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Teacher: Ella

Grade 11 Review:

Part A: Periodic Table and Periodic Trend

- metals (main group)
- metals (transition)
- metals (inner transition)
- metalloids
- nonmetals

MAIN GROUP ELEMENTS — TRANSITION ELEMENTS — MAIN-GROUP ELEMENTS

Period	1 (IA)	2 (IIA)	3 (IIIB)	4 (IVB)	5 (VB)	6 (VIB)	7 (VIIB)	8	9 (VIIIB)	10	11 (IB)	12 (IIB)	13 (IIIA)	14 (IVA)	15 (VA)	16 (VIA)	17 (VIIA)	18 (VIIIA)
1	1 H 1.01																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.13											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Uun (269)	111 Uuu (272)	112 Uub (277)		114 Uuq (285)		116 Uuh (289)		118 Uuo (293)

INNER TRANSITION ELEMENTS

6	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
7	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

- Each element is in a separate box, with its atomic number, atomic symbol, and atomic mass. (Different versions of the periodic table provide additional data and details.)
- Elements are arranged in seven numbered periods (horizontal rows) and 18 numbered groups (vertical columns).
- Groups are numbered according to two different systems. The current system numbers the groups from 1 to 18. An older system numbers the groups from I to VIII, and separates them into two categories labelled A and B. Both of these systems are included in this textbook.
- The elements in the eight A groups are the main-group elements. They are also called the representative elements. The elements in the ten B groups are known as the transition elements. (In older periodic tables, Roman numerals are used to number the A and B groups.)
- Within the B group transition elements are two horizontal series of elements called inner transition elements. They usually appear below the main periodic table. Notice, however, that they fit between the elements in Group 3 (IIIB) and Group 4 (IVB).
- A bold "staircase" line runs from the top of Group 13 (IIIA) to the bottom of Group 16 (VIA). This line separates the elements into three broad classes: metals, metalloids (or semi-metals), and non-metals. (See Figure 2.7 on the next page for more information.)
- Group 1 (IA) elements are known as *alkali metals*. They react with water to form alkaline, or basic, solutions.
- Group 2 (IIA) elements are known as *alkaline earth metals*. They react with oxygen to form compounds called oxides, which react with water to form alkaline solutions. Early chemists called all metal oxides "earths."
- Group 17 (VIIA) elements are known as *halogens*, from the Greek word *hals*, meaning "salt." Elements in this group combine with other elements to form compounds called salts.
- Group 18 (VIIIA) elements are known as *noble gases*. Noble gases do not combine in nature with any other elements.

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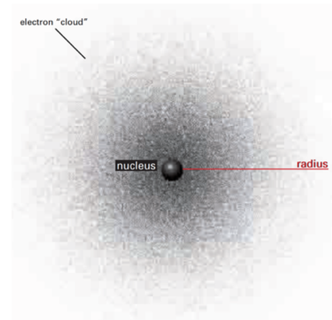
Atomic Radius (AR)



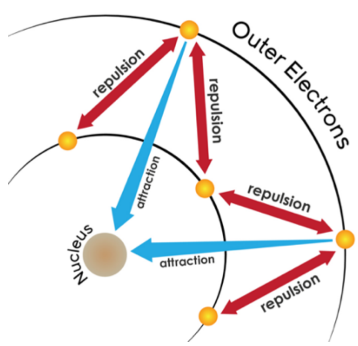
How is atomic radius measure? The definition of atomic radius: is the distance from the centre of an atom to the boundary within which the electrons spend 90percent of their time.

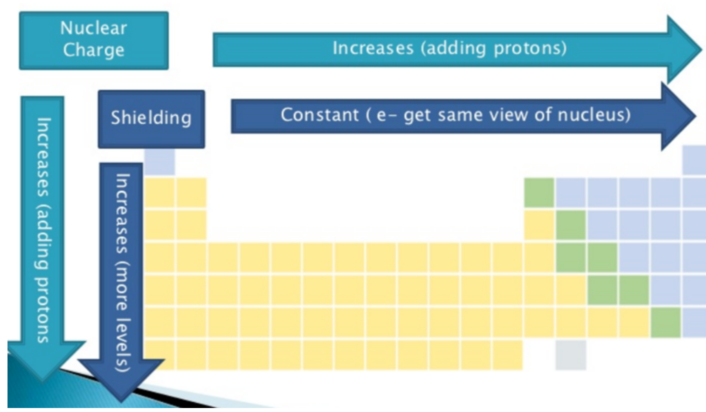
Generally, as you go down a group in the periodic table, atomic radius

____

What is shield effect & effective nuclear charge?

- The shielding effect describes the balance between the pull of the protons on valence electrons and the repulsion forces from inner electrons.
- The shielding effect explains why valence-shell electrons are more easily removed from the atom. The effect also explains atomic size. The more shielding, the further the valence shell can spread out and the bigger atoms will be.
- The effective nuclear charge is the net positive charge experienced by valence electrons. It can be approximated by the equation: $Z_{eff} = Z - S$, where Z is the atomic number and S is the number of shielding electrons.





Generally, as you go across a period in the periodic table atomic radius ____

Ionic radii for metal cations and non-metal anions

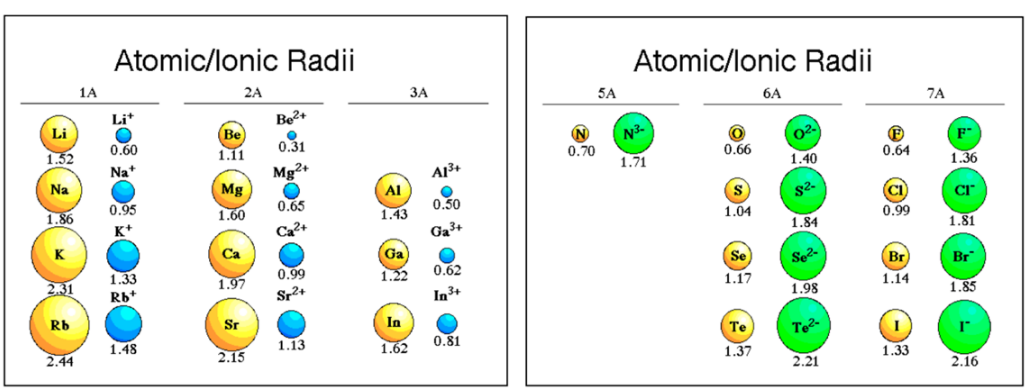
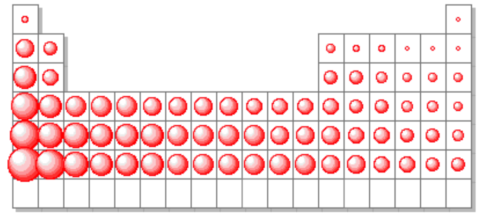


