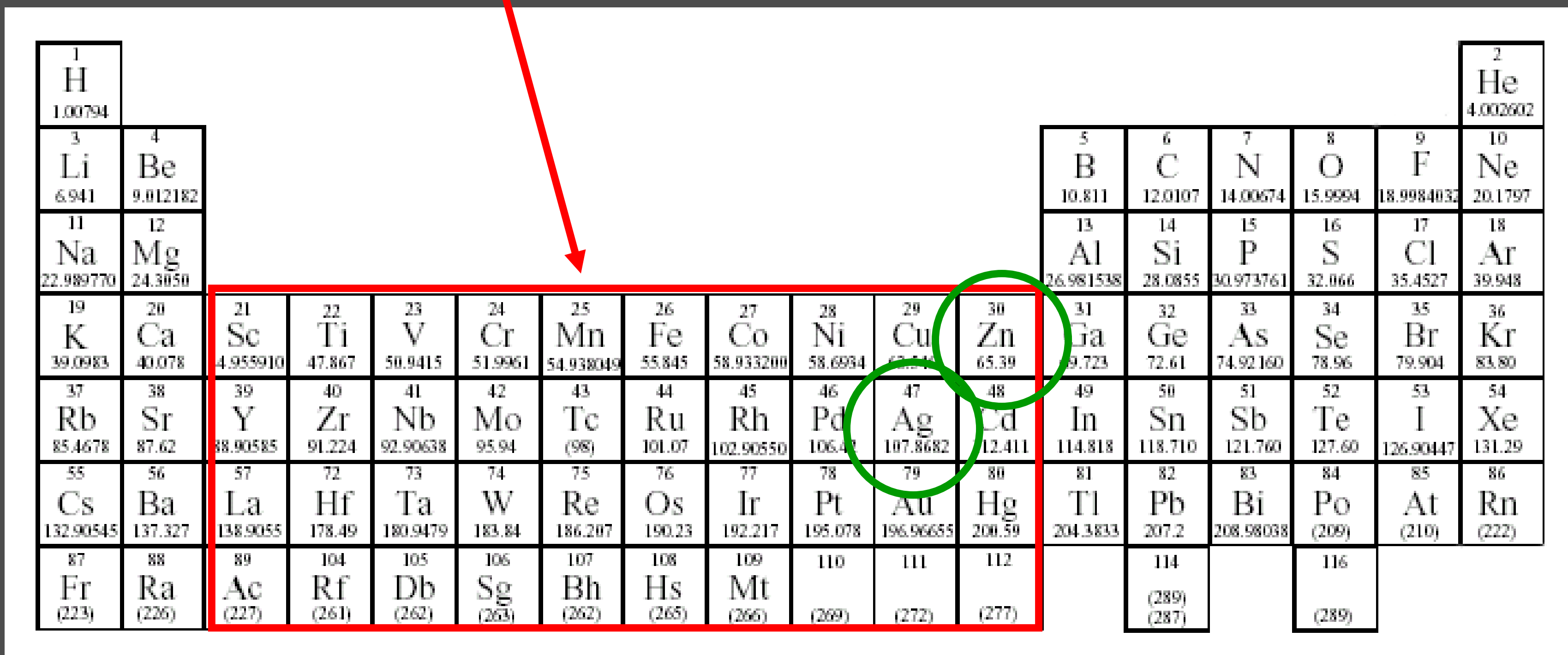
Iron(II) = Fe^{2+} Iron(III) = Fe^{3+}



Predicting Ionic Charges

<u>Groups 3 - 12</u>: Some **transition** elements have only one possible oxidation state.

Zinc = Zn^{2+} Silver = Ag^{+}



Writing Ionic Compound Formulas

Example: Barium nitrate

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

$$Ba^{2+}(NO_3^-)_2$$

Not balanced!

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

Writing Ionic Compound Formulas

Example: Ammonium sulfate

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

$(NH_4^{+})_2SO_4^{2-}$

Not balanced!

