Chapter 2

The Periodic Table and Some Properties of the Elements

Chapter 2: The Components of Matter

Definitions for Components of Matter

Element - the simplest type of substance with unique physical and chemical properties. *An element consists of only one type of atom.* It cannot be broken down into any simpler substances by physical or chemical means. Cu, Ag, N_2, O_2,

Molecule - a structure that consists of two or more atoms that are chemically bound together and thus behaves as an independent unit.

A Atoms of an element

Figure 2.1

B Molecules of an element

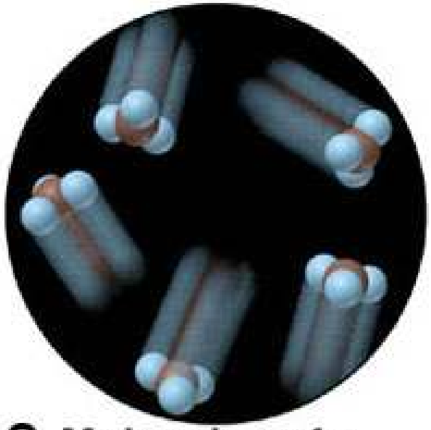
H_2O, O_3 , CO_2, NH_3, O_2

Figure 2.2

Definitions for Components of Matter

Compound - a substance composed of two or more elements which are chemically combined.

BH_3 (10.81g B with 3 g H)

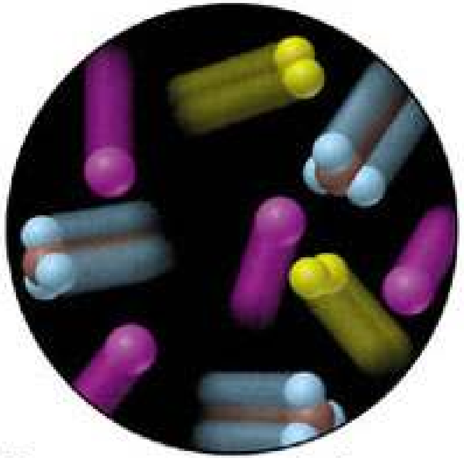


C Molecules of a compound

Figure 2.3

Mixture - a group of two or more elements and/or compounds that are physically intermingled (متداخلة) .

H_2O + NaCl



D Mixture of two elements and a compound

Figure 2.4

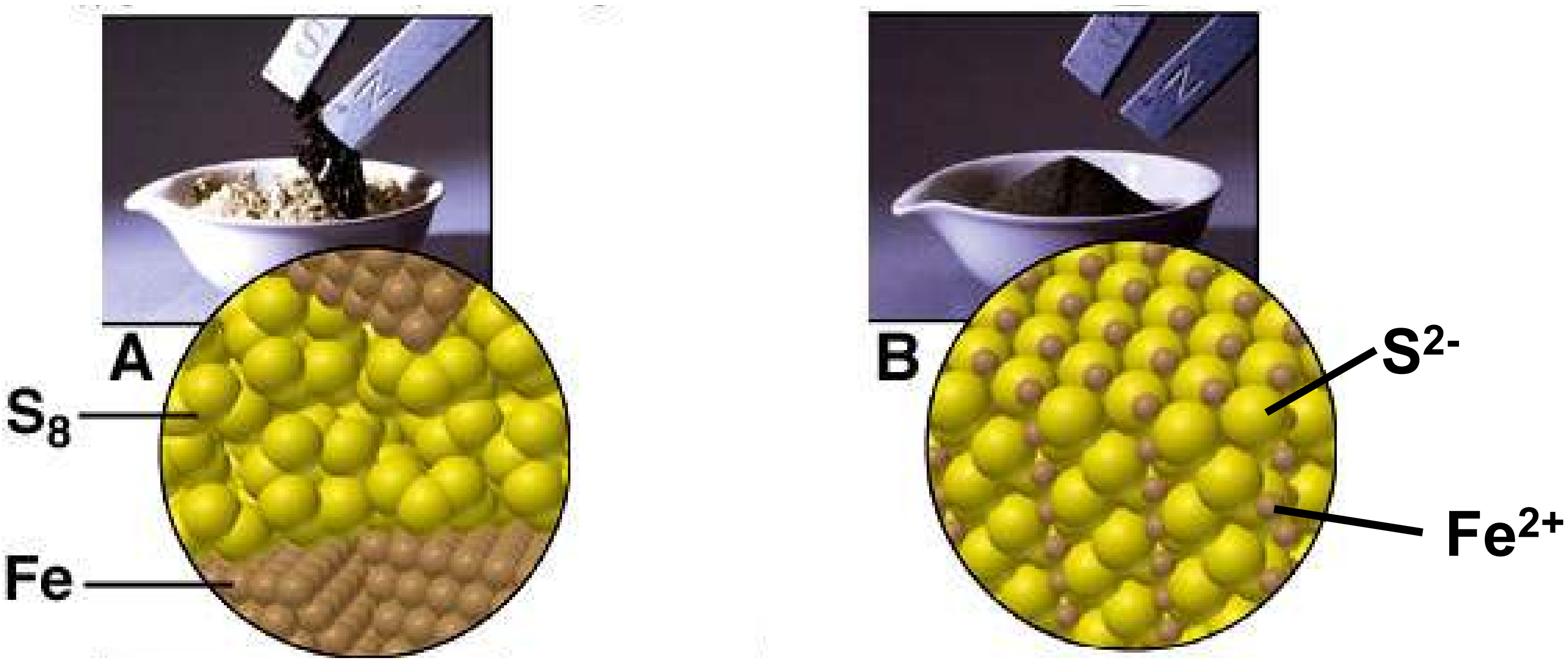
Mixtures

A ***heterogeneous mixture*** has one or more visible boundaries between the components.

A ***homogeneous mixture*** has no visible boundaries because the components are mixed as individual atoms, ions, and molecules.

A homogeneous mixture is also called a ***solution***. Solutions in water are called ***aqueous solutions***.

Figure 2.17 The distinction between mixtures and compounds.



A physical mixture of Fe and S_8 can be separated using a magnet.

Fe and S have reacted chemically to form the compound FeS. The elements cannot be separated by physical means.

Table 2.1 Some Properties of Sodium, Chlorine, and Sodium Chloride

Property	Sodium +	Chlorine →	Sodium Chloride
Melting point	97.8°C	-101°C	801°C
Boiling point	881.4°C	-34°C	1413°C
Color	Silvery	Yellow-green	Colorless (white)
Density	0.97 g/cm^3	0.0032 g/cm^3	2.16 g/cm^3
Behavior in water	Reacts	Dissolves slightly	Dissolves freely

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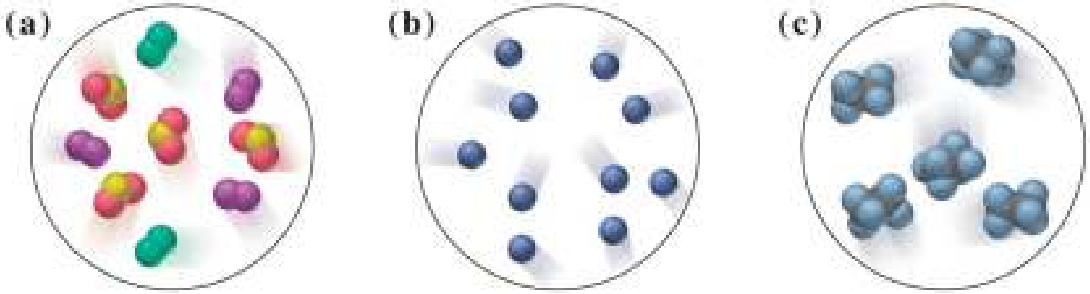
Sample Problem 2.1 Distinguishing Elements, Compounds, and Mixtures at the Atomic Scale

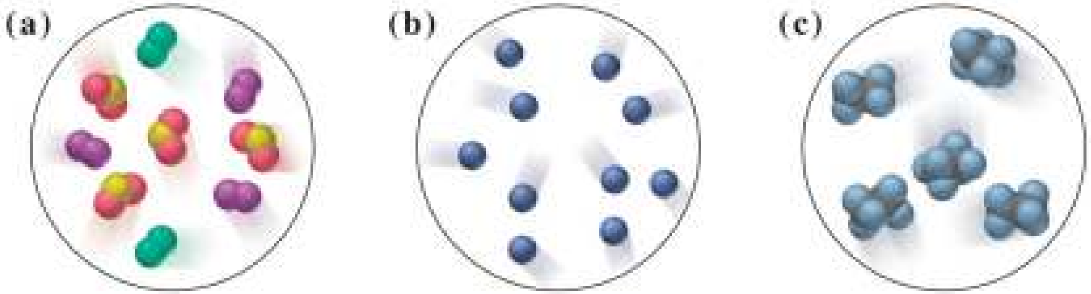
PROBLEM: The following scenes represent an atomic-scale view of three samples of matter. Describe each sample as an element, compound, or mixture.



PLAN: A sample that contains only one type of particle is either an element or a compound. The particles of an element consist of only one type of atom whereas the particles of a compound have two or more types of atom bonded together.

Sample Problem 2.1

SOLUTION:



Sample (a) contains three different types of particles and is therefore a **mixture**.

Sample (b) contains only one type of particle and each particle has only one atom. This is an **element**.

Sample (c) contains only one type of particle, each of which contains two different types of atoms. This is a **compound**.