Figure 2: Periodic trend of ionic radii for metal cations and non-metal anions

Practice Problems

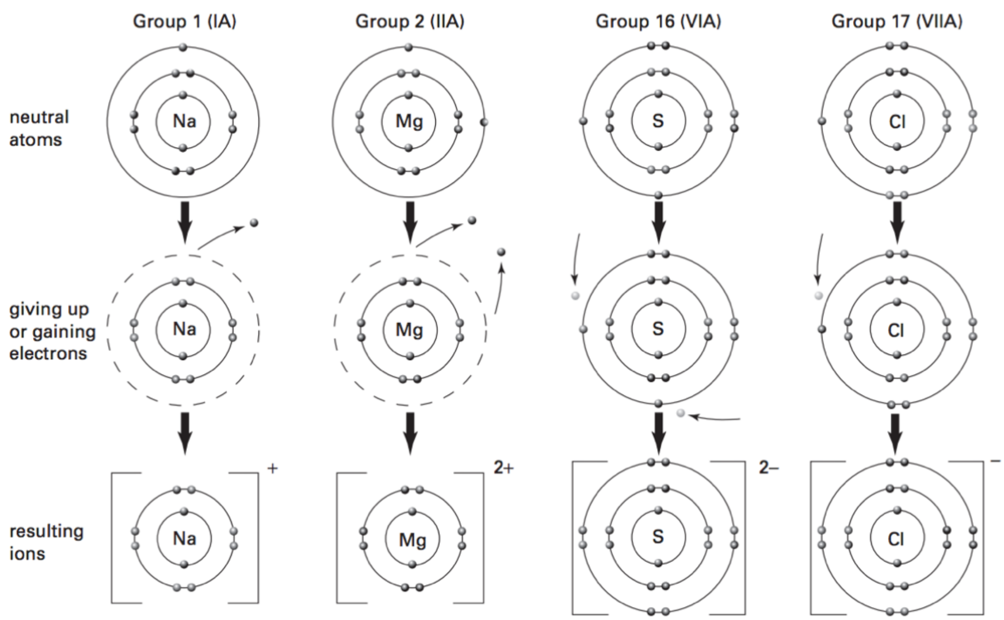
7. Using only their location in the periodic table, rank the atoms in each set by decreasing atomic size. Explain your answers.

(a) Mg, Be, Ba	**(f)** Se, Br, Cl
(b) Ca, Se, Ga	**(g)** Mg, Ca, Li
(c) Br, Rb, Kr	**(h)** Sr, Te, Se
(d) Se, Br, Ca	**(i)** In, Br, I
(e) Ba, Sr, Cs	**(j)** S, Se, O



Ionization Energy (IA)

Define ionization energy: ____.



Generally, as you go down a group in the periodic table, ionization energy ______________________________.

Generally, as you go across a period in the periodic table, ionization energy ______________________________.

How many ionization energies can an atom have? ____.

First ionization energy: $\mathrm{A(g)} + \mathrm{energy} \rightarrow A^{+}(g) + e^{-}$ Second ionization energy: $A^{+}\mathrm{(g)} + \mathrm{energy} \rightarrow A^{2+}(g) + e^{-}$

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Practice Problems

8. Using only a periodic table, rank the elements in each set by increasing ionization energy. Explain your answers.

(a) Xe, He, Ar
(b) Sn, In, Sb
(c) Sr, Ca, Ba
(d) Kr, Br, K
(e) K, Ca, Rb
(f) Kr, Br, Rb

9. Using only a periodic table, identify the atom in each of the following pairs with the *lower* first ionization energy.

(a) B, O
(b) B, In
(c) I, F
(d) F, N
(e) Ca, K
(f) B, Tl

Electron Affinity (EA)

Define Electron affinity: ____.

Generally, as you go down a group of elements E.A. ___________ which means it is ____________to add an electron because ____.

Generally, as you go across a period of elements E.A. ___________ which means it is ____________to add an electron because ____.

In which corner of the periodic table is it the highest? _______________________.

Pauling Electronegativity Values

H 2.1																	He
Li 1.0	Be 1.6											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.3											Al 1.5	Si 1.9	P 2.2	S 2.6	Cl 3.0	Ar
K 0.8	Ca 1.0	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.8	Ge 2.0	As 2.2	Se 2.6	Br 2.8	Kr
Rb 0.8	Sr 0.9	Y 1.2	Zr 1.3	Nb 1.6	Mo 2.2	Tc 1.9	Ru 2.2	Rh 2.3	Pd 2.2	Ag 1.9	Cd 1.7	In 1.8	Sn 2.0	Sb 2.1	Te 2.1	I 2.5	Xe

Charles E. Sundin, University of Wisconsin-Platteville

Higher the value, higher the electronegativity, stronger the ability to pull the electrons toward itself when form a covalent bond.

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$\triangle EN$

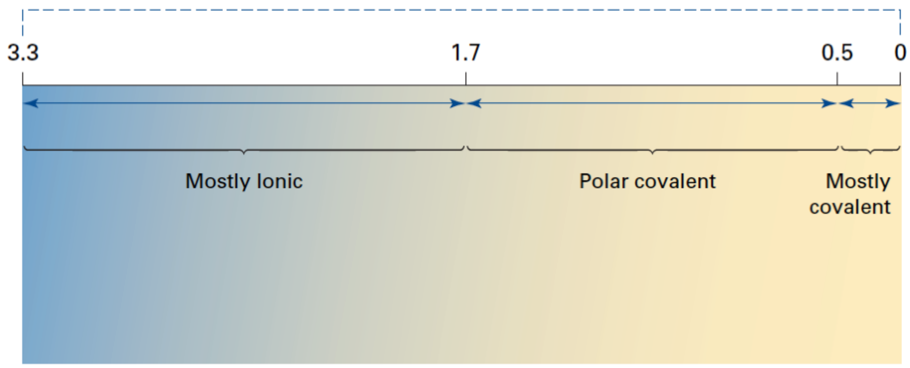
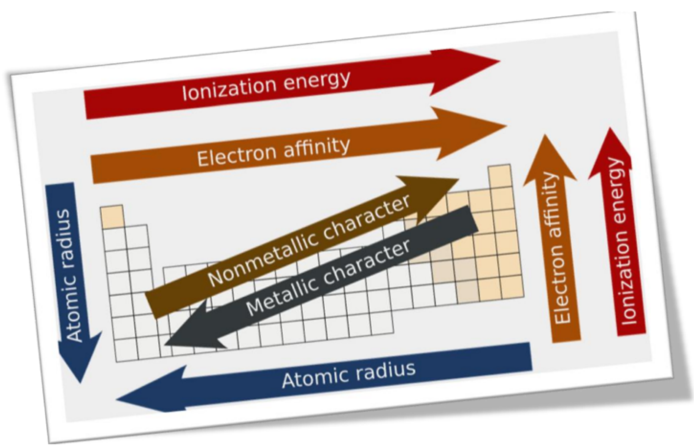


Figure 3.8 Chemical bonds range in character from mostly ionic to mostly covalent.

Section Wrap-up

Despite some irregularities and exceptions, the following periodic trends summarize the relationships among atomic size, ionization energy, and electron affinity:

- Trends for atomic size are the reverse of trends for ionization energy and electron affinity. Larger atoms tend to have lower ionization energies and lower electron affinities.
- Group 16 (VIA) and 17 (VIIA) elements attract electrons strongly. They do not give up electrons readily. In other words, they have a strong tendency to form negative ions. Thus, they have high ionization energies and high electron affinities.
- Group 1 (IA) and 2 (IIA) elements give up electrons readily. They have low or no attraction for electrons. In other words, they have a strong tendency to form positive ions. Thus, they have low ionization energies and low electron affinities.
- Group 18 (VIIIA) elements do not attract electrons and do not give up electrons. In other words, they do not naturally form ions. (They are very stable.) Thus, they have very high ionization energies and very low electron affinities.



Practice:

1 K/U How does your understanding of electron arrangement and forces in atoms help you explain the following periodic trends?
(a) atomic radius
(b) ionization energy
(c) electron affinity

2 K/U Using only their location in a periodic table, rank each of the following sets of elements in order of increasing atomic size. Explain your answer in each case.
(a) Mg, S, Cl
(b) Al, B, In
(c) Ne, Ar, Xe
(d) Rb, Xe, Te
(e) P, Na, F
(f) O, S, N

3 K/U Using only their location in a periodic table, rank each of the following sets of elements in order of decreasing ionization energy. Explain your answer in each case.
(a) Cl, Br, I
(b) Ga, Ge, Se
(c) K, Ca, Kr
(d) Na, Li, Cs
(e) S, Cl, Br
(f) Cl, Ar, K

4 K/U Which element in each of the following pairs will have the lower electron affinity? Explain your answer in each case.
(a) K or Ca
(b) O or Li
(c) S or Se
(d) Cs or F

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Part B: Naming ionic and molecular compounds

Two types of compounds:

Ionic compound – occurs when a metal loses all its valence electrons to a non-metal. The metal becomes a cation, while the non-metal becomes an anion.

