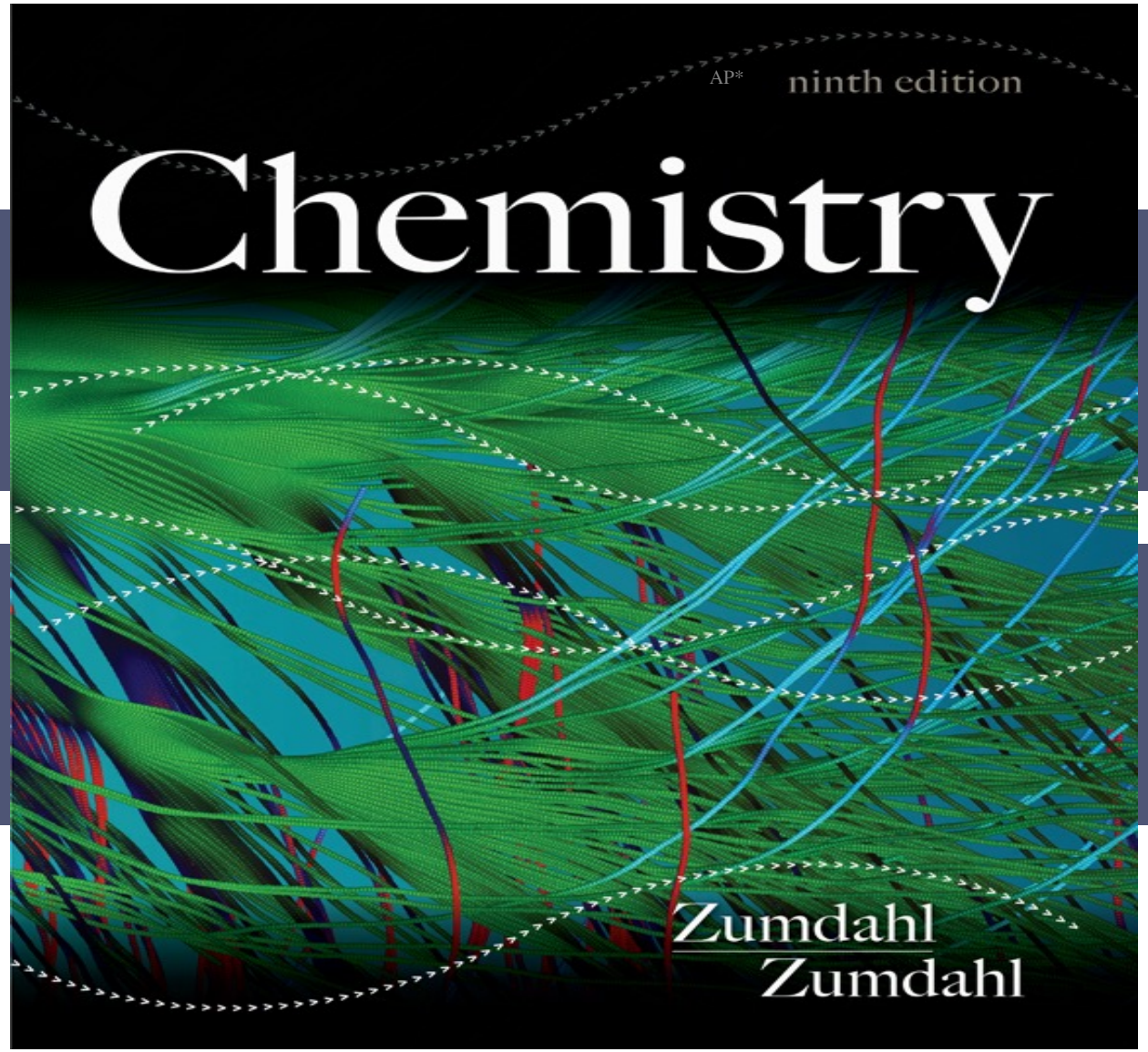
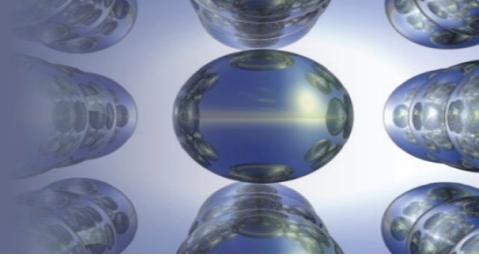


Chapter 2

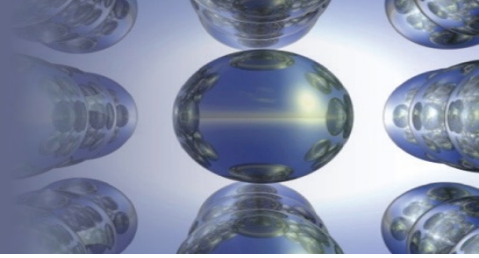
Atoms, Molecules, and Ions

Section 2.1
The Early History of Chemistry



- *(2.1) The early history of chemistry*
- *(2.2) Fundamental chemical laws*
- *(2.5) The modern view of atomic structure: An introduction*
- *(2.6) Molecules and ions*
- *(2.7) An introduction to the periodic table*
- *(2.8) Naming simple compounds*

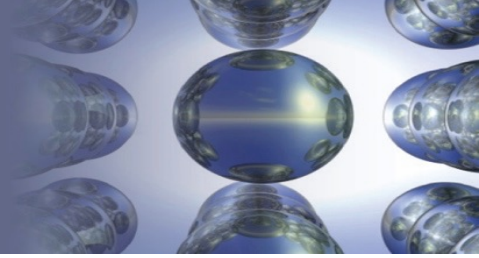
Section 2.2
Fundamental Chemical Laws



1-Law of conservation of mass (Lavoisier)

2-Law of definite proportion (Proust)

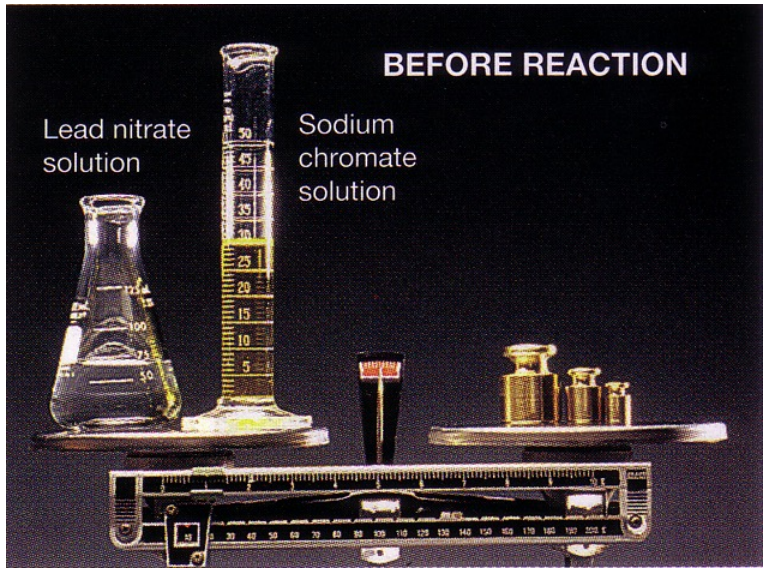
3-Law of multiple proportion (Dalton)

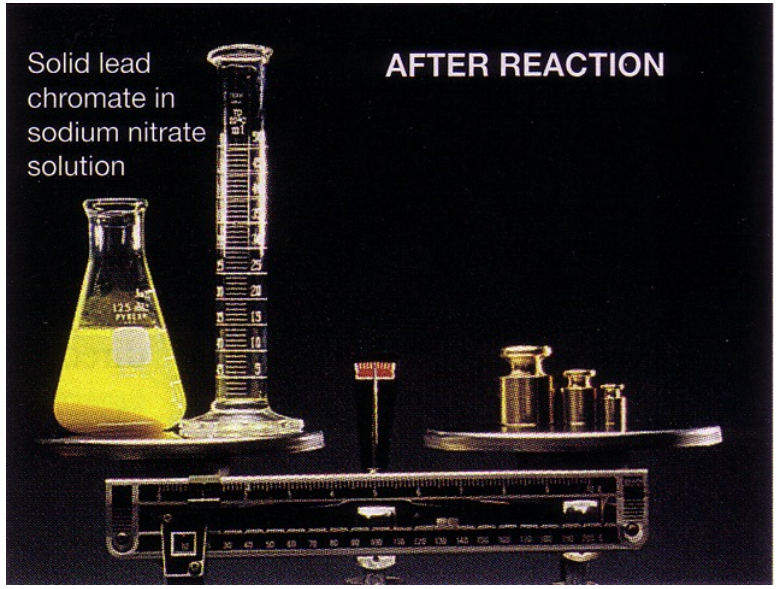


- Law of conservation of mass (Lavoisier):
  - Mass is neither created nor destroyed in a chemical reaction.