Law of Mass Conservation

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

reactant 1 + reactant 2 → **product**

total mass = ***total mass***

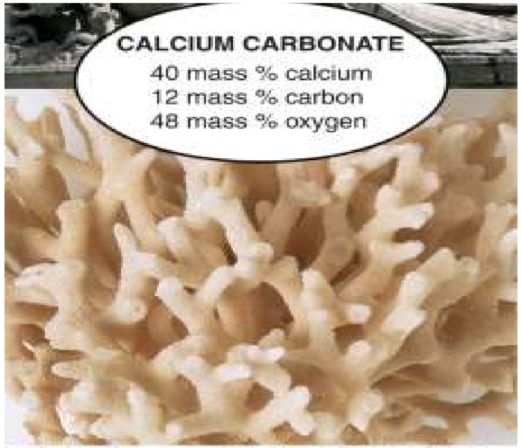
calcium oxide + carbon dioxide → calcium carbonate

$$\mathrm{CaO} + \mathrm{CO_2} \rightarrow \mathrm{CaCO_3}$$

56.08 g + 44.00 g → 100.08 g

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.



top: © Punchstock RF bottom: © Alexander Chereshnichenko/Shutterstock.com

Figure 2.2

Calcium carbonate

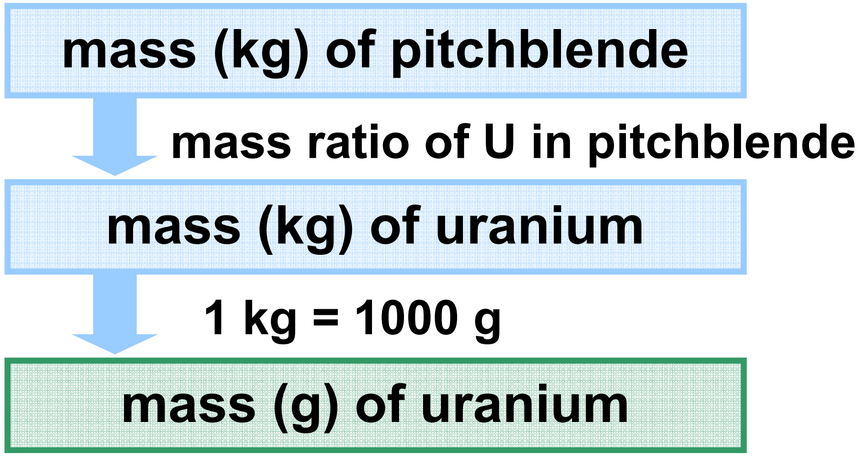
Analysis by Mass (grams/20.0 g)	Mass Fraction (parts/1.00 part)	Percent by Mass (parts/100 parts)
8.0 g calcium	8.0/20 = 0.40 calcium	40% calcium
2.4 g carbon	2.4/20 = 0.12 carbon	12% carbon
9.6 g oxygen	9.6/20 = 0.48 oxygen	48% oxygen
20.0 g	1.00 part by mass	100% by mass

Sample Problem 2.2

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.



mass (kg) of pitchblende

mass ratio of U in pitchblende

mass (kg) of uranium

1 kg = 1000 g

mass (g) of uranium

Sample Problem 2.2

SOLUTION:

mass (kg) of uranium =

$$\text{mass (kg) pitchblende} \times \frac{\text{mass (kg) uranium in pitchblende}}{\text{mass (kg) pitchblende}}$$

$$= 102\ \cancel{\text{kg pitchblende}} \times \frac{71.4\ \text{kg uranium}}{84.2\ \cancel{\text{kg pitchblende}}} = 86.5\ \text{kg uranium}$$

$$86.5\ \cancel{\text{kg}}\ \text{uranium} \times \frac{1000\ \text{g}}{1\ \cancel{\text{kg}}}\ \boxed{\mathbf{= 8.65 \times 10^4\ g\ uranium}}$$

Law of Multiple Proportions

If elements A and B react to form two compounds, the different masses of B that combine with a fixed mass of A can be expressed as a ratio of small whole numbers.

Example: Carbon Oxides A & B

Carbon Oxide I : 57.1% oxygen and 42.9% carbon

Carbon oxide I
(carbon monoxide)

Carbon oxide II
(carbon dioxide)

Carbon Oxide II : 72.7% oxygen and 27.3% carbon

Assume that you have 100 g of each compound.

In 100 g of each compound:
g O = 57.1 g for oxide I & 72.7 g for oxide II
g C = 42.9 g for oxide I & 27.3 g for oxide II

For oxide I:

$$\frac{\text{g O}}{\text{g C}} = \frac{57.1}{42.9} = 1.33$$

Carbon oxide I
(carbon monoxide)

For oxide II:

$$\frac{\text{g O}}{\text{g C}} = \frac{72.7}{27.3} = 2.66$$

Carbon oxide II
(carbon dioxide)

$$\frac{2.66 \text{ g O/g C in II}}{1.33 \text{ g O/g C in I}} = \frac{2}{1}$$

Dalton’s Atomic Theory

Dalton postulated that:

1. All matter consists of ***atoms***; tiny indivisible particles of an element that cannot be created or destroyed.
2. Atoms of one element ***cannot*** be converted into atoms of another element.
3. Atoms of an element are ***identical*** in mass and other properties and are different from the atoms of any other element.
4. Compounds result from the chemical combination of a ***specific ratio*** of atoms of different elements.

Dalton's Atomic Theory

explains the mass laws

Mass conservation

Atoms cannot be created or destroyed ***postulate 1***

or converted into other types of atoms. ***postulate 2***

Since every atom has a fixed mass, ***postulate 3***

during a chemical reaction the same atoms are present but in different combinations; therefore there is no mass change overall.

Dalton's Atomic Theory

explains the mass laws

Definite composition

Atoms are combined in compounds in specific ratios ***postulate 3***

and each atom has a specific mass. ***postulate 4***

Each element constitutes a fixed fraction of the total mass in a compound.

Dalton's Atomic Theory

explains the mass laws

Multiple proportions

Atoms of an element have the same mass **_postulate 3_**

and atoms are indivisible (لا يتجزأ). **_postulate 1_**

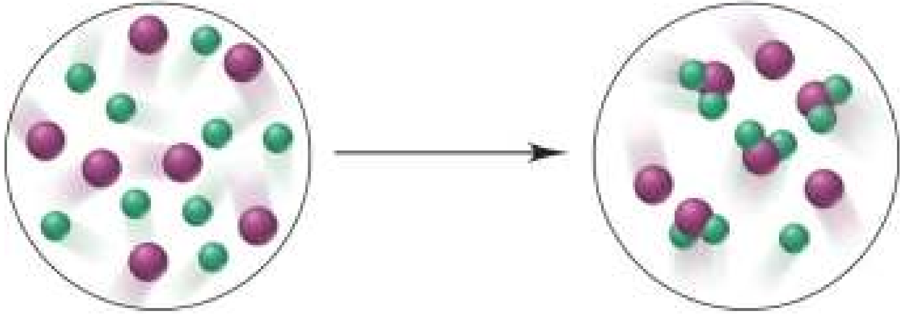
When different numbers of atoms of elements combine, they must do so in ratios of small, whole numbers.

Carbon oxide I
(carbon monoxide)

Carbon oxide II
(carbon dioxide)

Sample Problem 2.3 **Visualizing the Mass Laws**

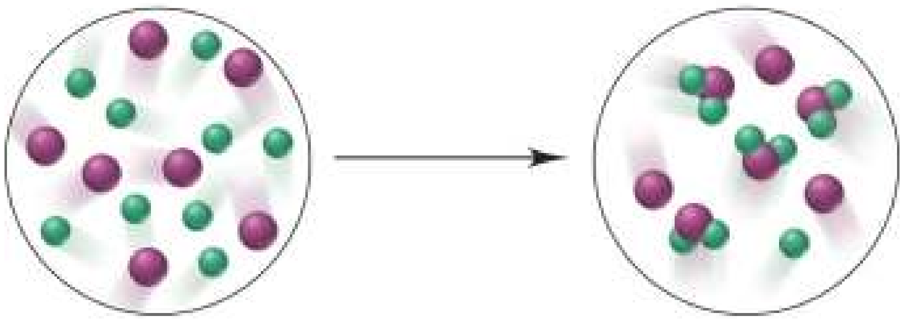
PROBLEM: The following scene represents an atomic-scale view of a chemical reaction. Which of the mass laws (mass conservation, definite composition, or multiple proportions) is (are) illustrated?



PLAN: Note the numbers, types and combination of atoms before and after the reaction.

Sample Problem 2.3

SOLUTION:



There are 7 purple and 9 green atoms both before and after the reaction. Mass is therefore conserved.

After the reaction some purple atoms remain unreacted, but some have combined with green atoms to form a compound. Each particle of this compound contains 1 purple and 2 green atoms – the composition is constant, illustrating the law of definite composition.

The ratio of the elements in the compound is a small, whole number.

There are 7 purple and 9 green atoms in the reactants and 7 purple and 9 green atoms in the product therefore mass is conserved.

Only one compound present therefore it does not illustrate the law of multiple proportions.

The observations that led to the nuclear atom model (Chem 141)

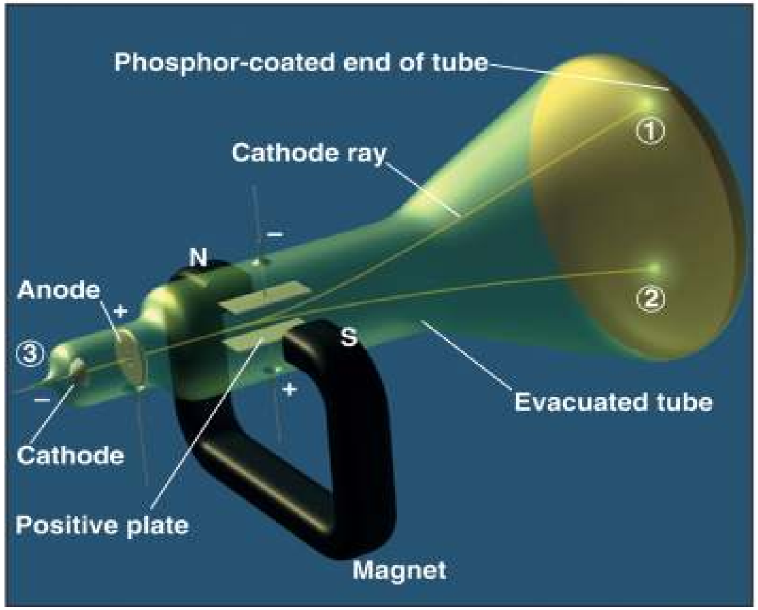
* **Discovery of the electron.**

* **Discovery of the nucleus.**

* **Discovery of the neutron.**

Figure 2.3

Observations that established the properties of cathode rays.



Observation	Conclusion
Ray bends in magnetic field.	Ray consists of charged particles.
Ray bends toward positive plate in electric field.	Ray consists of negative particles.
Ray is identical for any cathode.	These particles are found in ALL matter.