Covalent compound – two non-metals share electrons. Neither loses or gains electrons – they share electrons. Neither atom becomes an ion.

<u>Part I: How to name ionic compounds?</u>

Rules for naming Binary ionic compound:

1. The name of the metal ion is first, followed by the name of the non-metal ion.
2. The name of the metal ion is the same as the name of the metal atom.
3. If the metal is a transition metal, it might have more than one possible charge. In these cases, a roman numeral is written in brackets after the name of the metal to indicate the magnitude of the charge.
4. The name of the non-metal ion has the same root as the name of the atom, but the suffix is changed to **–ide.**

(common ionic charges in compounds)

Nonmetals ↕ Metals

Transition Metals

1 H 1+																	2 He n/a
3 Li 1+	4 Be 2+											5 B n/a	6 C n/a	7 N 3-	8 O 2-	9 F 1-	10 Ne n/a
11 Na 1+	12 Mg 2+											13 Al 3+	14 Si n/a	15 P 3-	16 S 2-	17 Cl 1-	18 Ar n/a
19 K 1+	20 Ca 2+	21 Sc 3+	22 Ti 4+,3+,2+	23 V 5+,4+,3+,2+	24 Cr 6+,3+,2+	25 Mn 7+,4+,3+,2+	26 Fe 3+,2+	27 Co 3+,2+	28 Ni 3+,2+	29 Cu 2+,1+	30 Zn 2+	31 Ga 3+	32 Ge 4+,2+	33 As 5+,3+,3-	34 Se 2-	35 Br 1-	36 Kr n/a
37 Rb 1+	38 Sr 2+	39 Y 3+	40 Zr 4+	41 Nb 5+,3+	42 Mo 6+	43 Tc 7+,6+,4+	44 Ru 3+	45 Rh 3+	46 Pd 4+,2+	47 Ag 1+	48 Cd 2+	49 In 3+	50 Sn 4+,2+	51 Sb 5+,3+,3-	52 Te 6+,4+,2-	53 I 1-	54 Xe n/a
55 Cs 1+	56 Ba 2+	57 La 3+	72 Hf 4+	73 Ta 5+	74 W 6+	75 Re 7+,6+,4+	76 Os 4+,3+	77 Ir 4+,3+	78 Pt 4+,2+	79 Au 3+,1+	80 Hg 2+,1+	81 Tl 3+,1+	82 Pb 4+,2+	83 Bi 5+,3+	84 Po 4+,2+,2-	85 At 1+,1-	86 Rn n/a
87 Fr 1+	88 Ra 2+	89 Ac 3+	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Not Yet Named	111	112	113	114	115	116	117	118

Example of transition metals: Mn^{4+} Manganese (IV) Fe^{2+} Iron (II) or ferrous Cu^{1+} Copper (I)

Mn^{6+} Manganese (VI) Fe^{3+} Iron (III) or ferric Cu^{2+} Copper (II)

Example: Name the following compounds.

Fe_2O_2		Cu_3P_2	
$ZnCl_2$		PbS_2	
$AgCl$		MnO_2	

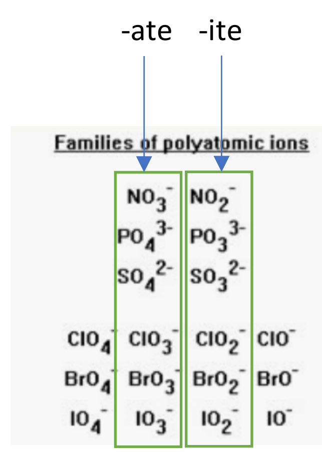
How about ionic compounds with polyatomic ions?

Valence = –1			
Ion	Name	Ion	Name
CN^-	cyanide	$H_2PO_3^-$	dihydrogen phosphite
CH_3COO^-	acetate	$H_2PO_4^-$	dihydrogen phosphate
ClO^-	hypochlorite	MnO_4^-	permanganate
ClO_2^-	chlorite	NO_2^-	nitrite
ClO_3^-	chlorate	NO_3^-	nitrate
ClO_4^-	perchlorate	OCN^-	cyanate
HCO_3^-	hydrogen carbonate	HS^-	hydrogen sulfide
HSO_3^-	hydrogen sulfite	OH^-	hydroxide
HSO_4^-	hydrogen sulfate	SCN^-	thiocyanate

Valence = –2			
Ion	Name	Ion	Name
CO_3^{2-}	carbonate	O_2^{2-}	peroxide
$C_2O_4^{2-}$	oxalate	SiO_3^{2-}	silicate
CrO_4^{2-}	chromate	SO_3^{2-}	sulfite
$Cr_2O_7^{2-}$	dichromate	SO_4^{2-}	sulfate
HPO_3^{2-}	hydrogen phosphite	$S_2O_3^{2-}$	thiosulfate
HPO_4^{2-}	hydrogen phosphate		

Valence = –3			
Ion	Name	Ion	Name
AsO_3^{3-}	arsenite	PO_3^{3-}	phosphite
AsO_4^{3-}	arsenate	PO_4^{3-}	phosphate

Prefix and suffix		Number of oxygen atoms
hypo	ite	$x - 2$ oxygen atoms
	ite	$x - 1$ oxygen atoms
	ate	x oxygen atoms
per	ate	$x + 1$ oxygen atoms



Example: Name the following Ionic compounds write chemical formula by using cross over rule.

Cation	Anion	Compound	Name
Ca^{2+}	NO_3^-		
Mg^{2+}	PO_4^{3-}		
Ba^{2+}	SO_4^{2-}		

Part II: How to name covalent compounds?

Rules for naming Binary covalent compound:

1. Name the element with the lower group number first. Name the element with the higher group number second.
2. The one exception to the first rule occurs when oxygen is combined with a halogen. In this situation, the halogen is named first.
3. If both elements are in the same group, name the element with the higher period number first.
4. The name of the first element is unchanged.
5. To name the second element, use the root name of the element and add the suffix **–ide.**
6. If there are two or more atoms of the first element, add a prefix to indicate the number of atoms.
7. Always add a prefix to the name of the second element to indicate the number of atoms of this element in the compound.
   (if the second element is oxygen, an "o" or "a" at the end of the prefix is usually omitted)

Binary compound of a metalloid and non-metal or 2 metalloids are usually molecular.

Example: Name these compounds:

Chemical formula	Name
CoF_2	
PCl_3	
Sr_3N_2	
KOH	
NH_3	

Number	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
9	nona-
10	deca-

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Practice:

Write the formulas for the following covalent compounds:

1) antimony tribromide ________________________

2) hexaboron silicide ________________________

3) chlorine dioxide ________________________

4) hydrogen iodide ________________________

5) iodine pentafluoride ________________________

6) dinitrogen trioxide ________________________

7) ammonia ________________________

8) phosphorus triiodide ________________________

Write the names for the following covalent compounds:

9) P_4S_5 ________________________

10) O_2 ________________________

11) SeF_6 ________________________

12) Si_2Br_6 ________________________

13) SCl_4 ________________________

14) CH_4 ________________________

15) B_2Si ________________________

16) NF_3 ________________________

For each of the following questions, determine whether the compound is ionic or covalent and name it appropriately.