Writing Ionic Compound Formulas

Example: Iron(III) chloride

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

Fe^{3+} Cl^{-}_{3}

Not balanced!

Writing Ionic Compound Formulas

Example: Aluminum sulfide

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

$Al^{3+}_{2}\ S^{2-}_{3}$

Not balanced!

Writing Ionic Compound Formulas

Example: Magnesium carbonate

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

Mg^{2+} CO_3^{2-}

They are balanced!

Writing Ionic Compound Formulas

Example: Zinc hydroxide

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

$Zn^{2+}(OH^{-})_2$

Not balanced!

Writing Ionic Compound Formulas

Example: Aluminum phosphate

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

Al^{3+} PO_4^{3-}

They ARE balanced!

Naming Ionic Compounds

- 1. Cation first, then anion
- 2. Monatomic cation = name of the element
  - Ca^{2+} = calcium ion
- 3. Monatomic anion = root + -ide
  - Cl^{-} = chloride
  - $CaCl_2$ = calcium chloride

Naming Ionic Compounds
(continued)

Metals with multiple oxidation states

- \- some metal forms more than one **cation**
- \- use **Roman numeral** in name

- $PbCl_2$
- Pb^{2+} is cation
- $PbCl_2$ = lead(**II**) chloride

Naming Binary Compounds

- - Compounds between two nonmetals
- - First element in the formula is named first.
- - Second element is named as if it were an anion.
- - Use prefixes
- - Only use mono on second element -

P_2O_5 = diphosphorus pentoxide

CO_2 = carbon dioxide

CO = carbon monoxide

N_2O = dinitrogen monoxide

Calculating Formula Mass

Calculate the formula mass of magnesium carbonate, $MgCO_3$.

12	6	8
Mg	C	O
24.3050	12.0107	15.9994

24.31 g + 12.01 g + 3(16.00 g) = 84.32 g

Calculating Percentage Composition

Calculate the percentage composition of magnesium carbonate, $MgCO_3$.

From previous slide:

24.31 g + 12.01 g + 3(16.00 g) = 84.32 g

$$Mg = \left(\frac{24.31}{84.32}\right) \bullet 100 = 28.83\%$$

$$C = \left(\frac{12.01}{84.32}\right) \bullet 100 = 14.24\%$$

$$O = \left(\frac{48.00}{84.32}\right) \bullet 100 = 56.93\%$$

100.00

Formulas

Empirical formula: the lowest whole number ratio of atoms in a compound.

Molecular formula: the true number of atoms of each element in the formula of a compound.

- molecular formula = (empirical formula)$_n$ [n = integer]
- molecular formula = C_6H_6 = $(CH)_6$
- empirical formula = CH

Formulas (continued)

Formulas for ionic compounds are ALWAYS empirical (lowest whole number ratio).

Examples:

$NaCl$ $MgCl_2$ $Al_2(SO_4)_3$ K_2CO_3

Formulas (continued)

Formulas for molecular compounds MIGHT be empirical (lowest whole number ratio).

Molecular:	H_2O	$C_6H_{12}O_6$	$C_{12}H_{22}O_{11}$
	↓	↓	↓
Empirical:	H_2O	CH_2O	$C_{12}H_{22}O_{11}$

Empirical Formula Determination

1. Base calculation on 100 grams of compound.
2. Determine moles of each element in 100 grams of compound.
3. Divide each value of moles by the smallest of the values.
4. Multiply each number by an integer to obtain all whole numbers.

Empirical Formula Determination

Adipic acid contains 49.32% C, 43.84% O, and 6.85% H by mass. What is the empirical formula of adipic acid?

$$\frac{(49.32 g\ C)(1\ mol\ C)}{(12.01\ g\ C)} = 4.107\ mol\ C$$

$$\frac{(6.85 g\ H)(1\ mol\ H)}{(1.01\ g\ H)} = 6.78\ mol\ H$$

$$\frac{(43.84 g\ O)(1\ mol\ O)}{(16.00\ g\ O)} = 2.74\ mol\ O$$

Empirical Formula Determination (part 2)

Divide each value of moles by the smallest of the values.