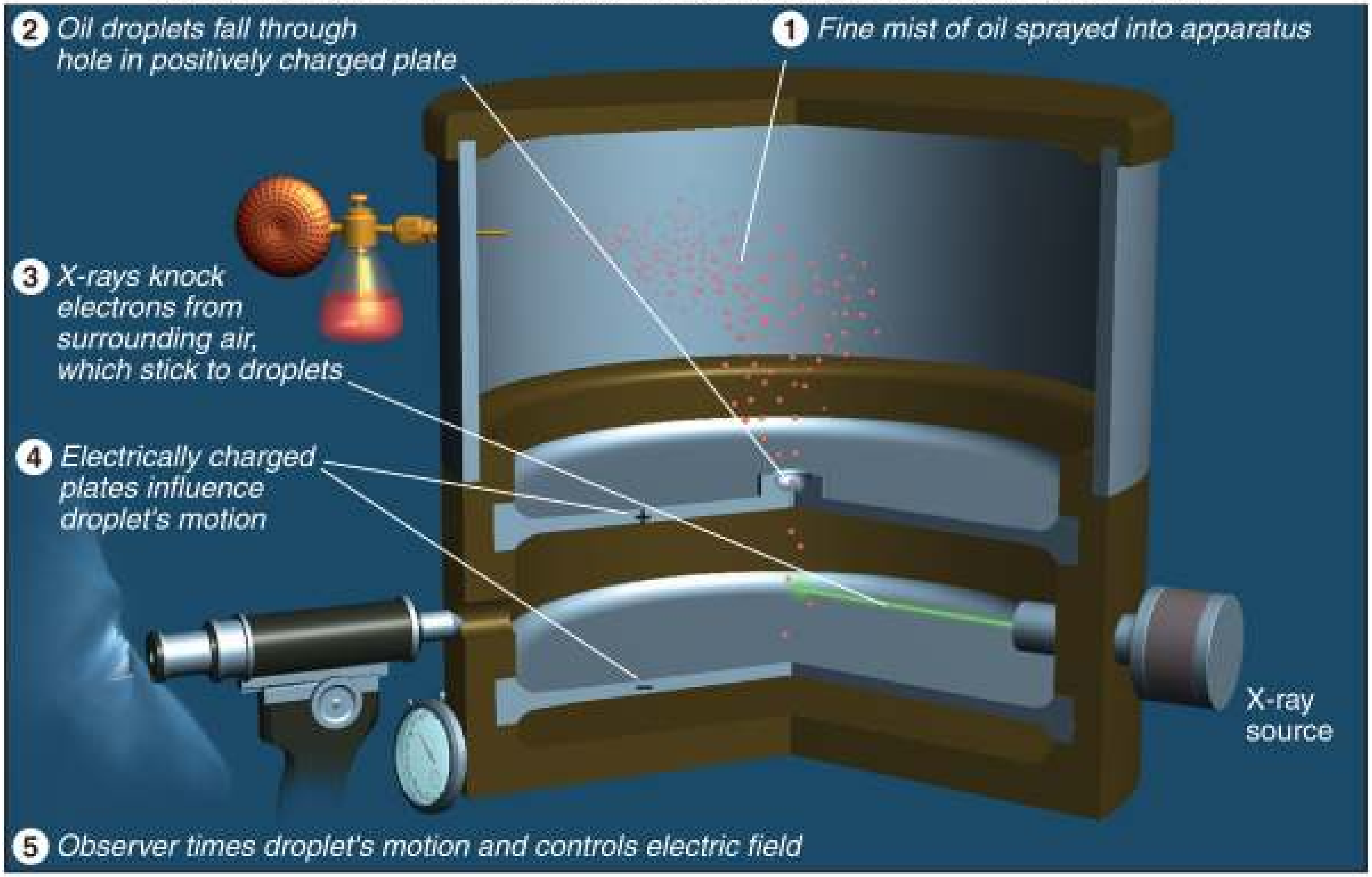
Mass and Charge of the Electron

Mass/charge ratio of the electron was measured by th British J.J. Thomson by comparing this value with the mass to charge ratio for the lightest charged particle in solution.

Thomsen estimated that the cathode ray particle weighed less than 1/1000 as much as hydrogen, the lightest atom.

J. J Thomson, (1897) measured the electron
Mass/charge = -5.686×10^{-12} Kg/C

Figure 2.4 **Millikan's oil-drop experiment for measuring an electron's charge. (1909)**



After repeating the experiment several times, Millikan's calculated the charge of the oil droplets to be n × -1.602 × $10^{-19,}$ where n is 1, 2,3,….. Which is the number of the electron sticked to the oil droplet

Millikan’s findings were used to calculate the mass of an electron.

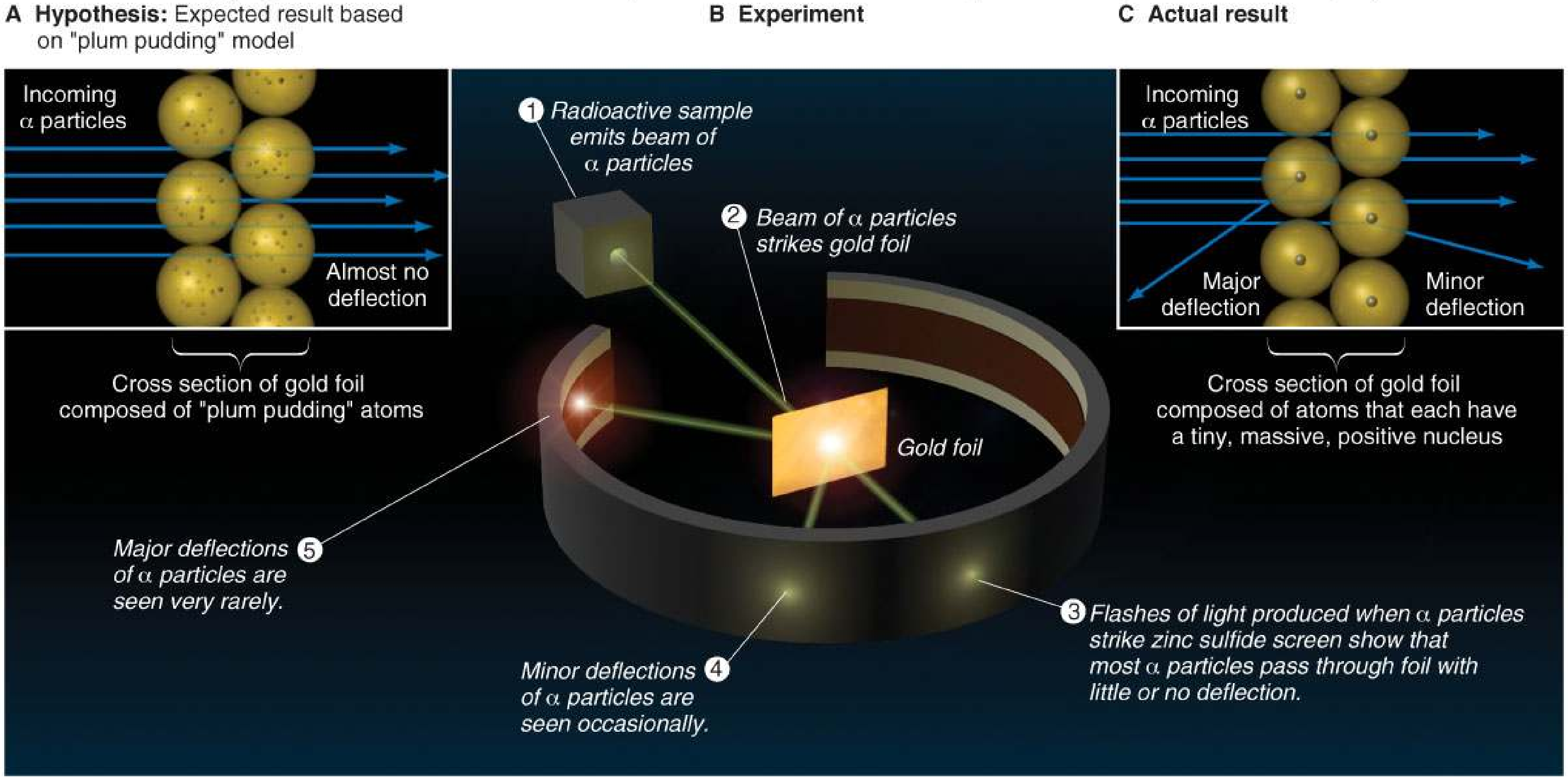
determined by J.J. Thomson and others

$$\text{mass of electron} = \frac{\text{mass}}{\text{charge}} \text{ x } \text{charge}$$

$$= (-5.686\text{x}10^{-12}\text{ kg/}\cancel{\text{C}}) \text{ x } (-1.602\text{x}10^{-19}\ \cancel{\text{C}})$$

$$= 9.109\text{x}10^{-31}\text{ kg} = 9.109\text{x}10^{-28}\text{ g}$$

Figure 2.5 Rutherford's α-scattering experiment and discovery of the atomic nucleus. (1910)

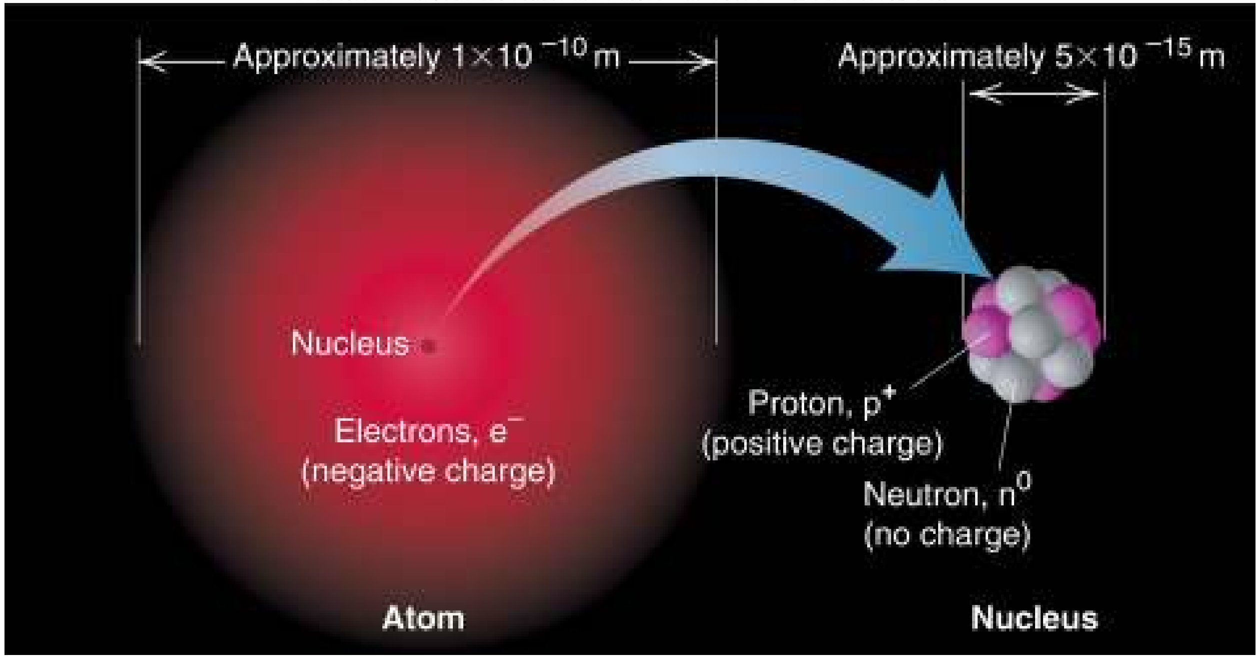


Rutherford: Atoms are empty space occupied by electrons, but in the center a tiny region he called nucleus contains all the positive particles and called them protons.

In 1932 James Chadwick discovered the Neutrons.

Figure 2.6 General features of the atom.