The law of mass conservation:

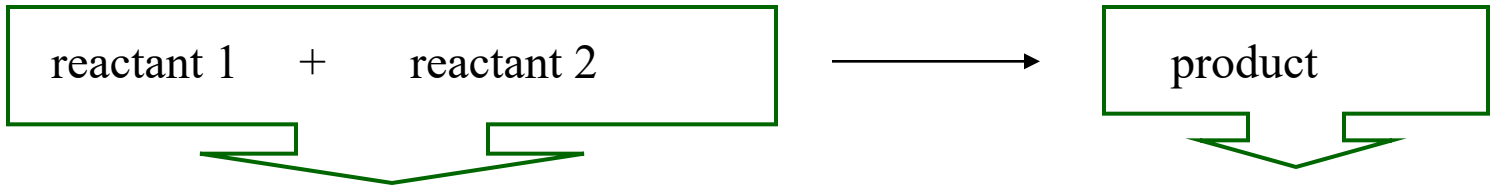
mass remains constant during a chemical reaction.





Law of Mass Conservation

The total mass of substances does not change during a chemical reaction.

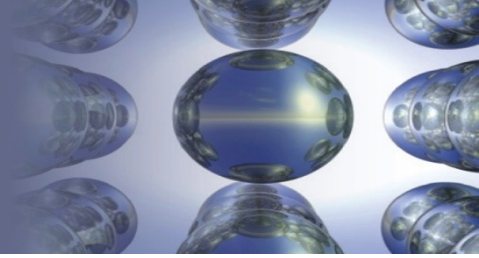


total mass = *total mass*

calcium oxide + carbon dioxide → calcium carbonate

CaO + CO_2 → $CaCO3$

56.08 g + 44.00 g → 100.08 g

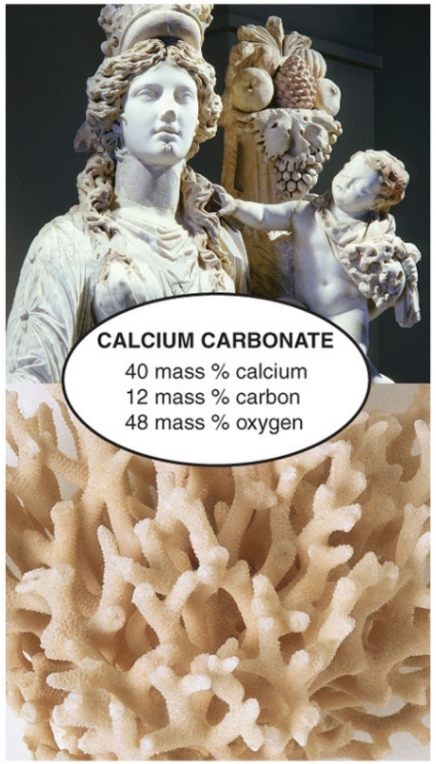


Important Laws

- Law of definite proportion (Proust):
  - A given compound always contains exactly the same proportion of elements by mass.

Law of Definite (or Constant) Composition

No matter the source, a particular compound is composed of the same elements in the same parts (fractions) by mass.



Calcium carbonate ($CaCO_3$)

Analysis by Mass (grams/20.0 g)	Mass Fraction (parts/1.00 part)	Percent by Mass (parts/100 parts)
8.0 g calcium	*0.40 calcium*	*40% calcium*
2.4 g carbon	*0.12 carbon*	*12% carbon*
9.6 g oxygen	*0.48 oxygen*	*48% oxygen*
20.0 g	***1.00 part by mass***	***100% by mass***

Law of definite proportion (Proust):

Example: The % of H in H_2O is 11% and the % of O is 89%. These percentages have fixed values in all other samples of H_2O regardless of their source.

how many gram of H and Oxygen in 100g in sample of H2O ?

Sample Problem ***Calculating the Mass of an Element in a Compound***

PROBLEM: *Analysis of 84.2 kg of the uranium containing compound pitchblende shows it is composed of 71.4 kg of uranium, with oxygen as the only other element. How many grams of uranium can be obtained from 102. kg of pitchblende?*

PLAN: *The mass ratio of uranium/pitchblende is the same no matter the source. We can use the ratio to find the answer.*

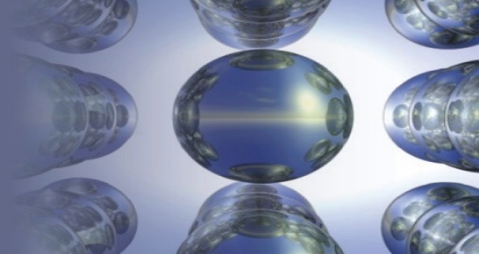
8.65×10^4 g uranium

Sample Problem **Calculating the Mass of an Element in a Compound**

35 P74:

A sample of chloroform is found to contain 12.0 g of carbon, 106.4 g of chlorine, and 1.01 g of hydrogen. If a second sample of chloroform is found to contain 30.0 g of carbon, what is the total mass of chloroform in the second sample?

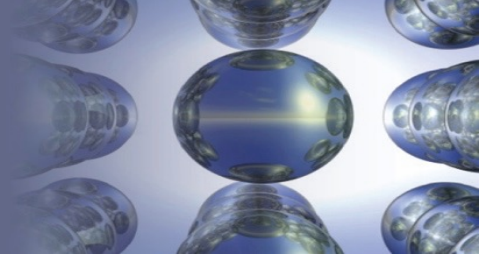
299g



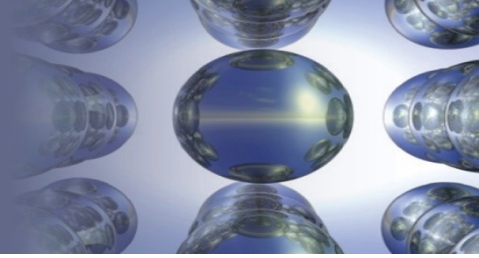
3-Law of multiple proportion (Dalton)

CO2
CO

H2O
H2O2



- *The atom contains:*
  - *Electrons – found outside the nucleus; negatively charged.*
  - *Protons – found in the nucleus; positive charge equal in magnitude to the electron's negative charge.*
  - *Neutrons – found in the nucleus; no charge; virtually same mass as a proton.*



- *The nucleus is:*
  - *Small compared with the overall size of the atom.*
  - *Extremely dense; accounts for almost all of the atom's mass.*