Carbon: $$\frac{4.107\ mol\ C}{2.74\ mol\ O} = 1.50$$

Hydrogen: $$\frac{6.78\ mol\ H}{2.74\ mol\ O} = 2.47$$

Oxygen: $$\frac{2.74\ mol\ O}{2.74\ mol\ O} = 1.00$$

Empirical Formula Determination (part 3)

Multiply each number by an integer to obtain all whole numbers.

Carbon: 1.50	Hydrogen: 2.50	Oxygen: 1.00
× 2	× 2	× 2
3	5	2

Empirical formula: $C_3H_5O_2$

Finding the Molecular Formula

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

1. Find the formula mass of $C_3H_5O_2$

$$3(12.01\ g) + 5(1.01) + 2(16.00) = 73.08\ g$$

Finding the Molecular Formula

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

2. Divide the molecular mass by the mass given by the emipirical formula.

$3(12.01\ g) + 5(1.01) + 2(16.00) = 73.08\ g$

$$\frac{146}{73} = 2$$

Finding the Molecular Formula

The empirical formula for adipic acid is $C_3H_5O_2$. The molecular mass of adipic acid is 146 g/mol. What is the molecular formula of adipic acid?

3. Multiply the empirical formula by this number to get the molecular formula.

3(12.01 *g*) + 5(1.01) + 2(16.00) = 73.08 *g*

$$\frac{146}{73} = 2$$

$(C_3H_5O_2) \times 2 = C_6H_{10}O_4$

Combination (Synthesis) Reactions

Two or more substances combine to form a new compound.

$$A + X \rightarrow AX$$

- Reaction of elements with oxygen and sulfur
- Reactions of metals with Halogens
- Synthesis Reactions with Oxides
- There are others not covered here!

Decomposition Reactions

A single compound undergoes a reaction that produces two or more simpler substances

$$AX \rightarrow A + X$$

Decomposition of:

- Binary compounds $H_2O(\ell) \rightarrow 2H_2(g) + O_2(g)$
- Metal carbonates $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
- Metal hydroxides $Ca(OH)_2(s) \rightarrow CaO(s) + H_2O(g)$
- Metal chlorates $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$
- Oxyacids $H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(\ell)$

Single Replacement Reactions

$$A + BX \rightarrow AX + B$$

$$BX + Y \rightarrow BY + X$$

Replacement of:

- Metals by another metal
- Hydrogen in water by a metal
- Hydrogen in an acid by a metal
- Halogens by more active halogens

The Activity Series of the Metals

- Lithium
- Potassium
- Calcium
- Sodium
- Magnesium
- Aluminum
- Zinc
- Chromium
- Iron
- Nickel
- Lead
- Hydrogen
- Bismuth
- Copper
- Mercury
- Silver
- Platinum
- Gold

Metals can replace other metals provided that they are above the metal that they are trying to replace.

Metals above hydrogen can replace hydrogen in acids.

Metals from sodium upward can replace hydrogen in water

The Activity Series of the Halogens

- Fluorine
- Chlorine
- Bromine
- Iodine

Halogens can replace other halogens in compounds, provided that they are above the halogen that they are trying to replace.

$2NaCl(s) + F_2(g) \rightarrow$??? $2NaF(s) + Cl_2(g)$

$MgCl_2(s) + Br_2(g) \rightarrow$??? No Reaction

Double Replacement Reactions

The ions of two compounds exchange places in an aqueous solution to form two new compounds.

$$AX + BY \rightarrow AY + BX$$

One of the compounds formed is usually a precipitate, an insoluble gas that bubbles out of solution, or a molecular compound, usually water.

Combustion Reactions

A substance combines with oxygen, releasing a large amount of energy in the form of light and heat.