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 Properties

	Charge		Mass		
Name (Symbol)	**Relative**	**Absolute (C)**[*]	**Relative (amu)**[†]	**Absolute (g)**	**Location in Atom**
Proton (p^+)	1+	$+1.60218x10^{-19}$	1.00727	$1.67262x10^{-24}$	Nucleus
Neutron (n^0)	0	0	1.00866	$1.67493x10^{-24}$	Nucleus
Electron (e^-)	1-	$-1.60218x10^{-19}$	0.00054858	$9.10939x10^{-28}$	Outside nucleus

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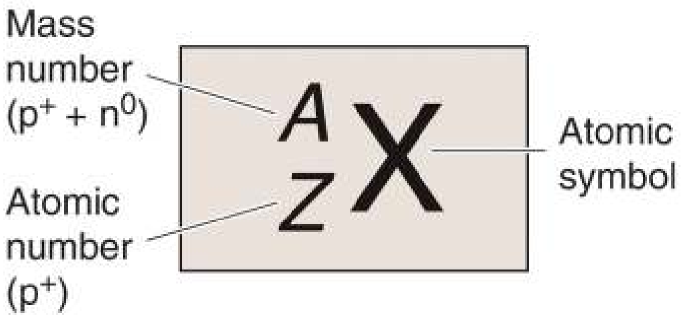
[*] The coulomb (C) is the SI unit of charge.

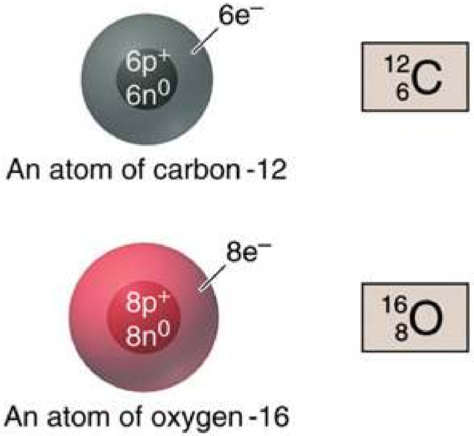
[†] The atomic mass unit (amu) equals $1.66054x10^{-24}$ g.

Homework: Use the information of the previous slide and this slide to calculate the density of the carbon nuclei

Atomic Number, Mass Number, and Atomic Symbol

Figure 2.7





An atom of carbon-12

An atom of oxygen-16

X = Atomic symbol of the element

A = mass number; $A = Z + N$

Z = atomic number

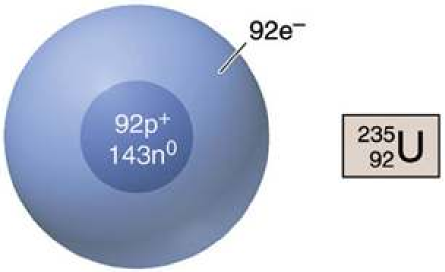
(the number of protons in the nucleus)

N = number of neutrons in the nucleus

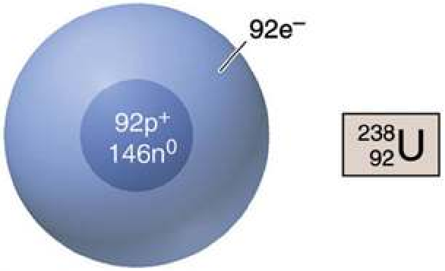
Isotopes

Isotopes are atoms of an element with the same number of ***protons***, but a different number of ***neutrons***.

Isotopes have the same atomic number, but a different mass number.



An atom of uranium-235



An atom of uranium-238

Figure 2.7

Sample Problem 2.4

Determining the Number of Subatomic Particles in the Isotopes of an Element

PROBLEM: Silicon (Si) has three naturally occurring isotopes: ^{28}Si, ^{29}Si, and ^{30}Si. Determine the number of protons, neutrons, and electrons in each silicon isotope.

PLAN: The mass number (A) is given for each isotope and is equal to the number of protons + neutrons. The atomic number *Z*, found on the periodic table, equals the number of protons. The number of neutrons = *A* – *Z*, and the number of electrons equals the number of protons for a neutral atom.

SOLUTION: The atomic number of silicon is 14; therefore

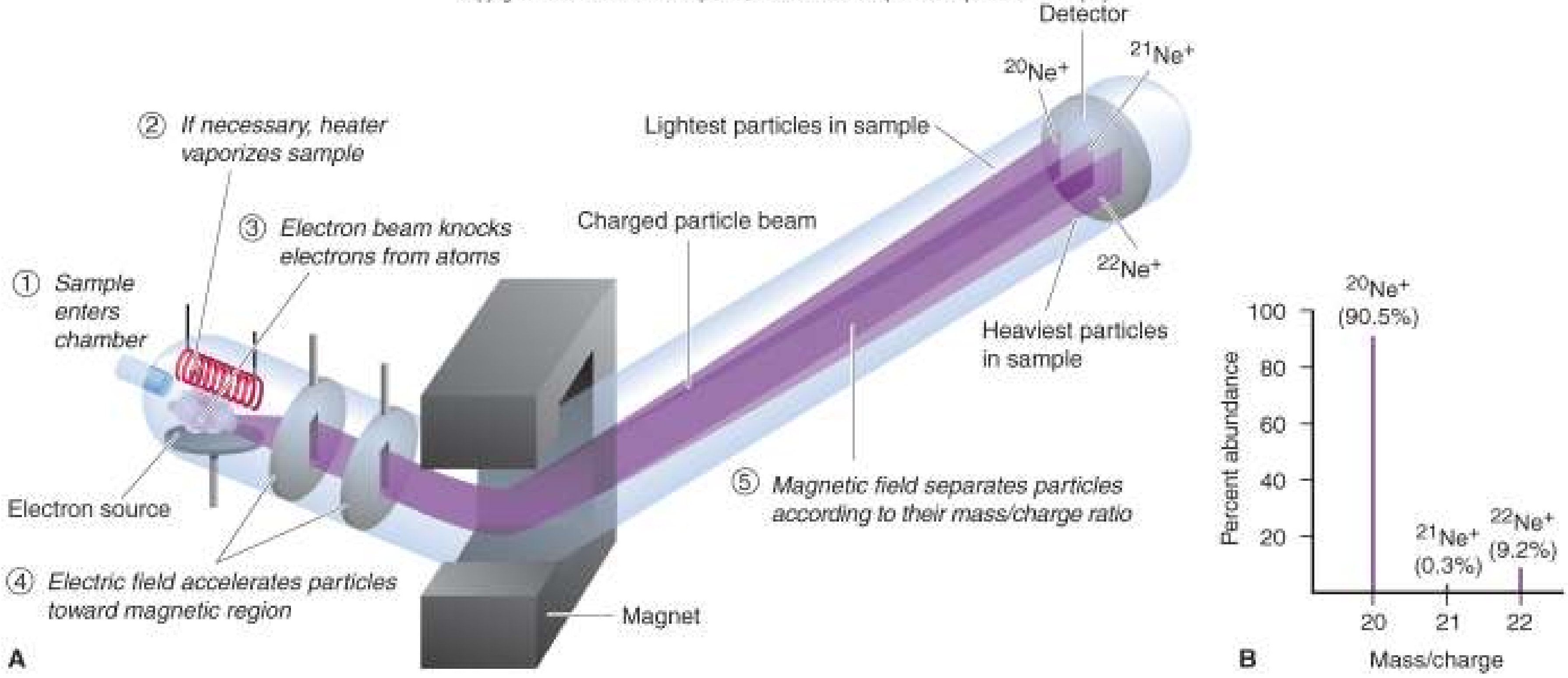
^{28}Si has 14p$^+$, 14e$^-$ and 14n^0 (28-14)

^{29}Si has 14p$^+$, 14e$^-$ and 15n^0 (29-14)

^{30}Si has 14p$^+$, 14e$^-$ and 16n^0 (30-14)

The Mass Spectrometer and Its Data

Mass Spectrometer measures the mass ratio and mass to charge ratio



Atomic Symbol

C Carbon   **Na (Natrium) Sodium**

Note: The chemical properties of an element are determined by the number of electrons or number of protons. So having Isotopes of an element will not change its chemical/physical properties **much**.

Mass of an atom

Atomic mass unit (amu) or Dalton (Da)

Today (u) only

amu = $\frac{1}{12}$ mass of ^{12}C

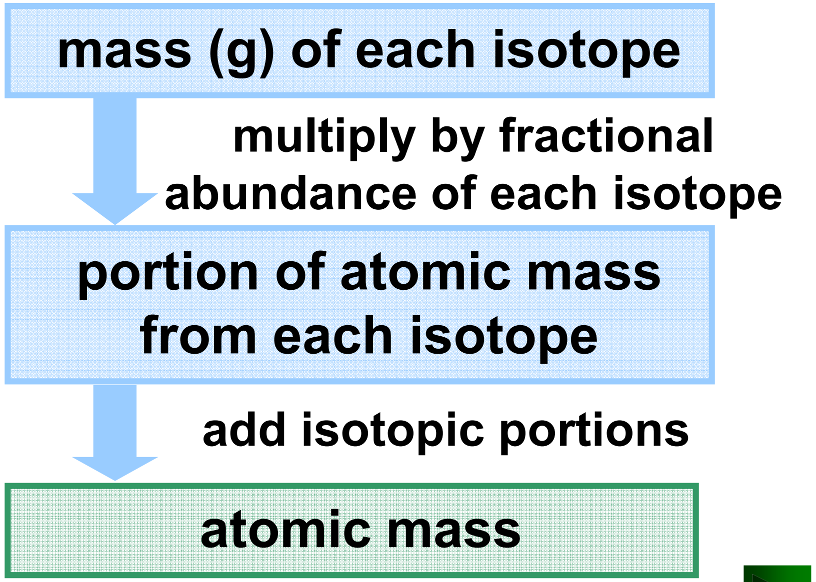
So ^{12}C has a mass of 12 u

Sample Problem 2.5 Calculating the Atomic Mass of an Element

PROBLEM: Silver (Ag, Z = 47) has two naturally occurring isotopes, ^{107}Ag and ^{109}Ag. From the mass spectrometric data provided, calculate the atomic mass of Ag.