2.5 The Modern Reassessment of the Atomic Theory

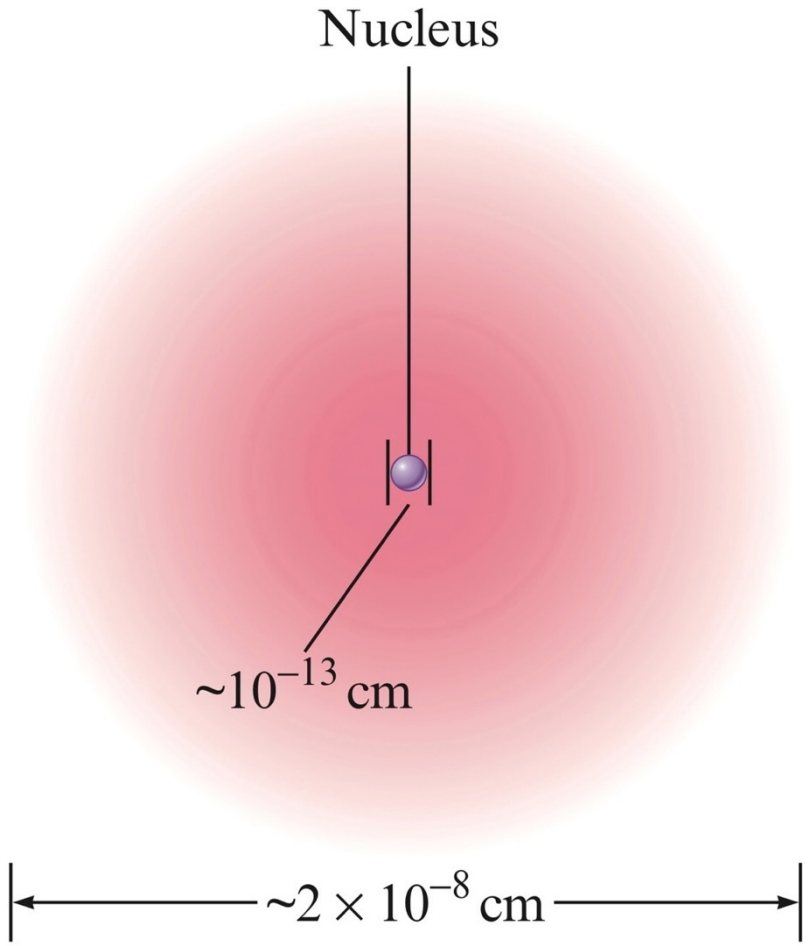
1. ***All matter is composed of atoms.*** *The atom is the smallest body that retains the unique identity of the element.*

2. ***Atoms of one element cannot be converted into atoms of another element in a chemical reaction.*** *Elements can only be converted into other elements in nuclear reactions.*

3. ***All atoms of an element have the same number of protons and electrons, which determines the chemical behavior of the element.*** *Isotopes of an element differ in the number of neutrons, and thus in mass number. A sample of the element is treated as though its atoms have an average mass.*

4. ***Compounds are formed by the chemical combination of two or more elements in specific ratios.***

Nuclear Atom Viewed in Cross Section



General features of the atom today.

- *The atom is an electrically neutral, spherical entity composed of a positively charged central nucleus surrounded by one or more negatively charged electrons.*
  - *The atomic nucleus consists of protons and neutrons.*

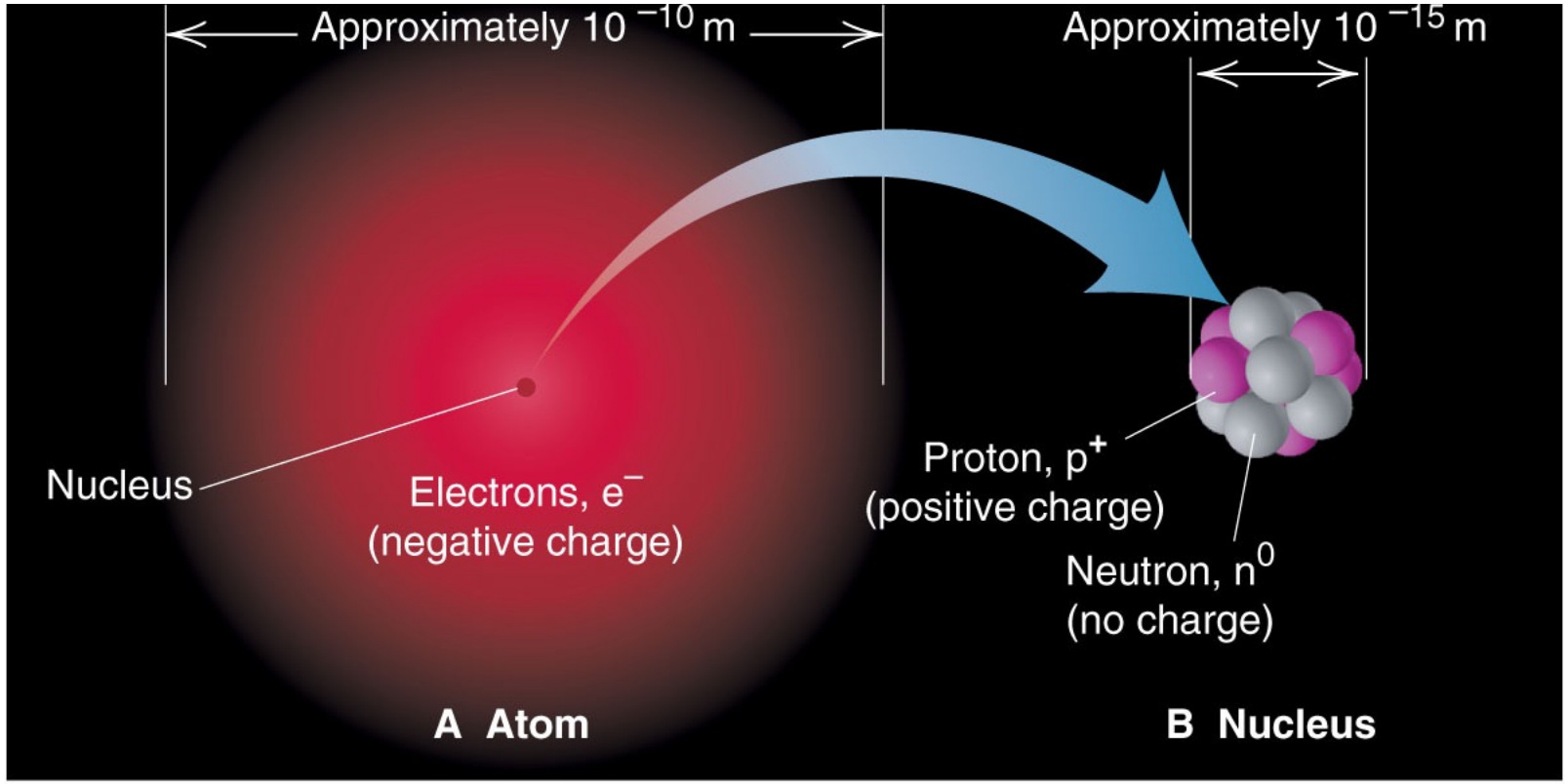


Table 2.2 Properties of the Three Key Subatomic Particles

	Charge		Mass		
Name(Symbol)	Relative	Absolute(C)*	Relative(amu)†	Absolute(g)	Location in the Atom
Proton (p^+)	1+	$+1.60218 \times 10^{-19}$	1.00727	1.67262×10^{-24}	Nucleus
Neutron (n^0)	0	0	1.00866	1.67493×10^{-24}	Nucleus
Electron (e^-)	1-	-1.60218×10^{-19}	0.00054858	9.10939×10^{-28}	Outside Nucleus

*** The coulomb (C) is the SI unit of charge.**

The atomic mass unit (amu) equals 1.66054×10^{-24} g.