- Reactive elements combine with oxygen

$$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$$

(This is also a synthesis reaction)

- The burning of natural gas, wood, gasoline

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

Stoichiometry

"In solving a problem of this sort, the grand thing is to be able to reason backward. This is a very useful accomplishment, and a very easy one, but people do not practice it much."

Sherlock Holmes, in Sir Arthur Conan Doyle's *A Study in Scarlet*

Stoichiometry - The study of quantities of materials **consumed** and **produced** in chemical reactions.

Review: Atomic Masses

- Elements occur in nature as mixtures of **isotopes**
- Carbon = 98.89% ^{12}C
- 1.11% ^{13}C
- <0.01% ^{14}C
- Carbon's atomic mass = 12.01 amu

Review: The Mole

- The number equal to the number of carbon atoms in exactly 12 grams of pure ^{12}C.
- 1 mole of anything = 6.022×10^{23} units of that thing

The Mole

- SI unit for amount of substance

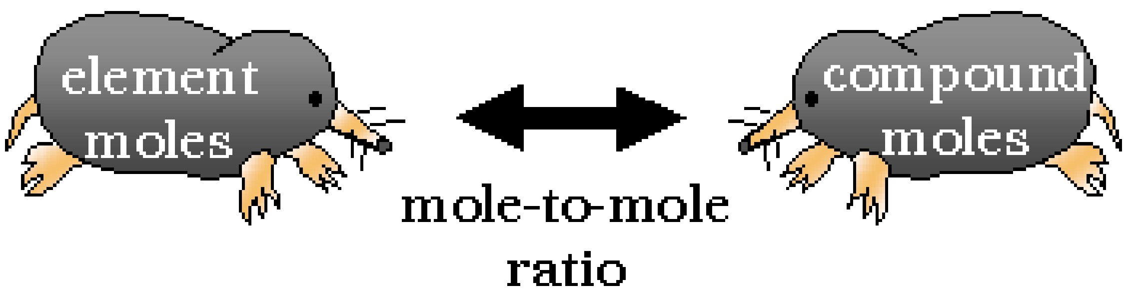
1 mole = 6.02×10^{23} particles

1 mole = 1 gram-molecular weight

Using Chemical Formulas:

Element & compound masses

- problems that convert one substance to another require mole-to-mole ratios!



How many grams of H_2 can be obtained from the electrolysis of 100.0 g of H_2O?

How many grams of CuO can be made from a piece of copper wire weighing 0.2134 g?

Review: Molar Mass

A substance's **molar mass** (molecular weight) is the mass in grams of one mole of the compound.

CO_2 = 44.01 grams per mole

H_2O = 18.02 grams per mole

$Ca(OH)_2$ = 74.10 grams per mole

Review: Chemical Equations

Chemical change involves a reorganization of the atoms in one or more substances.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

reactants products

When the equation is balanced it has quantitative significance:

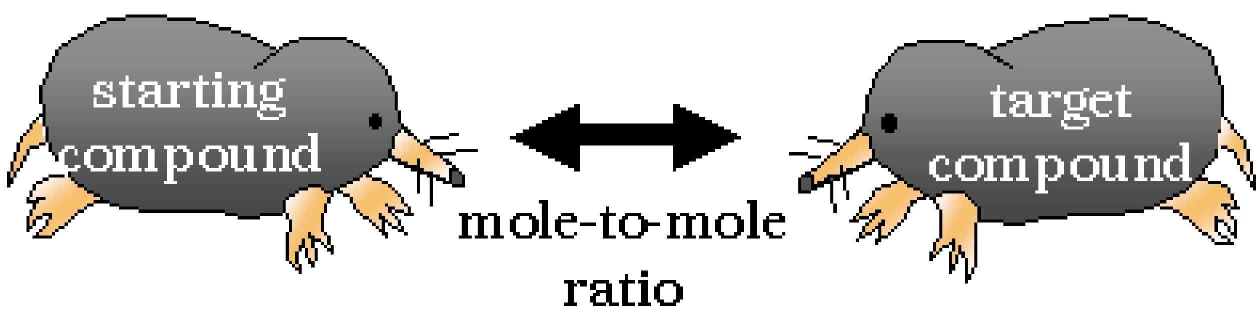
1 mole of ethanol reacts with 3 moles of oxygen to produce 2 moles of carbon dioxide and 3 moles of water