Isotope	Mass (amu)	Abundance (%)
^{107}Ag	106.90509	51.84
^{109}Ag	108.90476	48.16

PLAN: Find the weighted average of the isotopic masses.



mass (g) of each isotope

multiply by fractional abundance of each isotope

portion of atomic mass from each isotope

add isotopic portions

atomic mass

Sample Problem 2.5

SOLUTION:

mass portion from ^{107}Ag =
106.90509 amu x 0.5184 = 55.42 amu

mass portion from ^{109}Ag =
108.90476amu x 0.4816 = 52.45amu

atomic mass of Ag = 55.42amu + 52.45amu

$\boxed{\mathbf{= 107.87amu}}$

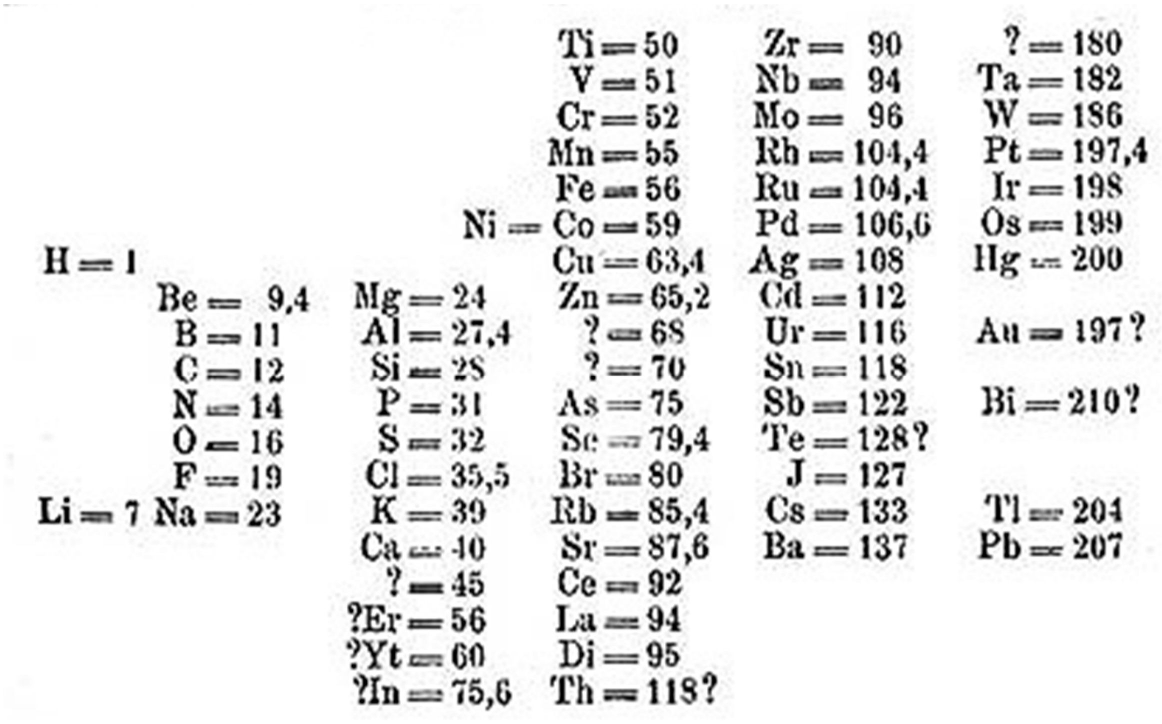
ELEMENTS: A FIRST LOOK AT THE PERIODIC TABLE.

1870 **65** elements were known

Today more than 116 elements

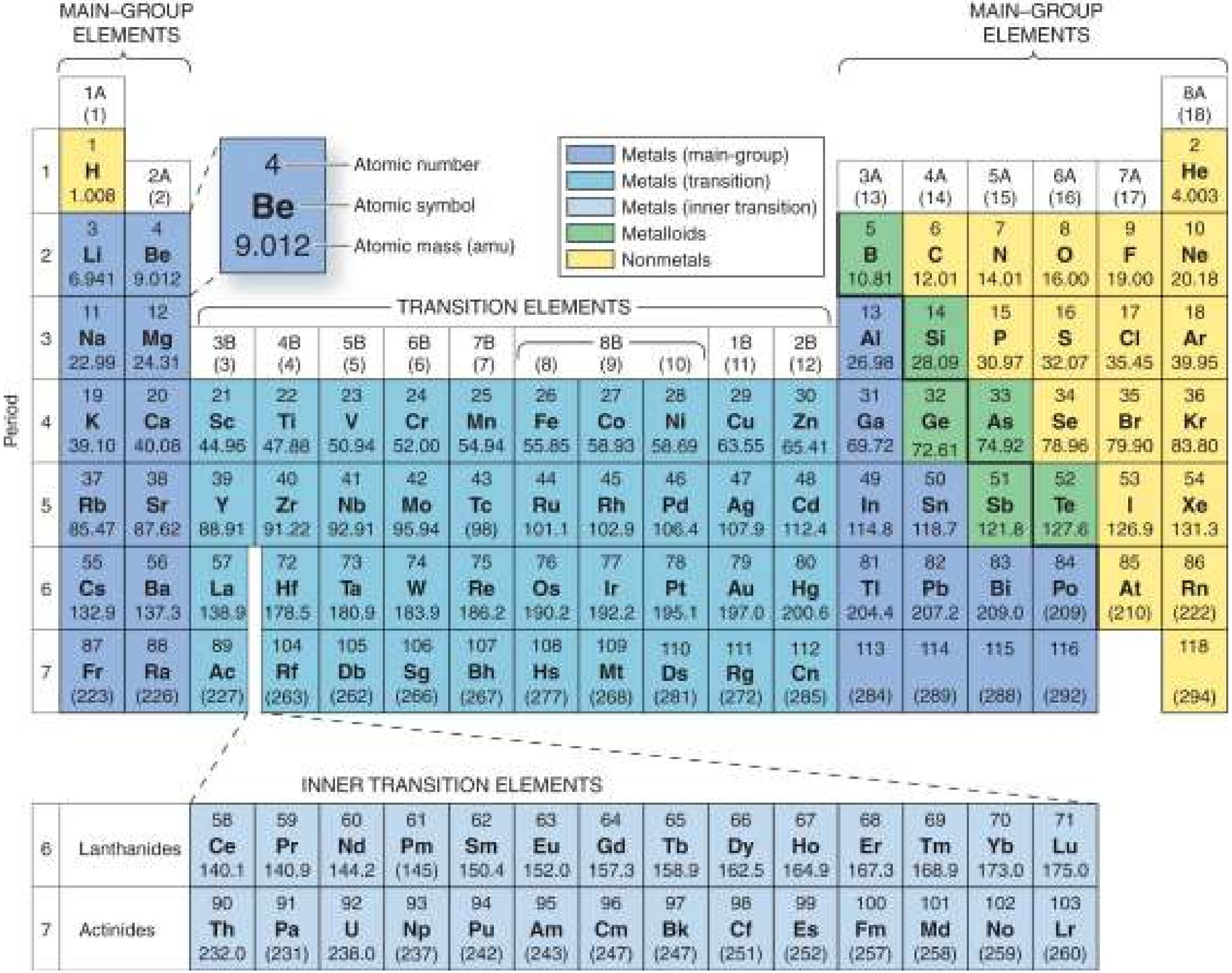
Dmitri Mendeleev and Meyer discovered the periodic table separately in 1869

Dmitri Mendeleev organized elements, he listed the elements by increasing atomic mass.



			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198
			Ni = Co = 59	Pd = 106,6	Os = 199
H = 1			Cu = 63,4	Ag = 108	Hg = 200
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

Figure 2.9 The modern periodic table.

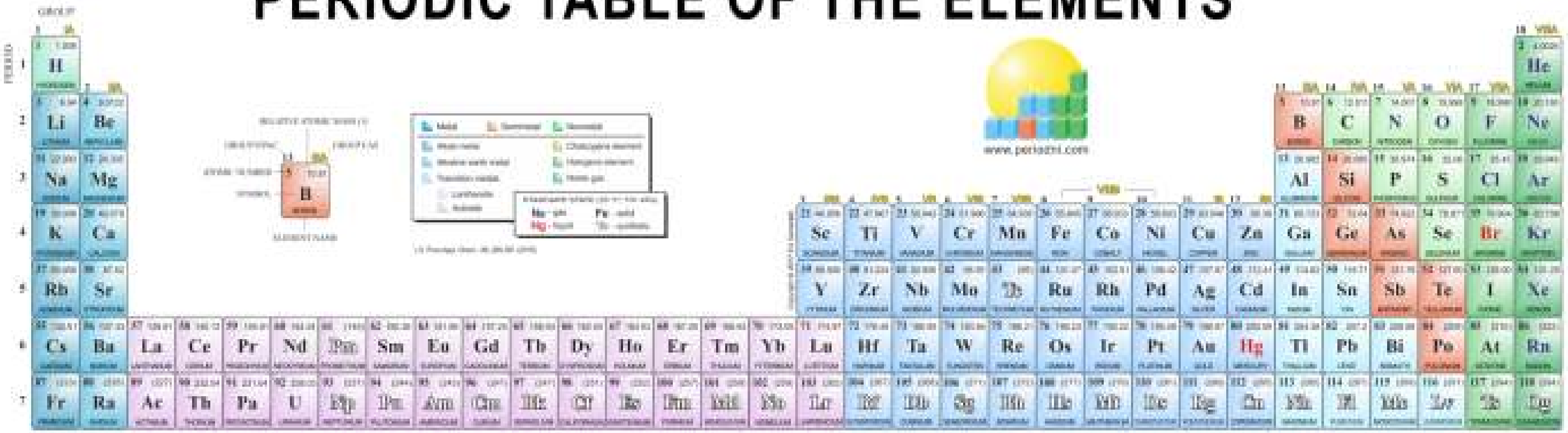


Period	1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	(9)	(10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											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 65.41	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 (263)	105 Db (262)	106 Sg (266)	107 Bh (267)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 (284)	114 (289)	115 (288)	116 (292)		118 (294)

INNER TRANSITION ELEMENTS

6	Lanthanides	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	Actinides	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)

PERIODIC TABLE OF THE 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	H																															He
2	Li	Be																									B	C	N	O	F	Ne
3	Na	Mg																									Al	Si	P	S	Cl	Ar
4	K	Ca															Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr															Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

Figure 2.10

The formation of an ionic compound.

Transferring electrons from the atoms of one element to those of another results in an ionic compound.