2.3 (P 44): Atomic Number, Mass Number, and Isotopes

$^{A}_{Z}X$ = *The symbol of the atom or isotope*

X = Atomic symbol of the element

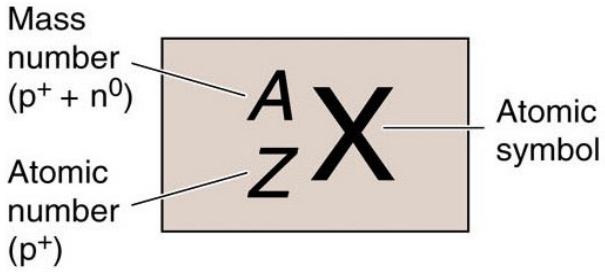
A = mass number; A = Z + N

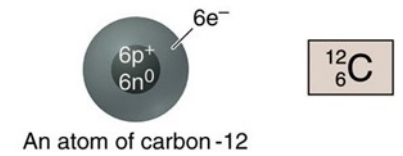
Z = atomic number

(the number of protons in the nucleus)

N = number of neutrons in the nucleus

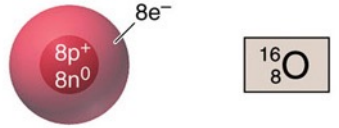
Isotope = atoms of an element with the same number of protons, but a different number of neutrons





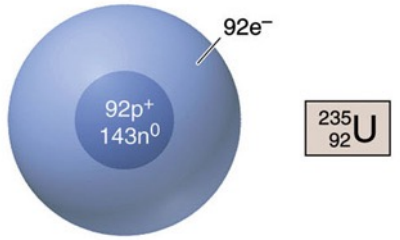
$^{12}_{6}C$

An atom of carbon-12



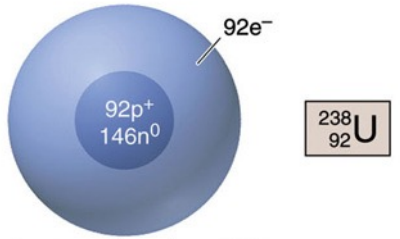
$^{16}_{8}O$

An atom of oxygen-16



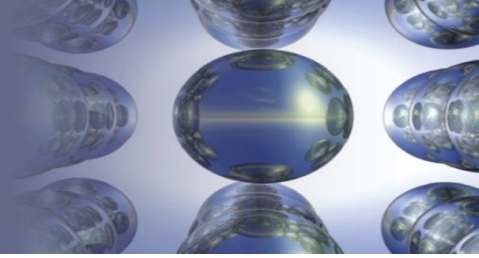
$^{235}_{92}U$

An atom of uranium-235



$^{238}_{92}U$

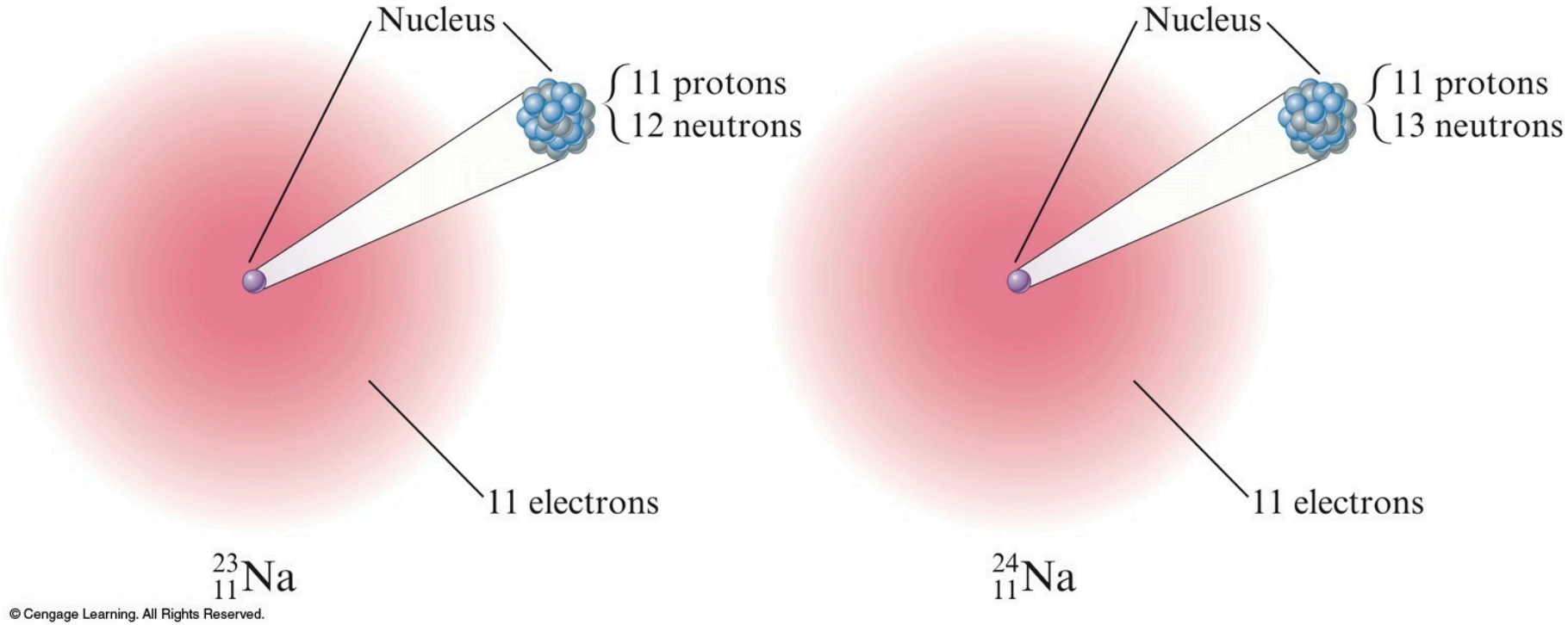
An atom of uranium-238



Isotopes

- *Atoms with the same number of protons but different numbers of neutrons.*
- *Show almost identical chemical properties; chemistry of atom is due to its electrons.*
- *In nature most elements contain mixtures of isotopes.*

Two Isotopes of Sodium



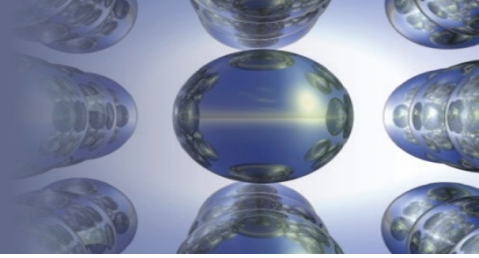
EXERCISE!

A certain isotope X contains 23 protons and 28 neutrons.

- *What is the mass number of this isotope?*
- *Identify the element.*

Mass Number = 51

Vanadium



Chemical Bonds

- *Covalent Bonds*
  - *Bonds form between atoms by sharing electrons.*
  - *Resulting collection of atoms is called a molecule.*

Covalent Bonding

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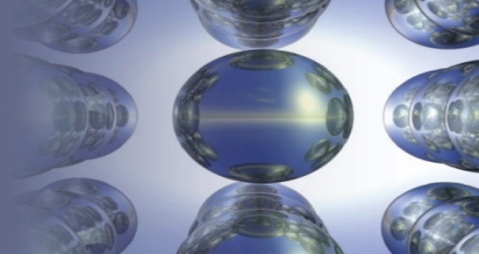
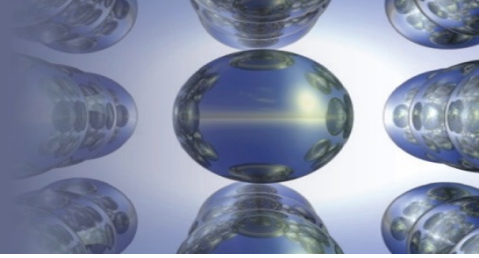
PC Users: Please wait for content to load, then click to play
Mac Users: **CLICK HERE**



Chemical Bonds

- *Ionic Bonds*
  - *Bonds form due to force of attraction between oppositely charged ions.*
  - *Ion – atom or group of atoms that has a net positive or negative charge.*
  - *Cation – positive ion; lost electron(s).*
  - *Anion – negative ion; gained electron(s).*



EXERCISE!

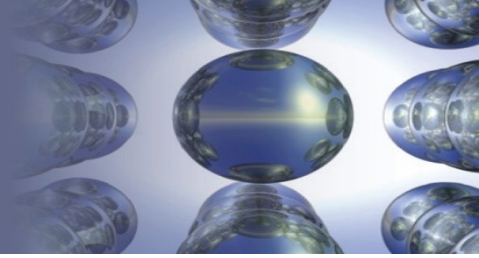
A certain isotope X+ contains 54 electrons and 78 neutrons.