1) Na_2CO_3 ________________________

2) P_2O_5 ________________________

3) NH_3 ________________________

4) $FeSO_4$ ________________________

5) SiO_2 ________________________

6) $GaCl_3$ ________________________

7) $CoBr_2$ ________________________

8) B_2H_4 ________________________

9) CO ________________________

10) P_4 ________________________

For each of the following questions, determine whether the compound is ionic or covalent and write the appropriate formula for it.

11) dinitrogen trioxide ________________________

12) nitrogen ________________________

13) methane ________________________

14) lithium acetate ________________________

15) phosphorus trifluoride ________________________

16) vanadium (V) oxide ________________________

Exceptions to Naming rules

Peroxides (highly reactive):

- Compounds that contain an oxygen-oxygen single bond
- Oxygen has charge of – 1
- "per" = an extra oxygen atom

Steps for writing peroxides:

1. Write formula of oxide
2. Add one more oxygen
3. Do NOT cancel subscripts

Example: Write chemical formulas of the following compounds.

a) sodium peroxide
b) hydrogen peroxide
c) barium peroxide

Hydrates:

- An ionic compound that contains loosely attached water molecules as part of its ionic crystal structure

For instance, when heat is applied to $CuSO_4 \cdot 5H_2O$ (the hydrate), it will decompose to produce water vapour and the associated ionic compound (the anhydrate).

Step 1: Name the ionic compound.

Step 2: Indicate the number of water molecules using a Greek prefix in front of "hydrate"

Example:

a) $MgSO_4 \cdot 7H_2O$
b) sodium carbonate decahydrate
c) lithium chlorate trihydrate
d) Iron (III) choride hexahydrate

Part III: How to name acids?

Acid is a compound in which one or more hydrogen ions are bonded to a negative ion.

For example:

$HF \rightarrow H^{+} + F^{-}$

$H_2S \rightarrow 2H^{+} + S^{2-}$

$HNO_3 \rightarrow H^{+} + NO_3{}^{-}$

$H_2SO_4 \rightarrow 2H^{+} + SO_4{}^{2-}$

The name of acid is based on the name of the negative ion that is part of the acid.

Naming acids without oxygen

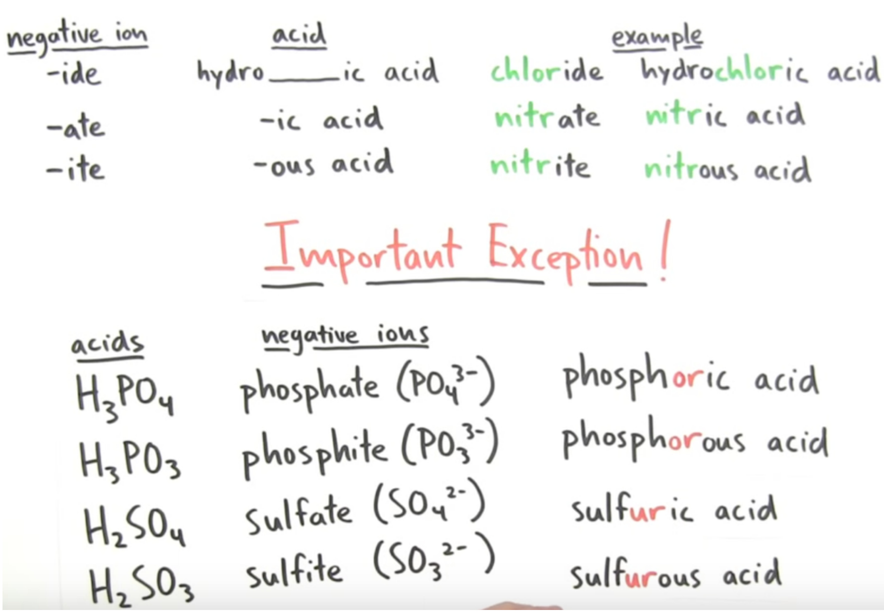
Take HCl as an example:

Negative ion	Acid
−ide	Hydro ______ic acid
Chloride	Hydro**chlor**ic acid

How about HBr:

Negative ion	Acid
−ide	Hydro ______ic acid
Bromide	Hydro**brom**ic acid

Negative Ions	
Fluoride	F^{-}
Chloride	Cl^{-}
Bromide	Br^{-}
Iodide	I^{-}
Oxide	O^{2-}
Sulfide	S^{2-}
Nitride	N^{2-}
Phosphide	P^{3-}



Naming acids with oxygen (oxoacids)

How about $HClO$:

Negative ion	Acid
$hypo$ −ite	$hypo$ −ous acid
Hypochlorite	**Hypochlor**ous acid

How about $HClO_2$:

Negative ion	Acid
−ite	−ous acid
Chlorite	**Chlor**ous acid

How about HNO_2:

Negative ion	Acid
−ite	−ous acid
Nitrite	**Nitr**ous acid

Take HNO_3 as an example:

Negative ion	Acid
−ate	−ic acid
Nitrate	**Nitr**ic acid

How about H_2CO_3:

Negative ion	Acid
−ate	−ic acid
Carbonate	**Carbon**ic acid

How about H_2MnO_4: (We call $MnO_4{}^{2-}$ $manganate$, Mn has charge of +6)

Negative ion	Acid
−ate	−ic acid
manganate	**mangan**ic acid

How about $HMnO_4$: (We call $MnO_4{}^{-}$ $permanganate$, Mn has charge of +7)

Negative ion	Acid
per −ate	per −ic acid
Permanganate	**Permangan**ic acid

MORE TO COME:

1. Basic Lewis structure (Exception octet rule in Unit 2)
2. Stoichiometry
   a) Balance chemical reaction
   b) Type of reactions
   c) Determine limiting reactant
   d) Calculation

PART C: Lewis Structures for covalent compounds

Steps:

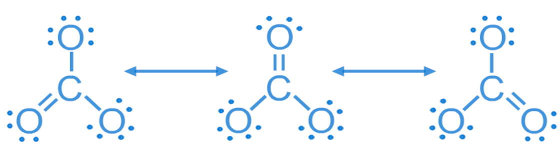
1. Place the central atom in the centre and other atoms around it evenly spaced.
2. Count the total number of valence electrons for all atoms involved in the bonding.
3. Placed the electrons in pairs between the central atom and each non-central atom
4. Place the remaining electrons around the non-central atom until each has 8 electrons (H atoms have only 2 electrons.)
5. If electrons remain they are placed in pairs around the central atom.
6. Exception: if the central atom is in group 14, 15, 16, 17, 18, the octet rule must be satisfied by moving electron pairs from non-central atoms, creating multiple bonds.

Example: Draw the Lewis diagrams of $AsBr_3$ and SO_2, and PCl_5.

Resonance structure:

When several structures with different electron distributions among the bonds are possible, all the structures contribute to the electronic structure of the molecule. These structures are called resonance structures

For instance: carbonate anion



Formal charge =	valence electrons −	NonBonding valence electrons −	$\frac{\text{Bonding electrons}}{2}$
Carbon: 0	4	0	$\frac{8}{2} = 4$
Oxygen:			
Oxygen:			

Summary:

When considering the resonance structure…

- Formal charge closest to zero is favoured
- Negative formal charges on the more negative elements are favoured.

When drawing Lewis diagrams…

- Symmetrical arrangements are favoured
- Hydrogen is never a central atom
- The **least** electronegative element is usually the central atom

Practice: Draw Lewis structure for the following compounds.