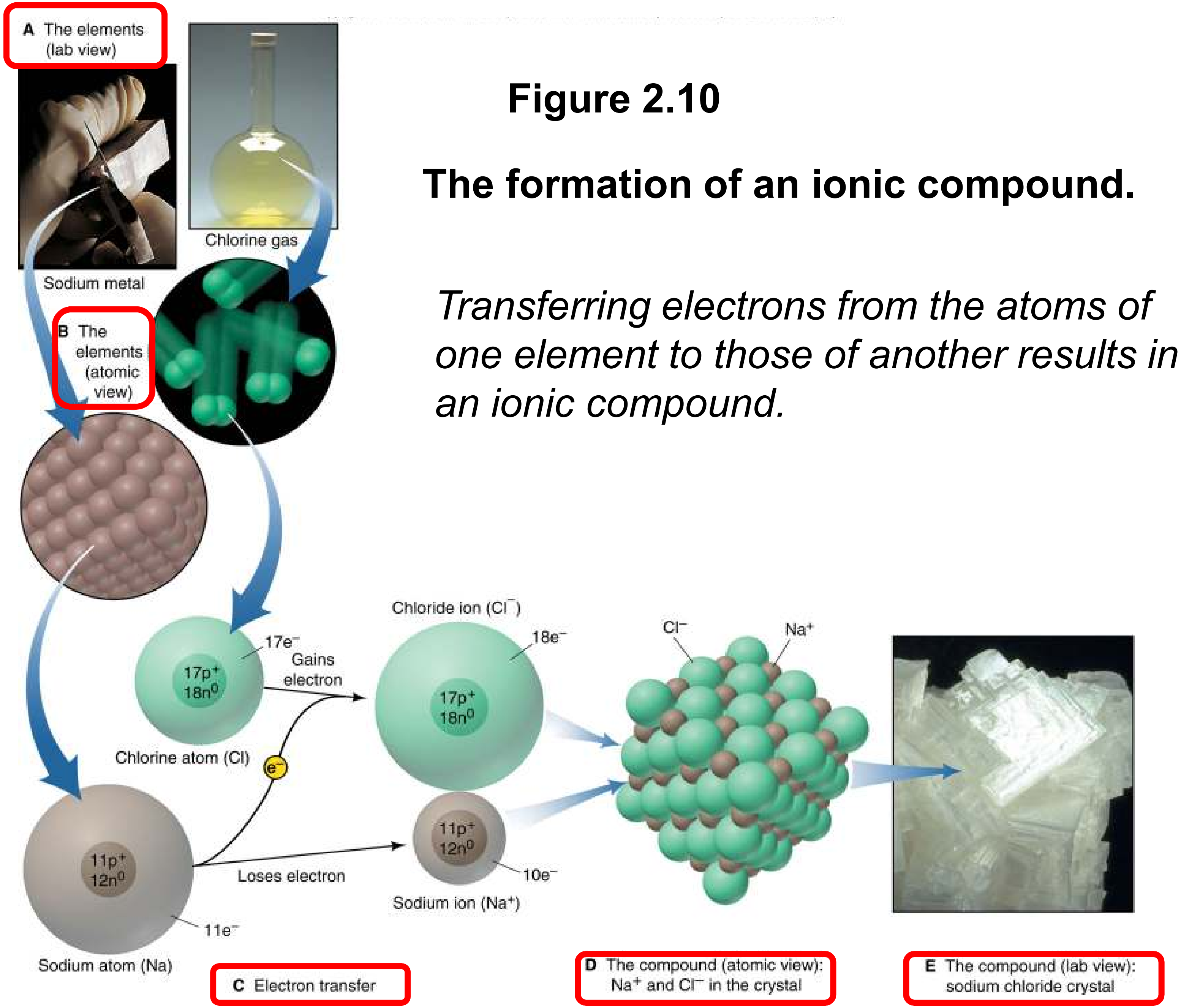
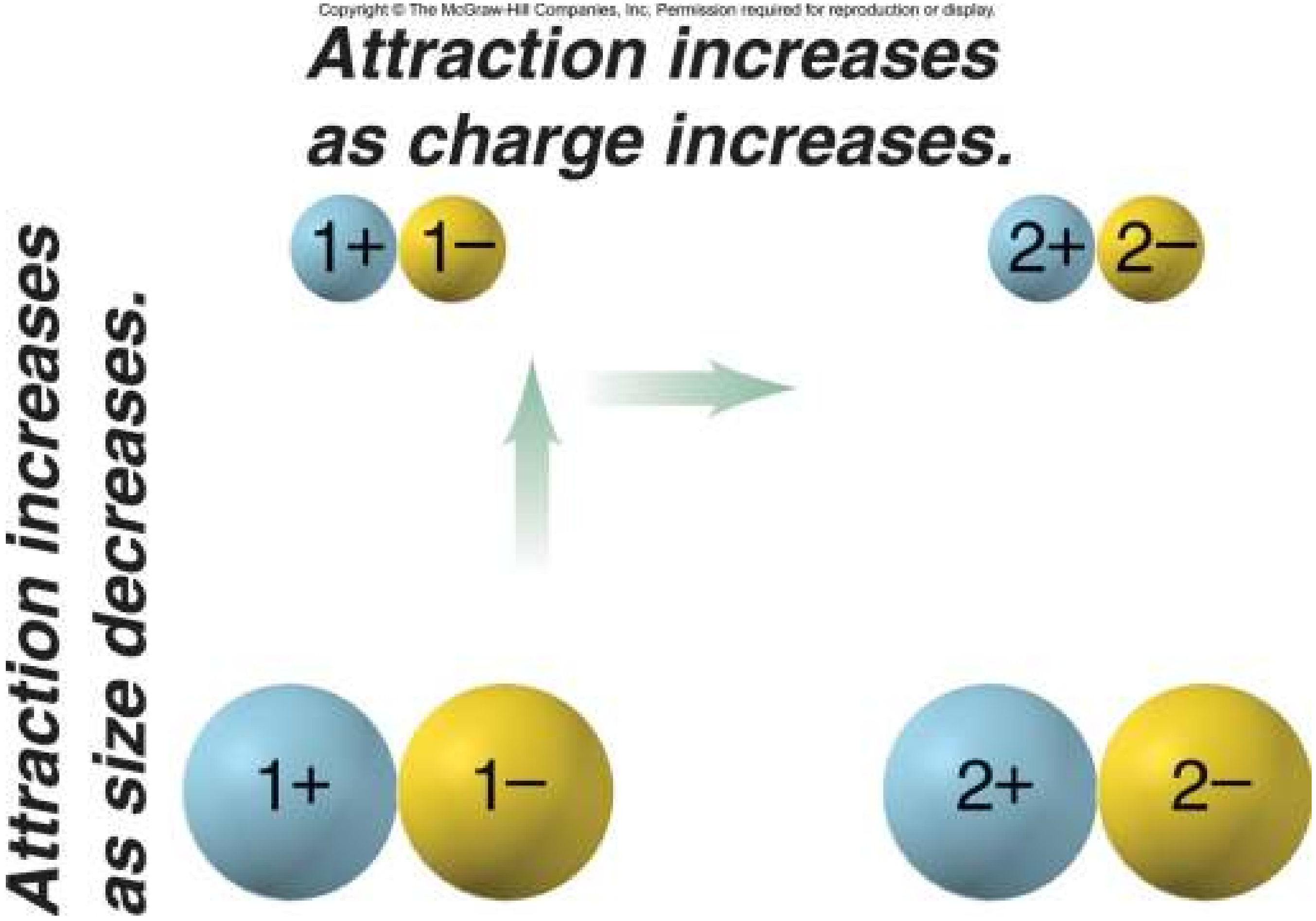


Figure 2.11 Factors that influence the strength of ionic bonding.



Sample Problem 2.6 Predicting the Ion an Element Forms

PROBLEM: Predict the monoatomic ion formed by each of the following elements:

(a) Iodine ($Z = 53$) **(b)** Calcium ($Z = 20$) **(c)** Aluminum ($Z = 13$)

PLAN: Use Z to find the element on the periodic table and see where it lies relative to its **nearest** noble gas.

SOLUTION:

(a) Iodine is a nonmetal in Group 7A(17). It gains one electron to have the same number of electrons as $_{54}Xe$.

The ion is I^-

(b) Calcium is a metal in Group 2A(2). It loses two electrons to have the same number of electrons as $_{18}Ar$.

The ion is Ca^{2+}

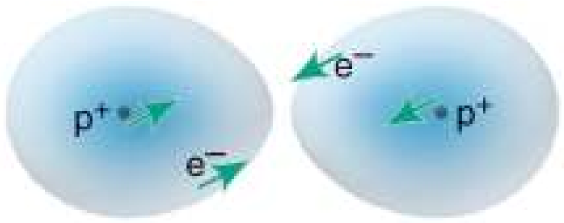
(c) Aluminum is a metal in Group 3A(13). It loses three electrons to have the same number of electrons as $_{10}Ne$.

The ion is Al^{3+}

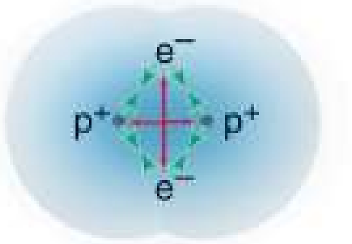
Figure 2.12 Formation of a covalent bond between two H atoms.

Covalent bonds form when elements share electrons, which usually occurs between nonmetals.

Atoms far apart: *No interactions.*



Atoms closer: *Attractions* (green arrows) *between nucleus of one atom and electron of the other increase. Repulsions between nuclei and between electrons are very weak.*



Optimum distance: *H_2 molecule forms because attractions* (green arrows) *balance repulsions* (red arrows).

Molecules and Ions

Molecule – the basic unit of an element or covalent compound, consisting of two or more atoms bonded by the sharing of electrons.

Most covalent substances consist of molecules.

Ion – a single atom or covalently bonded group of atoms that has an overall electrical charge.

There are ***no molecules*** in an ionic compound.

Figure 2.13 Elements that occur as molecules.