Mole Relations from Chemical Equations

- ratios of balanced coefficients = mole ratios

$$C_6H_{12}O_6(s) + 6\ O_2(g) = 6\ CO_2(g) + 6\ H_2O(l)$$

$$\frac{1\ mol\ C_6H_{12}O_6}{6\ mol\ O_2} \qquad \frac{1\ mol\ C_6H_{12}O_6}{6\ mol\ CO_2} \qquad \frac{1\ mol\ C_6H_{12}O_6}{6\ mol\ H_2O}$$



how many grams of oxygen are required to burn exactly 1 kg of glucose?

Calculating Masses of Reactants and Products

1. Balance the equation.
2. Convert mass to moles.
3. Set up mole ratios.
4. Use mole ratios to calculate moles of desired substituent.
5. Convert moles to grams, if necessary.

Working a Stoichiometry Problem

6.50 grams of aluminum reacts with an excess of oxygen. How many grams of aluminum oxide are formed.

1. Identify reactants and products and write the balanced equation.

$$4\,Al + 3\,O_2 \longrightarrow 2\,Al_2O_3$$

a. Every reaction needs a yield sign!

b. What are the reactants?

c. What are the products?

d. What are the balanced coefficients?

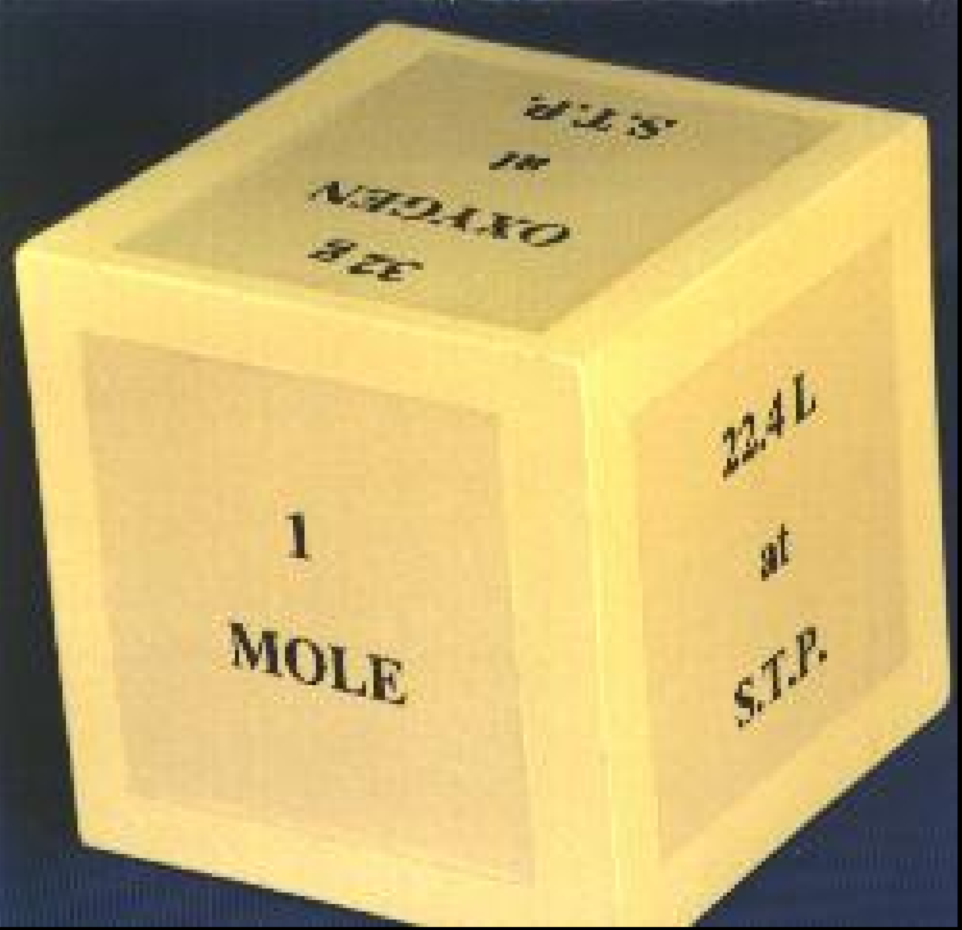
Working a Stoichiometry Problem

6.50 grams of aluminum reacts with an excess of oxygen. How many grams of aluminum oxide are formed?

$$4\,Al + 3\,O_2 \rightarrow 2Al_2O_3$$

6.50 g Al	1 mol Al	2 mol Al_2O_3	101.96 g Al_2O_3	= ? g Al_2O_3
	26.98 g Al	4 mol Al	1 mol Al_2O_3	

6.50 x 2 x 101.96 ÷ 26.98 ÷ 4 = **12.3 g Al_2O_3**



Standard Molar Volume