1) CCl_4
2) HCl
3) NH_3
4) OH^-
5) SO_4^{2-}
6) Nitrogen gas

PART D: Type of reactions

I: Combustion reaction

Reaction type	Generalization
combustion	AB + oxygen → commmon oxides of A and B
synthesis	A + B → AB
decomposition	AB → A + B
single displacement	A + BC → AC + B
double displacement	AB + CD → AD + CB

- To successfully predict the products of a complete combustion reaction, we must know the most common oxides.

1) For metal: the most common oxide is the one formed with the metal's most common ion.

2) For non-metal: see the table

Combustion situation	Element in reactant	Common oxide
coal in a coal-fired electricity generator	carbon	$CO_{2(g)}$
burning of rocket fuel	hydrogen	$H_2O_{(g)}$
commercial production of sulfuric acid	sulfur	$SO_{2(g)}$
lightning strikes and volcanoes	nitrogen	$NO_{2(g)}$

Carbon dioxide: wood burning; living organism cellular respiration;

Sulphur dioxide: volcanic eruptions; contribute to natural acidity of rain forming sulfuric acid;

Nitrogen dioxide: oxide from lightning strikes; plant decay; burning of gasoline at high temperature;

II: Synthesis reaction: a chemical reaction in which two or more substances combine to form a more complex substance.

Example: Sulfur trioxide is a by-product of the combustion of gasoline in car engines. In the atmosphere it reacts with condensed water on dust particles, producing sulfuric acid. Write a word equation and a balanced chemical equation for the reaction.

Example: Metal oxide such as sodium oxide reacting with water produces sodium hydroxide which has a wide variety of industrial uses including the production of paper, soaps, and detergents. Write a word equation and a balanced chemical equation for the reaction.

Teacher: Ella

III: Decomposition reactions: a chemical reaction in which a compound is broken down into two or more simpler substances.

- Decomposition of simple binary compounds generally yield two elements that make up the compound.
  For instance: sodium chloride decomposes into sodium and chlorine.

$$2NaCl_{(l)} \rightarrow 2Na_{(l)} + Cl_{2(g)}$$

- Decomposition of compounds consisting of more than 2 elements often form simpler compounds is harder to predict. In particular, **thermal decomposition**, taken place when heat applied.

  For instance: The thermal decomposition of hydrazine is used in the thruster rockets of the Phoenix Mars Lander, under the provision of massive thermal energy, hydrazine brakes down as following:

  Hydrazine is an effective fuel for thruster rockets because:

  1. Decompose **quickly** to produce a large volume of hot gases.
  2. Does not need to be mixed with another chemicals (catalyst) for a decomposition reaction to occur, could be precisely controlled by measuring how much hydrazine was burned.

Some rules:

- A metal nitrate decomposing into a metal nitrite and oxygen gas.
- A metal carbonate decomposing into a metal oxide and carbon dioxide.
- A metal hydroxide decomposing into a metal oxide and water.
- A metal chlorate decomposing into metal chloride and oxygen.

Practice:

1) Decomposition of aluminum carbonate:

2) Decomposition of calcium hydroxide:

3) Decomposition of aluminum nitrate:

4) Decomposition of magnesium chlorate:

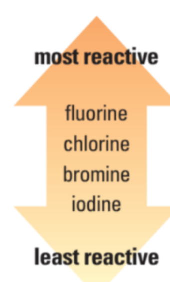
5) Decomposition of sodium hydrogen carbonate

IV: Single displacement reactions: the reaction of an element with a compound to produce a new element and a new compound.

- Like displaces like – a metallic element takes the place of a metal in a compound; a non-metallic element takes the place of a non-metal in a compound.
- In order to predict whether a single displacement reaction will take place, we need to refer to an **Activity Series**.
  1) The Activity Series was created in terms of the concept of electronegativity.
  2) For the metals, the lower the electronegativity, the more reactive the metal should be.
  3) For the non-metals (Halogen), the higher the electronegativity, the more reactive. Such that chorine will be displaced from a compound by fluorine.

Element	Electronegativity
lithium	1.0
potassium	0.8
barium	0.9
calcium	1.0
sodium	0.9
magnesium	1.2
aluminum	1.5
zinc	1.6
iron	1.8
nickel	1.8
tin	1.8
lead	1.8
hydrogen	2.1
copper	1.9
silver	1.9
gold	2.4

Example: in welding operations, aluminum is reacted with iron (III) oxide in what is called the Thermite process. Use the activity series to predict the products of this reaction and represent the reaction in a balanced chemical equation.



Example: Use the activity series to predict whether zinc reacts with magnesium nitrate and, if so, the products of this reaction.

Example: Predict the products of the reaction (if any) between chlorine gas and a solution of sodium bromide obtained from seawater (brine). Represent the reaction in a balanced equation.

Case study I: Extracting metals: Magnesium mining from seawater

1) From seawater, sodium is the most abundant cations and magnesium is the second most abundant.
2) Steps in the process of Magnesium mining

Calcium carbonate is decomposed to produce calcium oxide.

↓

Calcium hydroxide is produced by a synthesis reaction between calcium oxide and water.

↓

Magnesium hydroxide precipitates when calcium hydroxide is mixed with seawater.

↓

A neutralization reaction between magnesium hydroxide and hydrochloric acid produces magnesium chloride.

↓

Magnesium and chlorine are produced by the decomposition of magnesium chloride.

3) What happen next? <u>Manufacturing of aluminum-magnesium alloys.</u>

What is alloy?

____.

Why alloy?

Reason 1: ____.

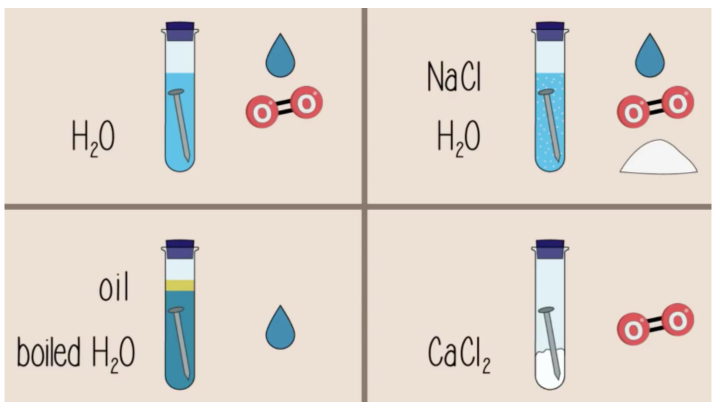
Reason 2: ____.

Reason 3: ____.

Case study II: Rusting and protection:

Rusting (or corrosion) may happen when Iron gets exposed to moisture, oxygen, and salt from surrounding atmosphere leads chemical reaction to take place. The rusting of iron will be forming hydrated iron (III) oxide that undergone an oxidation reaction.

Watch the video and take notes down: https://www.youtube.com/watch?v=jQoE_9x37mQ



How to prevent it?

Way 1: ____.

Way 2: ____ .

Way 3: ____.

V: Double displacement reactions: a reaction in which aqueous ionic compounds rearrange cations and anions, resulting in the formation of new compounds.

There are three main types of double displacement reaction:

1) Neutralization reactions: When an acid and a base are mixed, water will be produced as well as a salt.

   Example: How does Magnesium hydroxide react with hydrochloric acid?

2) Precipitation reactions: In order to predict whether a precipitation reaction will take place, we need to refer to a Solubility Table.