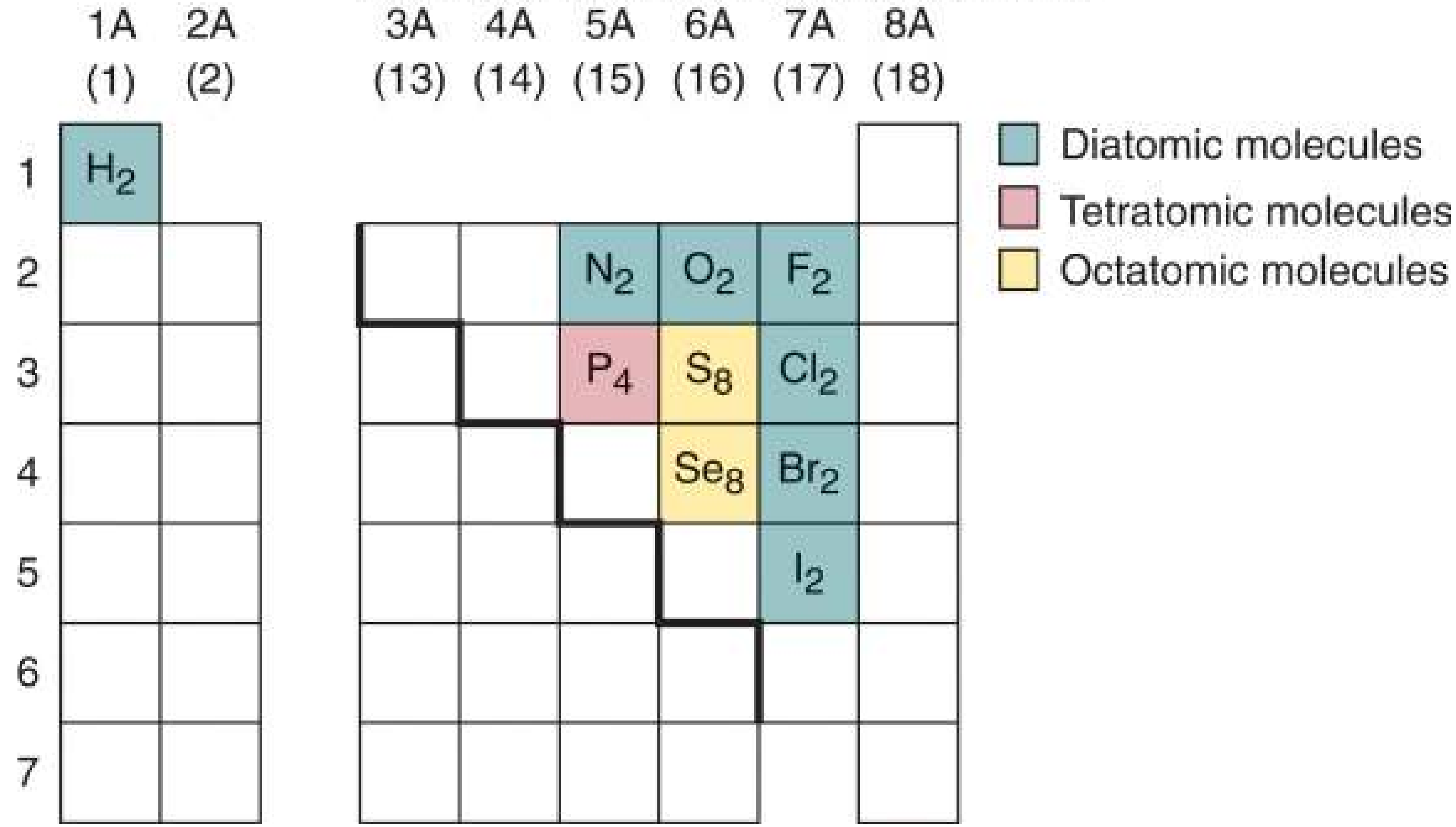
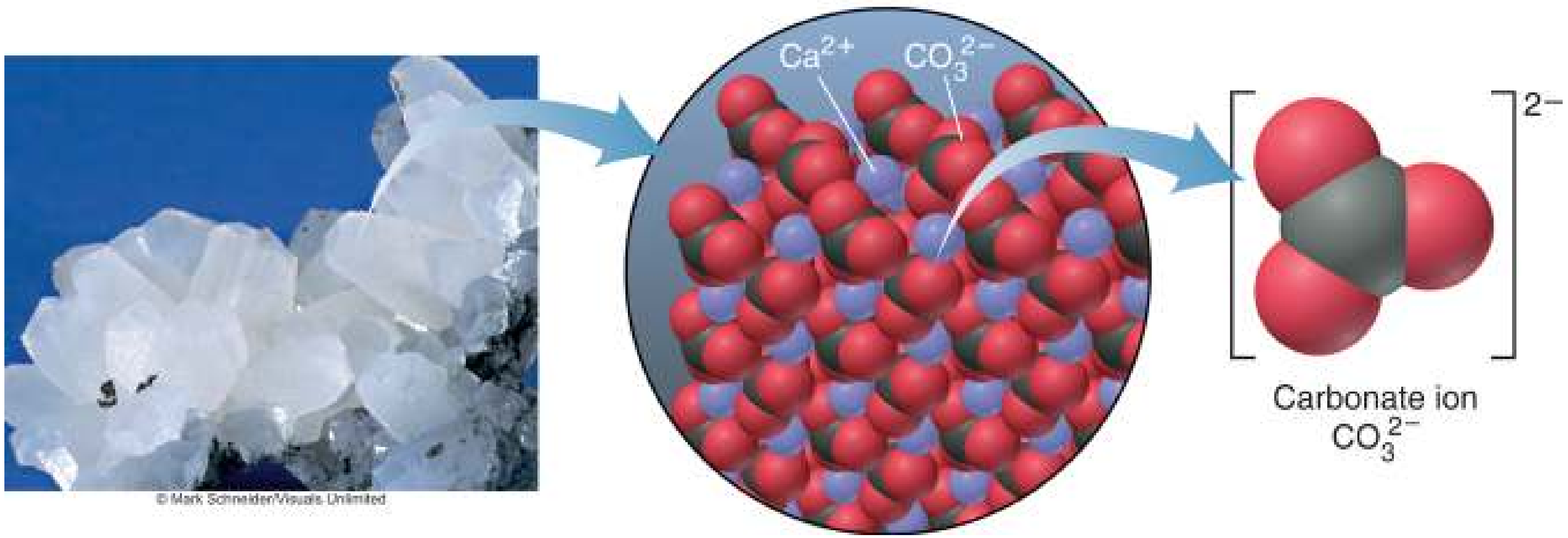


Figure 2.14 The carbonate ion in calcium carbonate.



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A polyatomic ion consists of two or more atoms covalently bonded together and has an overall charge.

In many reactions the polyatomic ion will remain together as a unit.

Chemical Formulas

- A chemical formula consists of
  - element symbols with
  - numerical subscripts.
- The chemical formula indicates the
  - **type** and **number** of each atom present
  - in the **smallest unit** of a substance.

Naming Binary Ionic Compounds

For **all** ionic compounds, the name and formula lists the **cation** first and the **anion** second.

In a **binary ionic** compound, both the cation and the anion are monatomic.

The name of the cation is the **same** as the name of the metal. Many metal names end in -ium.

The anion is named by adding the suffix *-ide* to the root of the nonmetal name.

Calcium and bromine form calcium bromide.

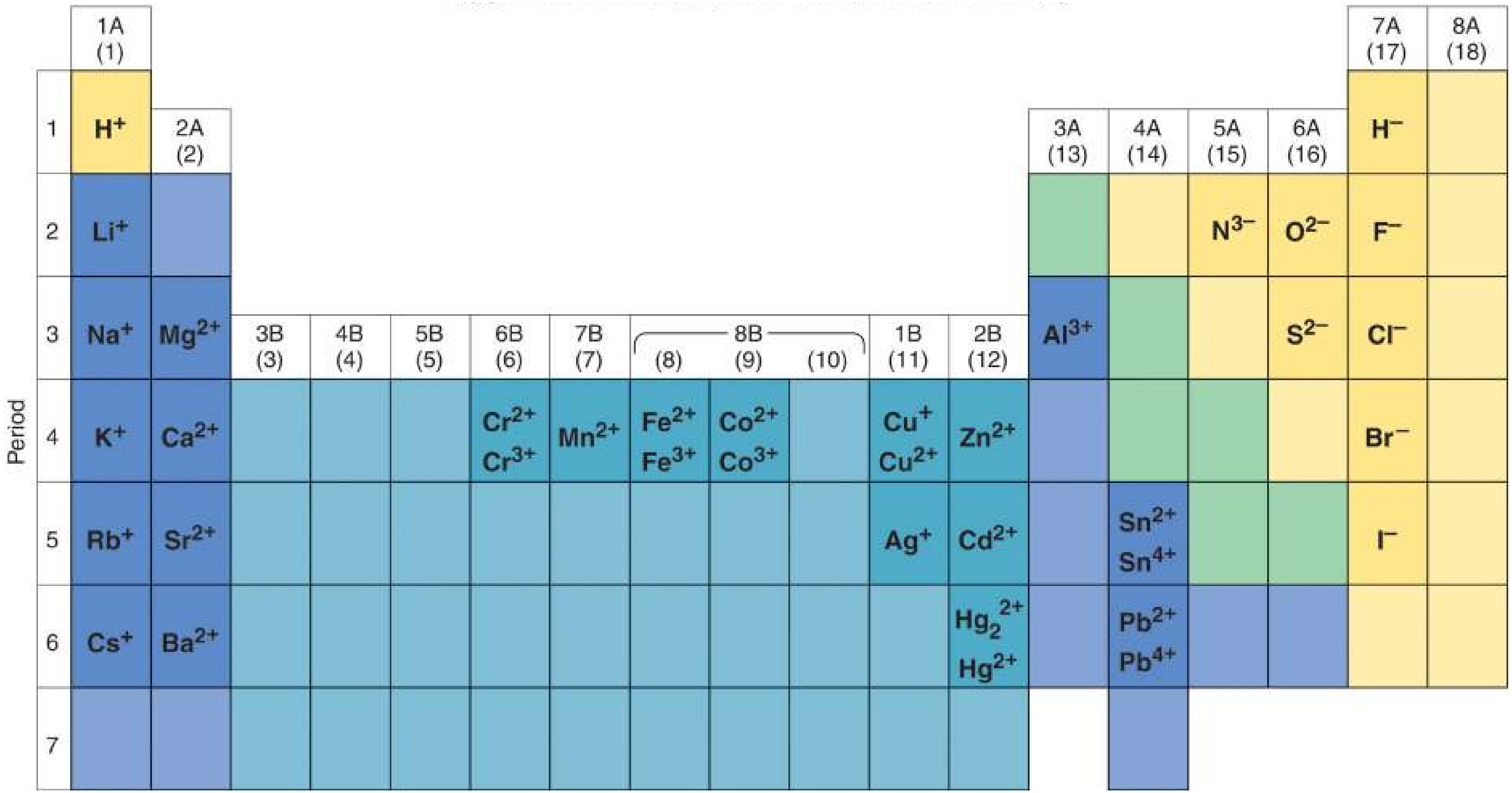
Table 2.3 Common Monatomic Ions*

	Cations	
Charge	**Formula**	**Name**
+1	H^+	**hydrogen**
	Li^+	**lithium**
	Na^+	**sodium**
	K^+	**potassium**
	Cs^+	cesium
	Ag^+	**silver**
+2	**Mg^{2+}**	**magnesium**
	Ca^{2+}	**calcium**
	Sr^{2+}	strontium
	Ba^{2+}	**barium**
	Zn^{2+}	**zinc**
	Cd^{2+}	cadmium
+3	Al^{3+}	aluminum

	Anions	
Charge	**Formula**	**Name**
-1	H^-	hydride
	F^-	**fluoride**
	Cl^-	**chloride**
	Br^-	**bromide**
	I^-	**iodide**
-2	**O^{2-}**	**oxide**
	S^{2-}	**sulfide**
-3	N^{3-}	nitride

*Listed by charge; those in boldface are most common.

Figure 2.15 Some common monatomic ions of the elements.



Period	1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	(8)	8B (9)	(10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	H^+																H^-	
2	Li^+														N^{3-}	O^{2-}	F^-	
3	Na^+	Mg^{2+}											Al^{3+}			S^{2-}	Cl^-	
4	K^+	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}		Cu^+ Cu^{2+}	Zn^{2+}					Br^-	
5	Rb^+	Sr^{2+}									Ag^+	Cd^{2+}		Sn^{2+} Sn^{4+}			I^-	
6	Cs^+	Ba^{2+}										Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				
7																		

Most main-group elements form one monatomic ion.
Most transition elements form two monatomic ions.