- *What is the mass number of this isotope? And what is the ion identity?*

133,Cs(Caesium)

EXERCISE!

- *Write the symbol for the atom that has an atomic no. of 9(fluorine) and mass number 0f 19.*
- *How many electrons and how many neutrons does this atom have*



The Periodic Table

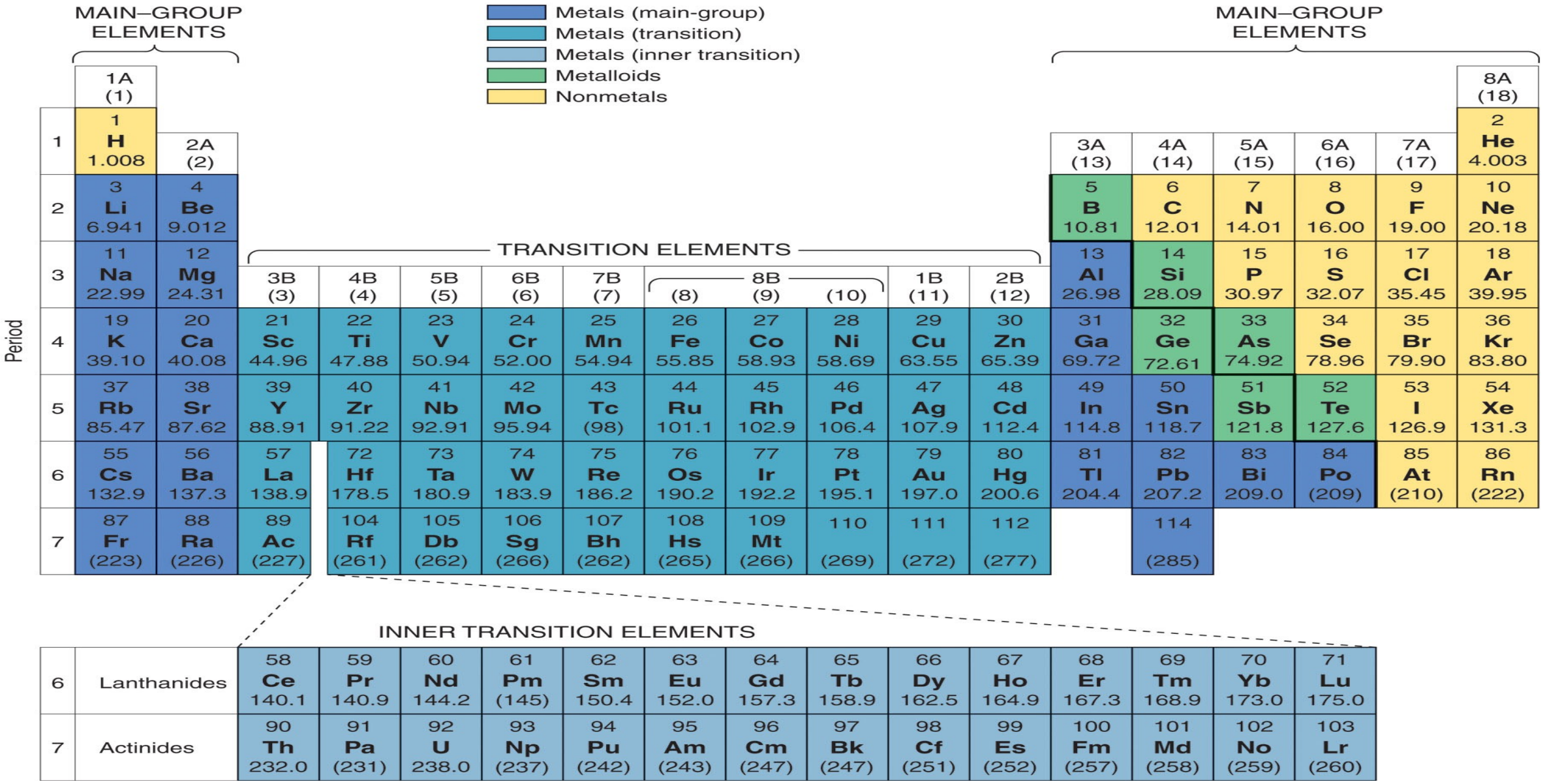
- *Metals vs. Nonmetals*
- *Groups or Families – elements in the same vertical columns; have similar chemical properties*
- *Periods – horizontal rows of elements*

- *Chemist noted that the physical and chemical prosperities of certain groups of elements were similar to one another. These similarities with the need to arrange the large volume of available information about the structure and prosperities of elements led to the Development of the Periodic Table.*

- *Elements are arranged in the Periodic Table By Atomic Number in horizontal rows called PERIODS.*

- *and the Elements are arranged according to their Physical and Chemical Properties in columns called GROUPS.*

The modern periodic table.



The elements in the Periodic Table can be categorized as

METALS, NON METALS, and METALLOIDS.

-Metals: *are good conductors of heat and electricity.*

Nonmetals: *are poor conductors of heat and electricity.*

Metalloids: *have properties that are intermediate between metals and nonmetals.*

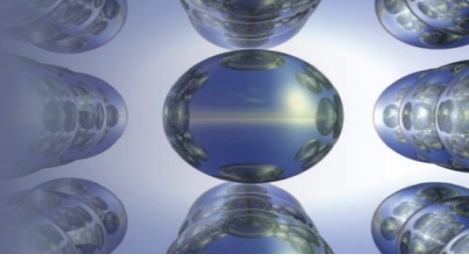
Groups or Families

- *Table of common charges formed when creating ionic compounds.*

Group or Family	*Charge*
Alkali Metals (1A)	*1+*
Alkaline Earth Metals (2A)	*2+*
Halogens (7A)	*1–*
Noble Gases (8A)	*0*

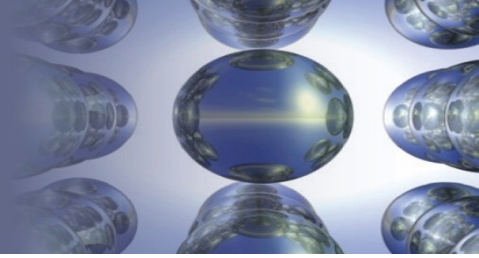
The periodic Table song

https://www.youtube.com/watch?v=VgVQKCcfwnU



Naming Compounds

- *Binary Compounds*
  - *Composed of two elements*
  - *Ionic and covalent compounds included*
- *Binary Ionic Compounds*
  - *Metal—nonmetal*
- *Binary Covalent Compounds*
  - *Nonmetal—nonmetal*



Binary Ionic Compounds (Type I)

1. *The cation is always named first and the anion second.*
2. *A monatomic cation takes its name from the name of the parent element.*
3. *A monatomic anion is named by taking the root of the element name and adding –ide.*

Binary Ionic Compounds (Type I)

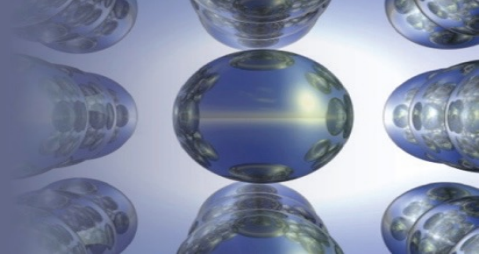
- *Examples:*

  KCl *Potassium chloride*

  $MgBr_2$ *Magnesium bromide*

  CaO *Calcium oxide*

Section 2.8
Naming Simple Compounds

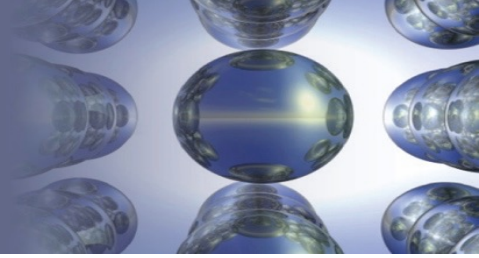


*1. Give the chemical **formula** for the following:*

- Lithium phosphide
- Aluminium Sulfide

*2. Give the chemical **name** for the following:*

- MgI_2
- CaO_2



Binary Ionic Compounds (Type II)

- *Metals in these compounds form more than one type of positive ion (TRANSITION METALS).*
- *Charge on the metal ion must be specified.*
- *Roman numeral indicates the charge of the metal cation.(I,II,III,IV,V,VI,VII,VIII,IX,X).*
- *Transition metal cations usually require a Roman numeral.*
- *Elements that form only one cation do not need to be identified by a roman numeral (Main group elements except Pb and Sn).*

Some common monatomic ions of the elements.