		Anions						
		Cl^-, Br^-, I^-	S^{2-}	OH^-	SO_4^{2-}	CO_3^{2-}, PO_4^{3-}, SO_3^{2-}	$C_2H_3O_2^-$	NO_3^-
Cations	High solubility (aq) ≥0.1 mol/L (at SATP)	most	Group 1, NH_4^+ Group 2	Group 1, NH_4^+ Sr^{2+}, Ba^{2+}, Tl^+	most	Group 1, NH_4^+	most	all
		All Group 1 compounds, including acids, and all ammonium compounds are assumed to have high solubility in water.						
	Low Solubility (s) <0.1 mol/L (at SATP)	Ag^+, Pb^{2+}, Tl^+, Hg_2^{2+}, (Hg^+), Cu^+	most	most	Ag^+, Pb^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Ra^{2+}	most	Ag^+	none

Example: Write a balanced equation to represent the reaction of an aqueous solution of barium chloride with an aqueous solution of potassium sulfate. Indicate the physical state of the reactants and products involved.

3) Gas-producing reactions: A double displacement reaction will take place if the reaction produces a gas

Example: Write a chemical equation when sodium sulfide solution and hydrochloric acid react to produce hydrogen sulfide gas.

PART E: Calculation involved in reactions

SUMMARY Calculating Mass, Amounts in Moles, and Number of Entities

1. n represents the amount in moles, m the mass measured, M the molar mass, N the number of entities, and N_A Avogadro's constant (**Table 1**).
2. $n = \frac{m}{M}$
3. $m = nM$
4. $N = nN_A$

Table 1: Stoichiometry, Symbols and Units

Symbol	Quantity	Unit
n	amount in moles	mol
m	mass	mg, g, kg
M	molar mass	g/mol
N	number of entities	atoms, ions, formula units, molecules
N_A	Avogadro's constant, 6.02×10^{23}	—

Calculation Examples:

Name of compound	Molecular (actual) formula	Empirical (simplest) formula	Lowest ratio of elements
hydrogen peroxide	H_2O_2	HO	1:1
glucose	$C_6H_{12}O_6$	CH_2O	1:2:1
benzene	C_6H_6	CH	1:1
acetylene (ethyne)	C_2H_2	CH	1:1
aniline	C_6H_7N	C_6H_7N	6:7:1
water	H_2O	H_2O	2:1

Problem

Calculate the empirical formula of a compound that is 85.6% carbon and 14.4% hydrogen.

$$\text{Number of moles of C in 100 g sample} = \frac{85.6\ \cancel{g}}{12.01\ \cancel{g}/\text{mol}} = 7.13\ \text{mol}$$

$$\text{Number of moles of H in 100 g sample} = \frac{14.4\ \cancel{g}}{1.01\ \cancel{g}/\text{mol}} = 14.3\ \text{mol}$$

Now determine the lowest whole number ratio. Divide both molar amounts by the lowest molar amount.

$$C_{\frac{7.13}{7.13}}H_{\frac{14.3}{7.13}} \rightarrow C_{1.00}H_{2.01} \rightarrow CH_2$$

Problem

The empirical formula of ribose (a sugar) is CH_2O. In a separate experiment, using a mass spectrometer, the molar mass of ribose was determined to be 150 g/mol. What is the molecular formula of ribose?

The "molar mass" of the empirical formula CH_2O, determined using the periodic table, is

$$12 \text{ g/mol} + 2(1) \text{ g/mol} + 16 \text{ g/mol} = 30 \text{ g/mol}$$

The molar mass of ribose is 150 g/mol.

$$\frac{150 \cancel{\text{g/mol}}}{30 \cancel{\text{g/mol}}} = 5$$

Molecular formula subscripts = 5 × Empirical formula subscripts

$$= C_{1\times5}H_{2\times5}O_{1\times5}$$
$$= C_5H_{10}O_5$$

Therefore, the molecular formula of ribose is $C_5H_{10}O_5$.

Problem

A 1.000 g sample of a pure compound, containing only carbon and hydrogen, was combusted in a carbon-hydrogen combustion analyzer. The combustion produced 0.6919 g of water and 3.338 g of carbon dioxide.

(a) Calculate the masses of the carbon and the hydrogen in the sample.

(b) Find the empirical formula of the compound.

Act on Your Strategy

(a) Mass of H in sample

$$= \frac{2.02 \text{ g } H_2}{18.02 \cancel{\text{g } H_2O}} \times 0.6919 \cancel{\text{g } H_2O} = 0.077\ 56 \text{ g } H_2$$

Mass of C in sample $= \frac{12.01 \text{ g C}}{44.01 \cancel{\text{g } CO_2}} \times 3.338 \cancel{\text{g } CO_2} = 0.9109 \text{ g C}$

The sample contained 0.077 56 g of hydrogen and 0.9109 g of carbon.

(b) Moles of H in sample $= \frac{0.07756 \cancel{\text{g}}}{1.008 \cancel{\text{g}}/\text{mol}} = 0.07694 \text{ mol}$

Moles of C in sample $= \frac{0.9109 \cancel{\text{g}}}{12.01 \cancel{\text{g}}/\text{mol}} = 0.07584 \text{ mol}$

Empirical formula $= C_{\frac{0.07584}{0.07584}}H_{\frac{0.07584}{0.07694}}$

$$= C_{1.0}H_{1.0}$$
$$= CH$$

Teacher: Ella

Problem

A hydrate of barium hydroxide, $Ba(OH)_2 \cdot xH_2O$, is used to make barium salts and to prepare certain organic compounds. Since it reacts with CO_2 from the air to yield barium carbonate, $BaCO_3$, it must be stored in tightly stoppered bottles.

(a) A 50.0 g sample of the hydrate contains 27.2 g of $Ba(OH)_2$. Calculate the percent, by mass, of water in $Ba(OH)_2 \cdot xH_2O$.

(b) Find the value of x in $Ba(OH)_2 \cdot xH_2O$.

Act on Your Strategy

(a) Mass percent of water in $Ba(OH)_2 \cdot xH_2O$

$$= \frac{\text{(Total mass of sample)} - \text{(Mass of Ba(OH)}_2\text{ in sample)}}{\text{(Total mass of sample)}} \times 100\%$$

$$= \frac{50.0\ \cancel{g} - 27.2\ \cancel{g}}{50.0\ \cancel{g}} \times 100\%$$

$$= 45.6\%$$

(b) Moles of $Ba(OH)_2$

$$= \frac{\text{Mass of Ba(OH)}_2}{\text{Molar mass of Ba(OH)}_2}$$

$$= \frac{27.2\ \cancel{g}}{171.3\ \cancel{g}/\text{mol}}$$

$$= 0.159 \text{ mol Ba(OH)}_2$$

Moles of H_2O

$$= \frac{\text{Mass of H}_2\text{O}}{\text{Molar mass of H}_2\text{O}}$$

$$= \frac{50.0\ \cancel{g} - 27.2\ \cancel{g}}{18.02\ \cancel{g}/\text{mol}}$$

$$= 1.27 \text{ mol H}_2\text{O}$$

$$\frac{0.159}{0.159} \text{ mol Ba(OH)}_2 : \frac{1.27}{0.159} \text{ mol H}_2\text{O} = 1.0 \text{ mol Ba(OH)}_2 : 8.0 \text{ mol H}_2\text{O}$$

The value of x in $Ba(OH)_2 \cdot xH_2O$ is 8.
Therefore, the molecular formula of the hydrate is $Ba(OH)_2 \cdot 8H_2O$.

Problem

White phosphorus consists of a molecule made up of four phosphorus atoms. It burns in pure oxygen to produce tetraphosphorus decaoxide.

$$P_{4(s)} + 5O_{2(g)} \rightarrow P_4O_{10(s)}$$

A 1.00 g piece of phosphorus is burned in a flask filled with 2.60×10^{23} molecules of oxygen gas. What mass of tetraphosphorus decaoxide is produced?