Equal volumes of all gases at the same temperature and pressure contain the same number of molecules.

- Amedeo Avogadro

At STP (Standard Temperature and Pressure):

<u>1 mole of a gas occupies 22.4 liters of volume</u>

Gas Stoichiometry #1

If reactants and products are at the same conditions of temperature and pressure, then mole ratios of *gases* are also volume ratios.

$3\ H_2(g) \quad + \quad N_2(g) \quad \rightarrow \quad 2NH_3(g)$

3 moles H_2 + 1 mole N_2 → 2 moles NH_3

3 liters H_2 + 1 liter N_2 → 2 liters NH_3

Gas Stoichiometry #2

How many liters of ammonia can be produced when 12 liters of hydrogen react with an excess of nitrogen?

$\underline{3}\ H_2(g) \quad + \quad N_2(g) \quad \rightarrow \quad \underline{2}\ NH_3(g)$

$$\frac{12\ \cancel{L\ H_2}}{} \left| \frac{2\ L\ NH_3}{3\ \cancel{L\ H_2}} \right. = 8.0\ L\ NH_3$$

Gas Stoichiometry #3

How many liters of oxygen gas, at STP, can be collected from the complete decomposition of 50.0 grams of potassium chlorate?

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

50.0 g $KClO_3$	1 mol $KClO_3$	3 mol O_2	22.4 L O_2
	122.55 g $KClO_3$	2 mol $KClO_3$	1 mol O_2

= 13.7 L O_2

Gas Stoichiometry #4

How many liters of oxygen gas, at 37.0°C and 0.930 atmospheres, can be collected from the complete decomposition of 50.0 grams of potassium chlorate?

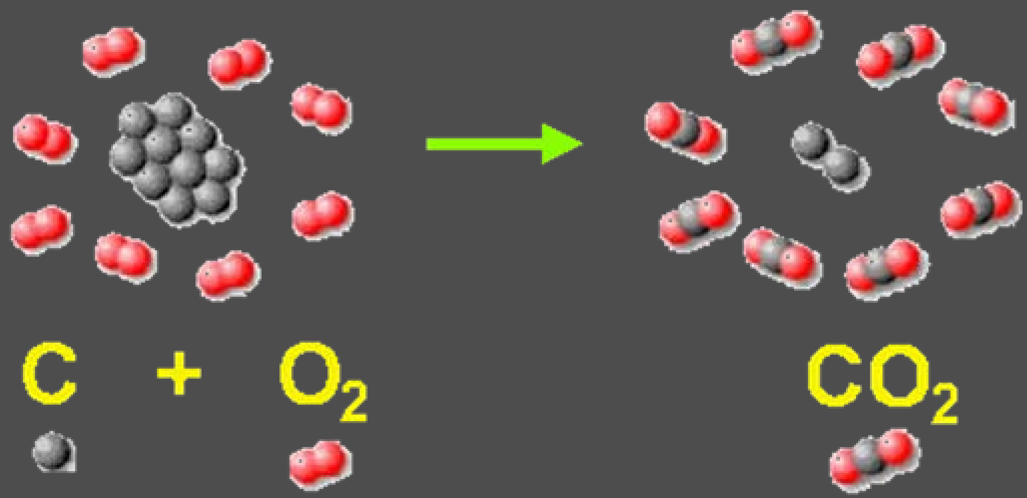
$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