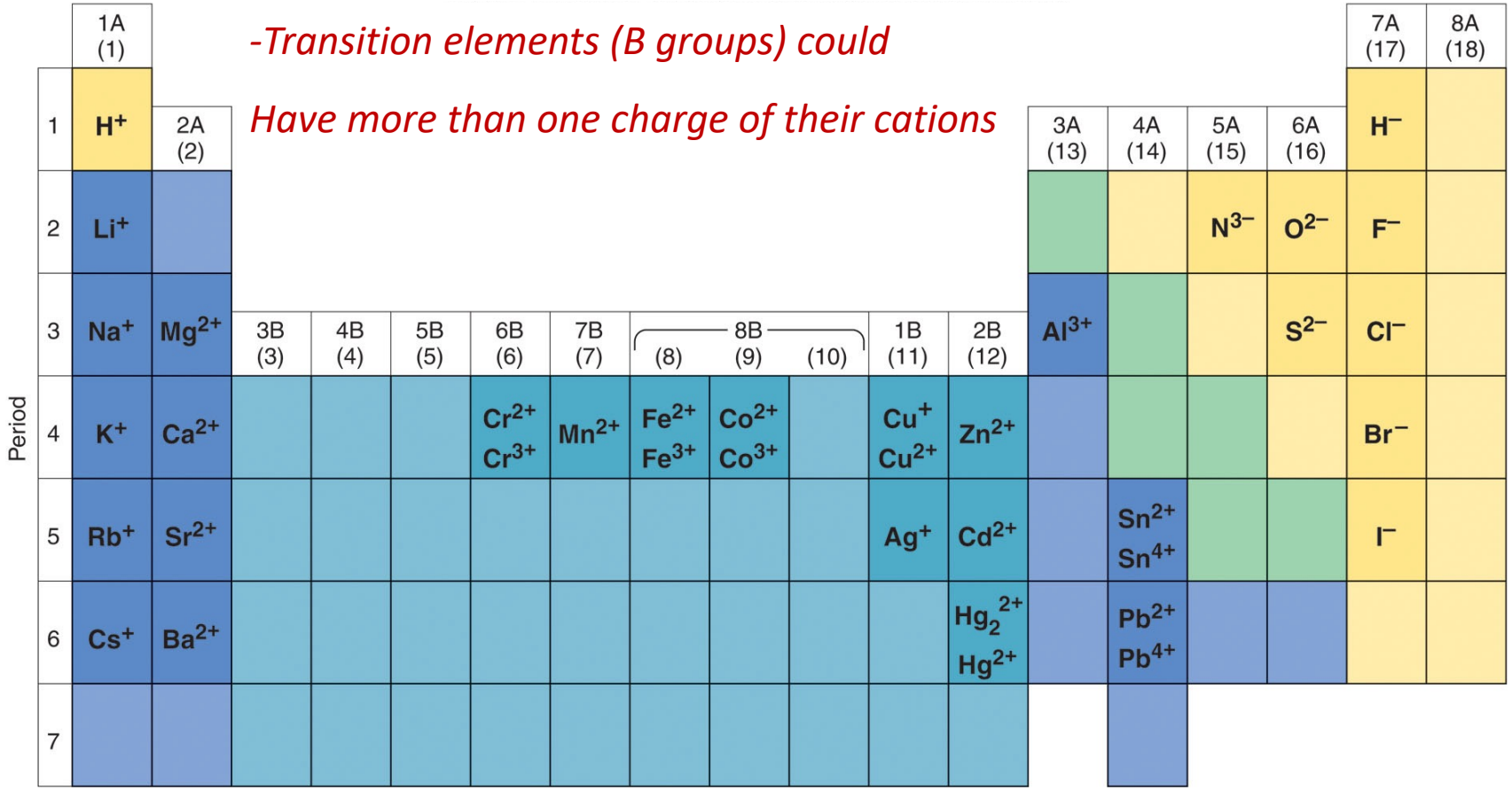
Can you see any patterns?

-The Charge of Cations formed by atoms Group 1A, 2A, and 3A equals the Number of their group.

-The Charge of Anions formed by atoms in Group 4A through 7A equals their group number minus 8.

-Transition elements (B groups) could

Have more than one charge of their cations



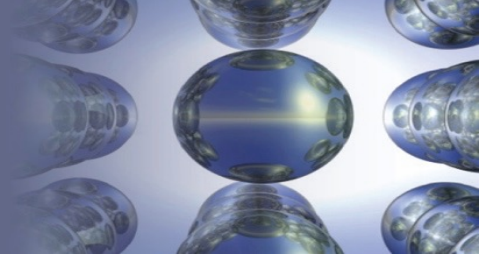
Binary Ionic Compounds (Type II)

- *Examples:*

  $CuBr$

  FeS

  PbO_2



Hg_2O

HgO

Binary Ionic Compounds (Type II)

- *Examples:*

$CuBr$	*Copper(I) bromide*
FeS	*Iron(II) sulfide*
PbO_2	*Lead(IV) oxide*

Common Monoatomic Ions

Common ions are in red.

Cations			Anions		
Charge	Formula	Name	Charge	Formula	Name
	H^+	hydrogen		H^-	hydride
	Li^+	lithium		F^-	fluoride
+1	Na^+	sodium	-1	Cl^-	chloride
	K^+	potassium		Br^-	bromide
	Cs^+	cesium		I^-	iodide
	Ag^+	silver			
	Mg^{2+}	magnesium		O^{2-}	oxide
	Ca^{2+}	calcium		S^{2-}	sulfide
+2	Sr^{2+}	strontium	-2		
	Ba^{2+}	barium			
	Zn^{2+}	zinc			
	Cd^{2+}	cadmium			
+3	Al^{3+}	aluminum	-3	N^{3-}	nitride

Some Metals That Form More Than One Monatomic Ion

Element	*Ion Formula*	*Systematic Name*	*Common Name*
Cobalt	Co^{+2}	*cobalt(II)*	
	Co^{+3}	*cobalt (III)*	
Copper	Cu^{+1}	*copper(I)*	*cuprous*
	Cu^{+2}	*copper(II)*	*cupric*
Iron	Fe^{+2}	*iron(II)*	*ferrous*
	Fe^{+3}	*iron(III)*	*ferric*
Lead	Pb^{+2}	*lead(II)*	
	Pb^{+4}	*lead(IV)*	
Tin	Sn^{+2}	*tin(II)*	*stannous*
	Sn^{+4}	*tin(IV)*	*stannic*

(partial table)

Some Common Polyatomic Ions

Formula	Name	Formula	Name
	Cations		
NH_4^+	ammonium	H_3O^+	hydronium
	Common Anions		
CH_3COO^-	acetate	CO_3^{-2}	carbonate
CN^-	cyanide	CrO_4^{-2}	chromate
OH^-	hydroxide	$Cr_2O_7^{-2}$	dichromate
ClO_4^-	perchlorate		
ClO_3^-	chlorate	PO_4^{-3}	phosphate
ClO_2^-	chlorite	MnO_4^-	permanganate
ClO^-	hypochlorite	SO_4^{-2}	sulfate
NO_2^-	nitrite	SO_3^{-2}	sulfite
NO_3^-	nitrate		

Polyatomic Ions

- *Examples of compounds containing polyatomic ions:*

$NaOH$	*Sodium hydroxide*
$Mg(NO_3)_2$	*Magnesium nitrate*
$(NH_4)_2SO_4$	*Ammonium sulfate*