Act on Your Strategy

$$n \text{ mol } P_4 = \frac{1.00 \cancel{\text{g}} \, P_4}{123.9 \cancel{\text{g}}/\text{mol } P_4} = 8.07 \times 10^{-3} \text{ mol } P_4$$

$$n \text{ mol } O_2 = \frac{2.60 \times 10^{23} \cancel{\text{molecules}}}{6.02 \times 10^{23} \cancel{\text{molecules}}/\text{mol}} = 0.432 \text{ mol } O_2$$

Calculate the amount of P_4O_{10} that would be produced by the P_4.

$$\frac{n \text{ mol } P_4O_{10}}{8.07 \times 10^{-3} \text{ mol } P_4} = \frac{1 \text{ mol } P_4O_{10}}{1 \text{ mol } P_4}$$

$$(\cancel{8.07 \times 10^{-3} \text{ mol } P_4})\frac{n \text{ mol } P_4O_{10}}{\cancel{8.07 \times 10^{-3} \text{ mol } P_4}} = \frac{1 \text{ mol } P_4O_{10}}{1 \cancel{\text{mol } P_4}}(8.07 \times 10^{-3} \cancel{\text{mol } P_4})$$

$$= 8.07 \times 10^{-3} \text{ mol } P_4O_{10}$$

Calculate the amount of P_4O_{10} that would be produced by the O_2.

$$\frac{n \text{ mol } P_4O_{10}}{0.432 \text{ mol } O_2} = \frac{1 \text{ mol } P_4O_{10}}{5 \text{ mol } O_2}$$

$$(\cancel{0.432 \text{ mol } O_2})\frac{n \text{ mol } P_4O_{10}}{\cancel{0.432 \text{ mol } O_2}} = \frac{1 \text{ mol } P_4O_{10}}{5 \cancel{\text{mol } O_2}}(0.432 \cancel{\text{mol } O_2})$$

$$= 8.64 \times 10^{-2} \text{ mol } P_4O_{10}$$

Since P_4 would produce less P_4O_{10} than O_2 would, P_4 is the limiting reactant.

$$P_{4(s)} \quad + \quad 5O_{2(g)} \longrightarrow P_4O_{10(s)}$$

0.00807 mol → 0.00807 mol

unknown ratio **known ratio**

$$\frac{n \text{ mol } P_4O_{10}}{0.00807 \text{ mol } P_4} = \frac{1 \text{ mol } P_4O_{10}}{1 \text{ mol } P_4}$$

$$(\cancel{0.00807 \text{ mol } P_4})\frac{n \text{ mol } P_4O_{10}}{\cancel{0.00807 \text{ mol } P_4}} = (0.00807 \cancel{\text{mol } P_4})\frac{1 \text{ mol } P_4O_{10}}{1 \cancel{\text{mol } P_4}}$$

$$= 0.00807 \text{ mol } P_4O_{10}$$

$0.00807 \text{ mol } P_4O_{10} \times 284 \text{ g/mol } P_4O_{10}$

↓

$2.29 \text{ g } P_4O_{10}$

Problem

Iron pyrite, FeS_2, is known as "fool's gold" because it looks similar to gold. Suppose that you have a 13.9 g sample of *impure* iron pyrite. (The sample contains a non-reactive impurity.) You heat the sample in air to produce iron(III) oxide, Fe_2O_3, and sulfur dioxide, SO_2.

$$4FeS_{2(s)} + 11O_{2(g)} \rightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

If you obtain 8.02 g of iron(III) oxide, what was the percentage of iron pyrite in the original sample? Assume that the reaction proceeds to completion. That is, all the available iron pyrite reacts completely.

Practice:

Practice Problems

41. Calculate the mass of 3.57 mol of vanadium.

42. Calculate the mass of 0.24 mol of carbon dioxide.

43. Calculate the mass of 1.28×10^{-3} mol of glucose, $C_6H_{12}O_6(s)$.

44. Calculate the mass of 0.0029 mol of magnesium bromide, $MgBr_2(s)$, in milligrams.

45. Name each compound, and then calculate its mass. Express this value in scientific notation.
- **a.** 4.5×10^{-3} mol of $Co(NO_3)_2(s)$
- **b.** 29.6 mol of $Pb(S_2O_3)_2(s)$

46. Determine the chemical formula for each compound, and then calculate its mass.
- **a.** 4.9 mol of ammonium nitrate
- **b.** 16.2 mol of iron(III) oxide

47. What is the mass of 1.6×10^{-3} mol of calcium chloride dihydrate, $CaCl_2 \cdot 2H_2O(s)$, in milligrams?

48. A litre of water contains 55.56 mol of water molecules. What is the mass of a litre of water, in kilograms?

49. For each group of three samples, determine the sample with the largest mass.
- **a.** 2.34 mol of bromine, $Br_2(\ell)$; 9.80 mol of hydrogen sulfide, $H_2S(g)$; 0.568 mol of potassium permanganate, $KMnO_4(s)$
- **b.** 13.7 mol of strontium iodate, $Sr(IO_3)_2(s)$; 15.9 mol of gold(III) chloride, $AuCl_3(s)$; 8.61 mol of bismuth silicate, $Bi_2(SiO_3)_3(s)$

50. Which has the smallest mass: 0.215 mol of potassium hydrogen sulfite, $KHSO_3(s)$; 1.62 mol of sodium hydrogen sulfite, $NaHSO_3(s)$; or 0.0182 mol of aluminum iodate, $Al(IO_3)_3(s)$?

Chapter 5 The Mole: A Chemist's Counter • **MHR** **237**

Practice Problems

51. Convert 29.5 g of ammonia to the amount in moles.

52. Determine the amount in moles of potassium thiocyanate, KSCN(s), in 13.5 kg.

53. Determine the amount in moles of sodium dihydrogen phosphate, NaH_2PO_4(s), in 105 mg.

54. Determine the amount in moles of xenon tetrafluoride, XeF_4(s), in 22 mg.

55. Write the chemical formula for each compound, and then calculate the amount in moles in each sample.

- **a.** 3.7×10^{-3} g of silicon dioxide
- **b.** 25.38 g of titanium(IV) nitrate
- **c.** 19.2 mg of indium carbonate
- **d.** 78.1 kg of copper(II) sulfate pentahydrate

56. The characteristic odour of garlic comes from allyl sulfide, $(C_3H_5)_2S(\ell)$. Determine the amount in moles of allyl sulfide in 168 g.

57. Road salt, $CaCl_2$(s), is often used on roads in the winter to prevent the build-up of ice. What amount in moles of calcium chloride is in a 20.0 kg bag of road salt?

58. Calculate the amount in moles of trinitrotoluene, $C_7H_5(NO_2)_3$(s), an explosive, in 3.45×10^{-3} g.

59. Arrange the following substances in order from largest to smallest amount in moles:

- 865 mg of $Ni(NO_3)_2$(s)
- 9.82 g of $Al(OH)_3$(s)
- 10.4 g of AgCl(s)

60. Place the following substances in order from smallest to largest amount in moles, given 20.0 g of each:

- glucose, $C_6H_{12}O_6$(s)
- barium perchlorate, $Ba(ClO_4)_2$(s)
- tin(IV) oxide, SnO_2(s)

Practice Problems

61. Calculate the mass of each sample.

- **a.** 1.05×10^{26} atoms of neon, Ne(g)
- **b.** 2.7×10^{24} molecules of phosphorus trichloride, $PCl_3(\ell)$
- **c.** 8.72×10^{21} molecules of karakin, $C_{15}H_{21}N_3O_{15}(s)$
- **d.** 6.7×10^{27} formula units of sodium thiosulfate, $Na_2S_2O_3(s)$

62. Determine the number of molecules or formula units in each sample.

- **a.** 32.4 g of lead(II) phosphate, $Pb_3(PO_4)_2(s)$
- **b.** 8.62×10^{-3} g of dinitrogen pentoxide, $N_2O_5(s)$
- **c.** 48 kg of molybdenum(VI) oxide, $MoO_3(s)$
- **d.** 567 g of tin(IV) fluoride, $SnF_4(s)$

63. Sodium hydrogen carbonate, $NaHCO_3(s)$, is the principal ingredient in many stomach-relief medicines.

- **a.** A teaspoon of a particular brand of stomach-relief medicine contains 6.82×10^{22} formula units of sodium hydrogen carbonate. What mass of sodium hydrogen carbonate is in the teaspoon?
- **b.** The bottle of this stomach-relief medicine contains 350 g of sodium hydrogen carbonate. How many formula units of sodium hydrogen carbonate are in the bottle?