$$\frac{50.0\ \text{g}\ KClO_3}{} \left|\ \frac{1\ \text{mol}\ KClO_3}{122.55\ \text{g}\ KClO_3}\ \right|\ \frac{3\ \text{mol}\ O_2}{2\ \text{mol}\ KClO_3} = \text{“n” mol}\ O_2 = 0.612\ \text{mol}\ O_2$$

$$V = \frac{nRT}{P} = \frac{(0.612\,\text{mol})(0.0821\,\frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(310\,\text{K})}{0.930\,\text{atm}} = 16.7\ \text{L}$$

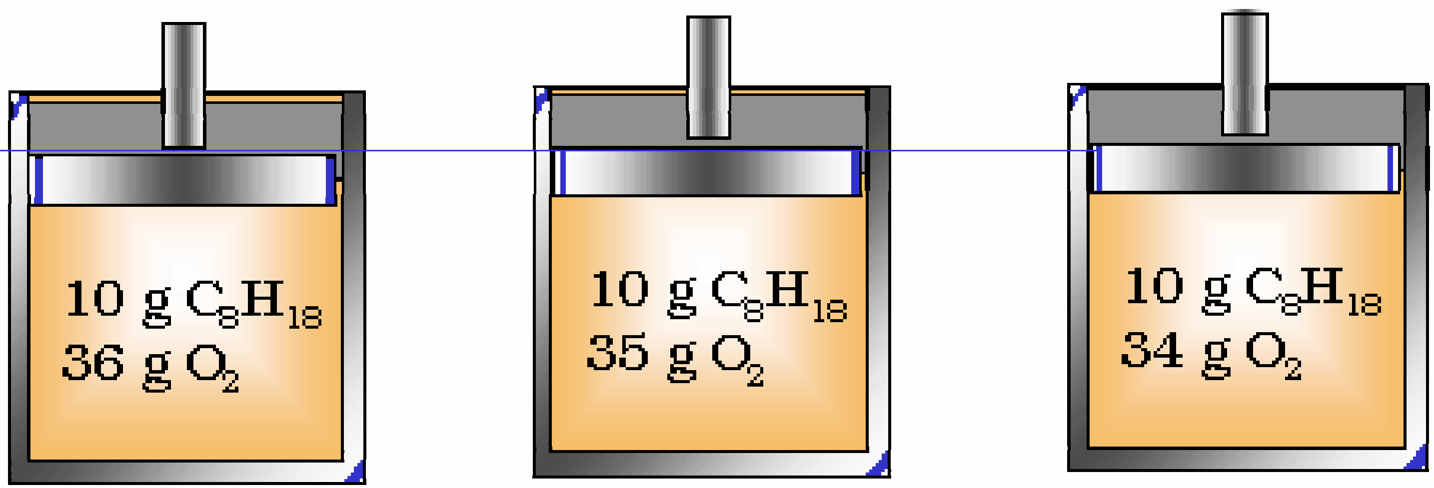
Limiting Reactant

The **limiting reactant** is the reactant that is **consumed first**, limiting the amounts of products formed.



Limiting Reagents

$$2\ C_8H_{18}(l) + 25\ O_2(g) = 16\ CO_2(g) + 18\ H_2O(l)$$



octane is limiting
engine stalls

optimal

oxygen is limiting
dirty exhaust

Solving a Stoichiometry Problem

1. Balance the equation.
2. Convert masses to moles.
3. Determine which reactant is limiting.
4. Use moles of limiting reactant and mole ratios to find moles of desired product.
5. Convert from moles to grams.