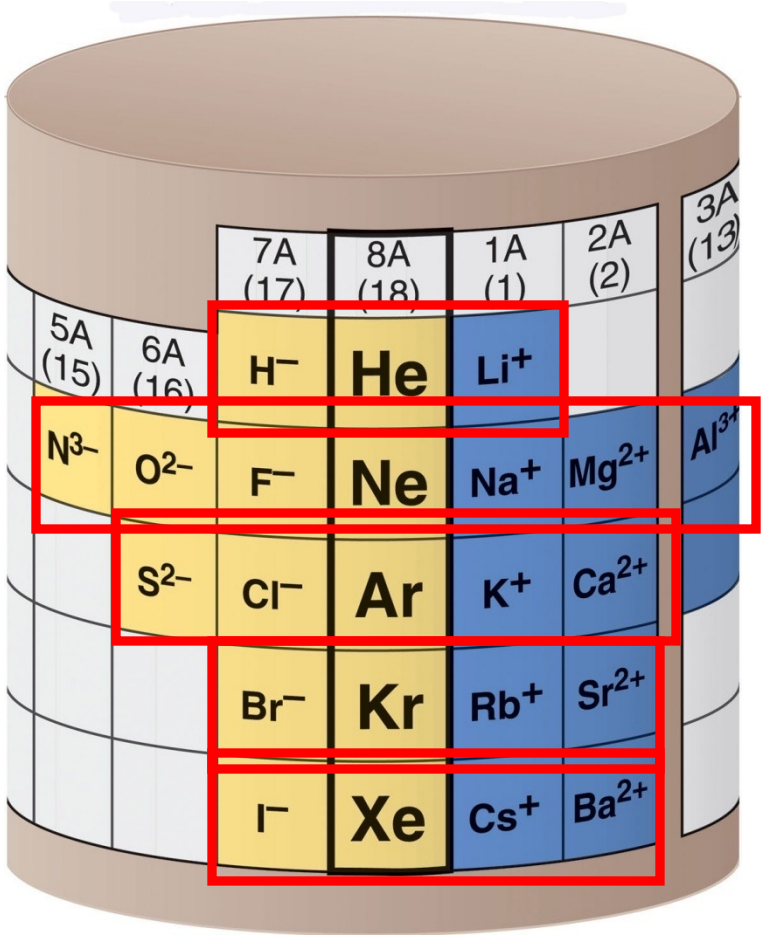
-Monatomic ions: are ions that consist of just one atom of positive or negative charge.

-How can we Indicate the Charge of monatomic ions???

-Because ***Nobel Gases*** are stable during to their electronic distribution as we will discuss in the coming chapters, metals try to lose electrons to have the same number of electrons of the corresponding ***NOBEL GAS***. While Nonmetals try to gain electrons to get the same number of electrons of their corresponding ***NOBEL GAS***.

-The relation between atoms and their corresponding Nobel Gas is shown in the next figure.

The relationship between ions formed and the nearest noble gas.



Formulas of Ionic Compounds:

In order to write the chemical formula of Ionic Compound you must make the total charge of the compounds equals zero (Electrically neutral)

To do so……the following equation must be satisfied:
(Number of cationic atoms x their charge) + (Number of anionic atoms x their charge) =0

Example: The chemical formula of the ionic compound formed by the combination between Mg+2 and Cl-1 is MgCl2
(1x2)+(2x-1)=0

Determining Formulas of Binary Ionic Compounds

PROBLEM: *Write empirical formulas for the compounds named in Sample Problem 2.7:*

(a) magnesium nitride *(b) cadmium iodide*

(c) strontium fluoride *(d) cesium sulfide*

PLAN: *Compounds are neutral. We find the smallest number of each ion which will produce a neutral formula. Use subscripts to the right of the element symbol.*

SOLUTION:

(a) Mg^{2+} and N^{3-}; three Mg^{2+}(6+) and two N^{3-}(6-); Mg_3N_2

(b) Cd^{2+} and I^-; one Cd^{2+}(2+) and two I^-(2-); CdI_2

(c) Sr^{2+} and F^-; one Sr^{2+}(2+) and two F^-(2-); SrF_2

(d) Cs^+ and S^{2-}; two Cs^+(2+) and one S^{2-} (2-); Cs_2S

Determining Formulas of Binary Ionic Compounds

PROBLEM: *Write the formulas and the names of the compounds that will result from the following combinations?*

(a) Sodium and sulfate (b) Magnesium and Sulfur

(c) Mercury(I) and Oxygen

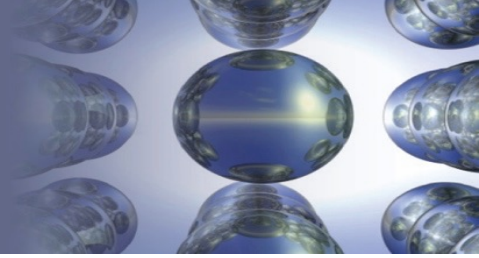
PLAN: *Compounds are neutral. We find the smallest number of each ion which will produce a neutral formula. Use subscripts to the right of the element symbol.*

SOLUTION:

(a) Sodium will form Na^+ and Sulfate is SO_4^{-2}; Two Na^+(2+) and one SO_4^{-2} (2-); Na_2SO_4

(b) Magnesium will form Mg^{2+} and Sulfur forms S^{2-} ;One Mg^{2+}(2+); and one Sulfide (-2); MgS

(c) Mercury(I) is Hg_2^{2+} and Oxygen will form O^{2-} ; one Hg_2^{2+} (2+) and one O^{2-} (2-); Hg_2O



Binary Covalent Compounds (Type III)

- Formed between two nonmetals.

1. *The first element in the formula is named first, using the full element name.*
2. *The second element is named as if it were an anion (changing the end of its name by ide).*
3. *Prefixes (mono, di, tri, ...etc.) are used to denote the numbers of atoms present.*
4. *The prefix mono- is never used for naming the first element.*

Prefixes Used to Indicate Number in Chemical Names

Table 2.6 | Prefixes Used to Indicate Number in Chemical Names

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

Binary Covalent Compounds (Type III)

- Examples:

CO2	*Carbon dioxide*
SF6	*Sulfur hexafluoride*
N2O4	*Dinitrogen tetroxide*

-The Perfix Mono is Generally Omitted for the first element.

EXAMPLE: Write the name of the following compounds:

-CO_2 :
-CO:
--SO_2:

--SO_3:

--NO_2:

-NO:

--N_2O_5:

-NF3:

-Cl_2O_5:

-The Perfix Mono is Generally Omitted for the first element.

EXAMPLE: Write the name of the following compounds:

-CO_2 : Carbon Dioxide Not Monocarbon Dioxide

-CO: Carbon Monoxide

--SO_2: Sulfur Dioxide

--SO_3: Sulfur Trioxide

--NO_2: Nitrogen Dioxide

-NO: Nitrogen Monoxide

--N_2O_5: Dinitrogen Pentoxide

-NF3: Nitrogen Trifluoride

-Cl_2O_5: Dichlorine Pentoxide

EXAMPLE: Write the Chemical Formula for the following compounds:

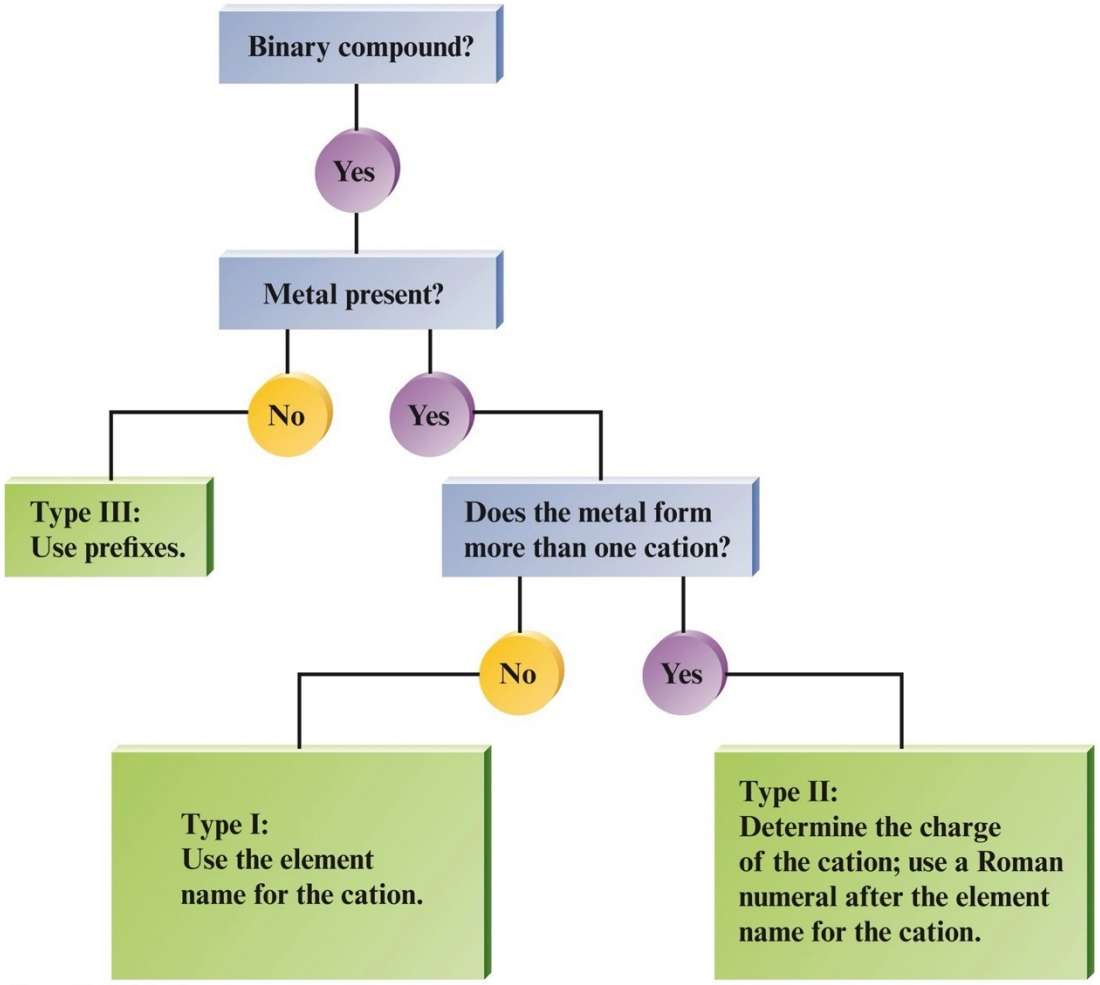
-Boron trichloride: BCl_3

-Sulfur tetrafluoride: SF_4

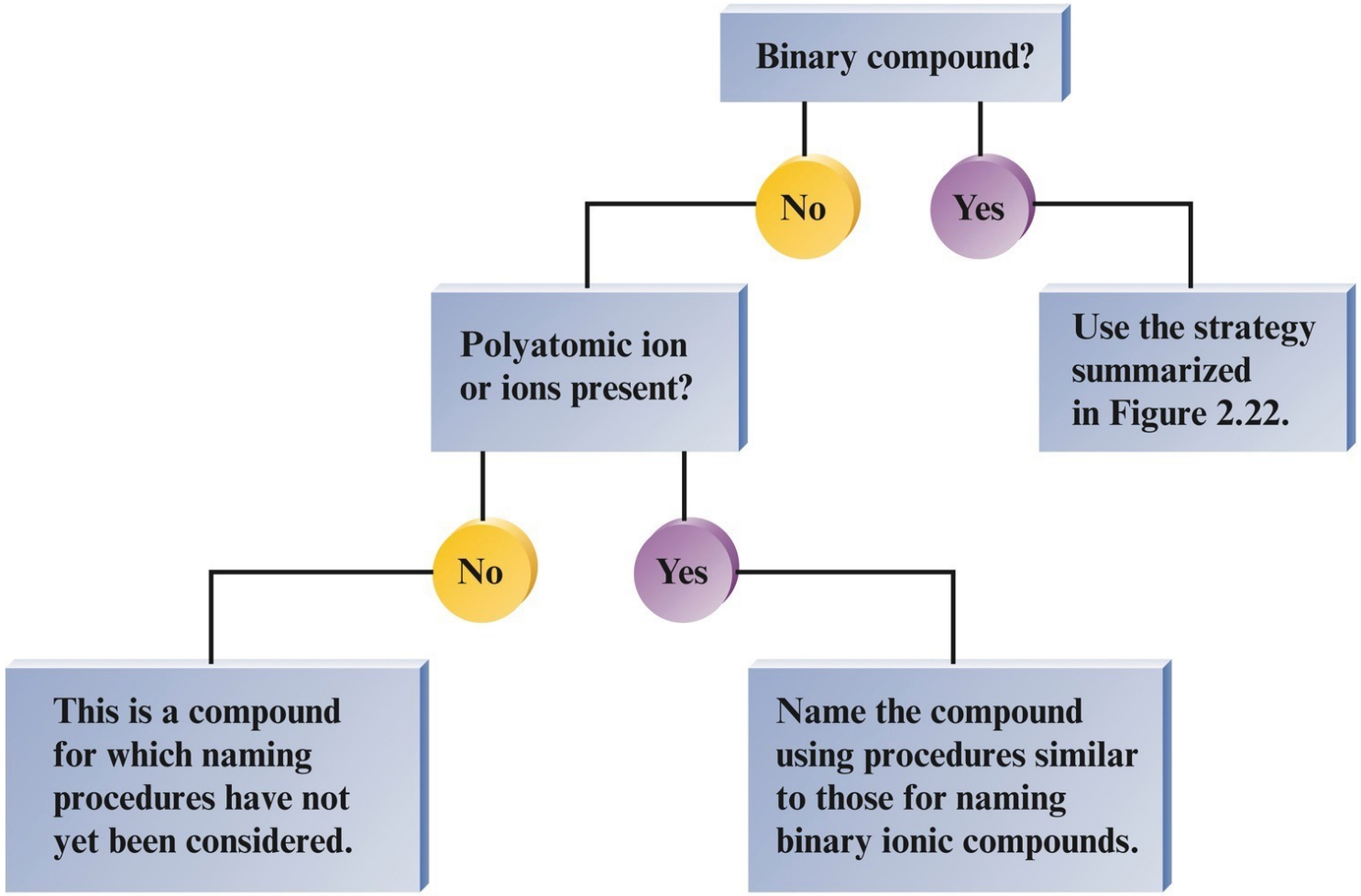
-Tetraphosphorus DecaSulfide: P_4S_{10}

-Carbon tetrachloride: CCl_4

Flowchart for Naming Binary Compounds



Overall Strategy for Naming Chemical Compounds



EXERCISE!

Which of the following compounds is named incorrectly?

a) KNO3	*potassium nitrate*
b) TiO2	*titanium(II) oxide*
c) Sn(OH)4	*tin(IV) hydroxide*
d) PBr5	*phosphorus pentabromide*
e) CaCrO4	*calcium chromate*

Exceptions:

Some molecular compounds containing hydrogen do not usually conform to the nomenclature gaudiness.

B_2H_6: Diborane

SiH_4: Silane

NH_3: Ammonia

PH_3: Phosphine
H_2O: Water

H_2S: Hydrogen sulfide. (hydrosulfuric acid)

Naming Hydrates :

Hydrate: an ionic compound contains loosely bonded water. The name of a hydrate follows a set pattern: the name of the ionic compound followed by a numerical prefix and the suffix "-hydrate."

Example:

$CaCl_2.2H_2O$

Calcium chloride dihydrate

Table 2.6 | Prefixes Used to Indicate Number in Chemical Names

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

The chemical name of the following compounds are:

ZnSO4.7H2O

CuSO4.5H2O

The chemical formula of the following are:

Cobalt(II)chloride hexahydrate

Sodium carbonate decahydrate