64. Riboflavin, $C_{17}H_{20}N_4O_6(s)$, is an important vitamin in the metabolism of fats, carbohydrates, and proteins in your body.

- **a.** The current recommended dietary allowance (RDA) of riboflavin for adult men is 1.3 mg/day. How many riboflavin molecules are in this RDA?
- **b.** The RDA of riboflavin for adult women contains 1.8×10^{18} molecules of riboflavin. What is the RDA for adult women, in milligrams?

65. What is the mass, in grams, of a single atom of platinum?

66. Rubbing alcohol often contains propanol, $C_3H_7OH(\ell)$. Suppose that you have an 85.9 g sample of propanol.

- **a.** How many carbon atoms are in the sample?
- **b.** How many hydrogen atoms are in the sample?
- **c.** How many oxygen atoms are in the sample?

67. a. How many formula units are in a 3.14 g sample of aluminum sulfide, $Al_2S_3(s)$?

- **b.** How many ions (aluminum and sulfide), in total, are in this sample?

68. Which of the following two substances contains the greater mass?

- 6.91×10^{22} molecules of nitrogen dioxide, $NO_2(g)$
- 6.91×10^{22} formula units of gallium arsenide, GaAs(s)

69. Many common dry-chemical fire extinguishers contain ammonium phosphate, $(NH_4)_3PO_4(s)$, as their principal ingredient. If a sample of ammonium phosphate contains 4.5×10^{21} atoms of nitrogen, what is the mass of the sample?

70. Place the following three substances in order, from greatest to smallest number of hydrogen atoms:

- 268 mg of sucrose, $C_{12}H_{22}O_{11}(s)$
- 15.2 g of hydrogen cyanide, $HCN(\ell)$
- 0.0889 mol of acetic acid, $CH_3COOH(\ell)$

Teacher: Ella

Empirical and molecular formulas

Practice Problems

41. The empirical formula for glucose is $CH_2O(s)$. The molar mass of glucose is 180.18 g/mol. Determine the molecular formula for glucose.

42. The empirical formula for xylene is $C_4H_5(\ell)$, and its molar mass is 106 g/mol. What is the molecular formula for xylene?

43. The empirical formula for 1,4-butanediol is $C_2OH_5(\ell)$. Its molar mass is 90.14 g/mol. What is its molecular formula?

44. The empirical formula for styrene is $CH(\ell)$, and its molar mass is 104 g/mol. What is its molecular formula?

45. Calomel is a compound that was once popular for treating syphilis. It contains 84.98% mercury and 15.02% chlorine. It has a molar mass of 472 g/mol. What is its empirical formula?

46. The molar mass of caffeine is 194 g/mol. Determine whether the molecular formula for caffeine is $C_4H_5N_2O(s)$ or $C_8H_{10}N_4O_2(s)$.

47. An unknown compound contains 42.6% oxygen, 32% carbon, 18.7% nitrogen, and the remainder hydrogen. Using mass spectrometry, its molar mass was determined to be 75.0 g/mol. What is the molecular formula for the compound?

48. A compound that contains 6.44 g of boron and 1.80 g of hydrogen has a molar mass of approximately 28 g/mol. What is its molecular formula?

49. The molar mass of a compound is 148.20 g/mol. Its percentage composition is 48.63% carbon, 21.59% oxygen, 18.90% nitrogen, and the rest hydrogen.

a. Find the empirical formula for the compound.

b. Find its molecular formula.

50. Estradiol is the main estrogen compound that is found in humans. Its molar mass is 272.38 g/mol. The percentage composition of estradiol is 72.94% carbon, 10.80% oxygen, and 8.16% hydrogen. Determine whether its molecular formula is the same as its empirical formula. If not, what is each formula?

Limiting reactant, percentage yield, and calculations in stoichiometry

8. Propane is a gas at room temperature, but it exists as a liquid under pressure in a propane tank. It reacts with oxygen in the air to form carbon dioxide and water vapour.

$$C_3H_{8(\ell)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$

What mass of carbon dioxide gas is expected when 97.5 g of propane reacts with sufficient oxygen?

9. Powdered zinc and sulfur react in an extremely rapid, exothermic reaction. The zinc sulfide that is formed can be used in the phosphor coating on the inside of a television tube.

$$Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$$

A 6.00 g sample of Zn is allowed to react with 3.35 g of S.

(a) Determine the limiting reactant.

(b) Calculate the mass of ZnS expected.

(c) How many grams of the excess reactant will remain after the reaction?

10. Titanium(IV) chloride reacts violently with water vapour to produce titanium(IV) oxide and hydrogen chloride gas. Titanium(IV) oxide, when finely powdered, is extensively used in paint as a white pigment.

$$TiCl_{4(s)} + H_2O_{(\ell)} \rightarrow TiO_{2(s)} + 4HCl_{(g)}$$

The reaction has been used to create smoke screens. In moist air, the $TiCl_4$ reacts to produce a thick smoke of suspended TiO_2 particles. What mass of TiO_2 can be expected when 85.6 g of $TiCl_4$ is reacted with excess water vapour?

12. 20.8 g of calcium phosphate, $Ca_3(PO_4)_2$, 13.3 g of silicon dioxide, SiO_2, and 3.90 g of carbon react according to the following equation:

$$2Ca_3(PO_4)_{2(s)} + 6SiO_{2(s)} + 10C_{(s)} \rightarrow P_{4(s)} + 6CaSiO_{3(s)} + 10CO_{(g)}$$

Determine the mass of calcium silicate, $CaSiO_3$, that is produced.

13. 1.56 g of As_2S_3, 0.140 g of H_2O, 1.23 g of HNO_3, and 3.50 g of $NaNO_3$ are reacted according to the equation below:

$$3As_2S_{3(s)} + 4H_2O_{(\ell)} + 10HNO_{3(aq)} + 18NaNO_{3(aq)} \rightarrow 9Na_2SO_{4(aq)} + 6H_3AsO_{4(aq)} + 28NO_{(g)}$$

What mass of H_3AsO_4 is produced?

14. 2.85×10^2 g of pentane, C_5H_{12}, reacts with 3.00 g of oxygen gas, according to the following equation:

$$C_5H_{12(\ell)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(\ell)}$$

What mass of carbon dioxide gas, is produced?

15. Silica (also called silicon dioxide), along with other silicates, makes up about 95% of Earth's crust—the outermost layer of rocks and soil. Silicon dioxide is also used to manufacture transistors. Silica reacts with hydrofluoric acid to produce silicon tetrafluoride and water vapour.

$$SiO_{2(s)} + 4HF_{(aq)} \rightarrow SiF_{4(g)} + 2H_2O_{(g)}$$

(a) 12.2 g of SiO_2 is reacted with a small excess of HF. What is the theoretical yield, in grams, of H_2O?

(b) If the actual yield of water is 2.50 g, what is the percentage yield of the reaction?

(c) Assuming the yield obtained in part (b), what mass of SiF_4 is formed?