Sample Problem 2.7

Naming Binary Ionic Compounds

PROBLEM: Name the ionic compound formed from each of the following pairs of elements:

(a) magnesium and nitrogen **(b)** iodine and cadmium

(c) strontium and fluorine **(d)** sulfur and cesium

PLAN: Use the periodic table to decide which element is the metal and which the nonmetal. The metal (cation) is named first and the suffix-*ide* is added to the root of the non-metal name.

SOLUTION:

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

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

Sample Problem 2.8

Determining Formulas of Binary Ionic Compounds

PROBLEM: Write empirical formulas for each of the compounds named in Sample Problem 2.7.

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

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

PLAN: A compound is neutral. We find the smallest number of each ion that will produce a neutral formula. These numbers appear as *right subscripts* to the relevant element symbol.

SOLUTION:

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

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

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

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

Table 2.4 Some Metals That Form More Than One Monatomic Ion*

Element	Ion Formula	Systematic Name	Common Name
Chromium	Cr^{2+}	chromium(II)	chromous
	Cr^{3+}	**chromium(III)**	chromic
Cobalt	Co^{2+}	cobalt(II)	
	Co^{3+}	cobalt(III)	
Copper	**Cu^{+}**	**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)	
Mercury	Hg_2^{2+}	mercury (I)	mercurous
	Hg^{2+}	**mercury (II)**	mercuric
Tin	**Sn^{2+}**	**tin(II)**	stannous
	Sn^{4+}	tin(IV)	stannic

*Listed alphabetically by metal name; the ions in boldface are most common.

Sample Problem 2.9

Determining Names and Formulas of Ionic Compounds of Elements That Form More Than One Ion

PROBLEM: Give the systematic name for each formula or the formula for each name for the following compounds:

(a) tin(II) fluoride **(b)** CrI_3 **(c)** ferric oxide **(d)** CoS

PLAN: Find the smallest number of each ion that will produce a neutral formula.

SOLUTION:

(a) Tin(II) is Sn^{2+}; fluoride is F^-; so the formula is $\mathbf{SnF_2}$.

(b) The anion I^- is iodide; $3I^-$ means that Cr (chromium) is +3. CrI_3 is **chromium(III) iodide**.

(c) Ferric is a common name for Fe^{3+}; oxide is O^{2-}; therefore the formula is $\mathbf{Fe_2O_3}$.

(d) Co is cobalt; the anion S^{2-} is sulfide; the compound is **cobalt(II) sulfide**.

Table 2.5 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	**HCO_3^-**	**bicarbonate**
OH^-	**hydroxide**	CrO_4^{2-}	chromate
ClO^-	hypochlorite	**$Cr_2O_7^{2-}$**	**dichromate**
ClO_2^-	chlorite	O_2^{2-}	peroxide
ClO_3^-	**chlorate**	**PO_4^{3-}**	**phosphate**
NO_2^-	nitrite	HPO_4^{2-}	hydrogen phosphate
NO_3^-	**nitrate**	SO_3^{2-}	sulfite
MnO_4^-	**permanganate**	**SO_4^{2-}**	**sulfate**

*Bold face ions are most common.

(partial table)

Figure 2.16 Naming oxoanions

No. of O atoms ↑

Prefix	Root	Suffix	Example	
per	*root*	ate	ClO_4^-	perchlorate
	root	ate	ClO_3^-	chlorate
	root	ite	ClO_2^-	chlorite
hypo	*root*	ite	ClO^-	hypochlorite

Sample Problem 2.10

Determining Names and Formulas of Ionic Compounds Containing Polyatomic Ions

PROBLEM: Give the systematic name for each formula or the formula for each name for the following compounds:

(a) $Fe(ClO_4)_2$ **(b)** sodium sulfite **(c)** $Ba(OH)_2{\cdot}8H_2O$

PLAN: Remember to use parentheses when more than one unit of a particular polyatomic ion is present in the compound.

SOLUTION: **(a)** ClO_4^- is perchlorate; Fe must have a 2+ charge since there are 2 ClO_4^- ions. This is **iron(II) perchlorate**.

(b) The anion sulfite is SO_3^{2-}; therefore you need 2 Na^+ for each sulfite. The formula is $\mathbf{Na_2SO_3}$.

(c) The ionic compound is barium hydroxide. When water is included in the formula, we use the term “hydrate” and a prefix that indicates the number of molecules of H_2O. This compound is **barium hydroxide octahydrate**.

Sample Problem 2.11

Recognizing Incorrect Names and Formulas of Ionic Compounds

PROBLEM: There is an error in the second part of each statement. Provide the correct name or formula in each case.

(a) $Ba(C_2H_3O_2)_2$ is called barium diacetate.

(b) Sodium sulfide has the formula $(Na)_2SO_3$.

(c) Iron(II) sulfate has the formula $Fe_2(SO_4)_3$.

(d) Cesium carbonate has the formula $Cs_2(CO_3)$.

SOLUTION:

(a) The charge of Ba^{2+} *must* be balanced by *two* $C_2H_3O_2^-$ ions. The prefix "di" is not required and is not used in this way when naming ionic compounds. The correct name is simply **barium acetate**.

(b) An ion of a single element does not need parentheses, and sulfide is S^{2-}, not SO_3^{2-}. The correct formula is **Na_2S**.

Sample Problem 2.11

(c) Sulfate or SO_4^{2-} has a 2⁻ charge, and only ***one*** Fe^{2+} is needed to form a neutral compound. The formula should be **$FeSO_4$**.

(d) The parentheses are unnecessary, since only ***one*** CO_3^{2-} ion is present. The correct formula is **Cs_2CO_3**.

Naming Acids

1) ***Binary acid*** solutions form when certain gaseous compounds dissolve in water.

For example, when gaseous hydrogen chloride (HCl) dissolves in water, it forms a solution called hydrochloric acid.

Prefix ***hydro-*** + anion nonmetal ***root*** + suffix ***-ic*** + the word ***acid*** -

hydro + **chlor** + **ic** + acid

hydrochloric acid

2) Oxoacid names are similar to those of the oxoanions, except for two suffix changes:

-ate in the anion becomes ***–ic*** in the acid

-ite in the anion becomes ***–ous*** in the acid

The oxoanion prefixes ***hypo-*** and ***per-*** are retained. Thus,

BrO_4^- is ***perbromate***, and $HBrO_4$ is ***perbromic*** acid;

IO_2^- is ***iodite***, and HIO_2 is ***iodous acid***.

Figure 2.16 Naming oxoanions

No. of O atoms ↑

Prefix	Root	Suffix	Example		
per	chlor	ate	ClO_4^-	perchlorate	perchloric acid
	chlor	ate	ClO_3^-	chlorate	Chloric acid
	chlor	ite	ClO_2^-	chlorite	Chlorous acid
hypo	chlor	ite	ClO^-	hypochlorite	Hypochlorous acid

Sample Problem 2.12

Determining Names and Formulas of Anions and Acids

PROBLEM: Name the following anions and give the name and formula of the acid derived from each:

(a) Br^- **(b)** IO_3^- **(c)** CN^- **(d)** SO_4^{2-} **(e)** NO_2^-

SOLUTION:

(a) The anion is **bromide**; the acid is **hydrobromic acid, HBr**.

(b) The anion is **iodate**; the acid is **iodic acid, HIO_3**.

(c) The anion is **cyanide**; the acid is **hydrocyanic acid, HCN**.

(d) The anion is **sulfate**; the acid is **sulfuric acid, H_2SO_4**.

(e) The anion is **nitrite**; the acid is **nitrous acid, HNO_2**.

Naming Binary Covalent Compounds

A binary covalent compound is typically formed by the combination of two non-metals.

Some of these compounds are very common and have *trivial* names, eg., H_2O is water.

For a binary covalent compound, the element with the ***lower*** group number (or the larger size) in the periodic table is ***first*** in the name and formula. Its name remains unchanged.

The element that is second is named using the root with the suffix ***–ide***. Numerical prefixes indicate the number of atoms of each element present.

Table 2.6 Numerical Prefixes* for Hydrates and Binary Covalent Compounds

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

Sample Problem 2.13

Determining Names and Formulas of Binary Covalent Compounds

PROBLEM: **(a)** What is the formula of carbon disulfide?

(b) What is the name of PCl_5?

(c) Give the name and formula of the compound whose molecules each consist of two N atoms and four O atoms.

SOLUTION:

(a) Carbon is C, sulfide is sulfur S and di-means two; the formula is $\mathbf{CS_2}$.

(b) P is phosphorous, Cl is chloride, the prefix for 5 is penta-. This is **phosphorous pentachloride**.

(c) N is nitrogen and is in a lower group number than O (oxygen). The compound formula is $\mathbf{N_2O_4}$ and the name is **dinitrogen tetroxide (dinitrogen tetraoxide)**.

Sample Problem 2.14

Recognizing Incorrect Names and Formulas of Binary Covalent Compounds

PROBLEM: Explain what is wrong with the name of formula in the second part of each statement and correct it:

(a) SF_4 is monosulfur pentafluoride.

(b) Dichlorine heptaoxide is Cl_2O_6.

(c) N_2O_3 is dinitrotrioxide.

SOLUTION:

(a) The prefix mono- is not needed if there is only one atom of the first element, and the prefix for four is tetra-. So the name is **sulfur tetrafluoride**.

(b) Hepta- means 7; the formula should be $\mathbf{Cl_2O_7}$.

(c) The first element is given its elemental name so this is **dinitrogen trioxide**.

Naming Straight-Chain Alkanes

Hydrocarbons are compounds that contain only carbon and hydrogen atoms.

Alkanes are the simplest type of hydrocarbon.

Alkanes are named using a root name followed by the suffix ***–ane***.

Table 2.7 The First 10 Straight-Chain Alkanes

Name (Formula)	Model
Methane (CH_4)	
Ethane (C_2H_6)	
Propane (C_3H_8)	
Butane (C_4H_{10})	
Pentane (C_5H_{12})	
Hexane (C_6H_{14})	
Heptane (C_7H_{16})	
Octane (C_8H_{18})	
Nonane (C_9H_{20})	
Decane ($C_{10}H_{22}$)	

Molecular Masses from Chemical Formulas

Molecular mass = sum of atomic masses

For the H_2O molecule:

molecular mass =

(2 x atomic mass of H) + (1 x atomic mass of O)

= (2 x 1.008 amu) + (1 x 16.00 amu)

= 18.02 amu

By convention, we read masses off the periodic table to ***4 significant figures****.*

For **ionic compounds** we refer to a **formula mass** since ionic compounds do not consist of molecules.

Sample Problem 2.15

Calculating the Molecular Mass of a Compound

PROBLEM: Using the periodic table, calculate the molecular (or formula) mass of:

(a) tetraphosphorous trisulfide **(b)** ammonium nitrate

PLAN: Write the formula and then multiply the number of atoms by the respective atomic masses. Add the masses for each compound.

SOLUTION:

(a) P_4S_3

molecular mass = (4 x atomic mass of P) + (3 x atomic mass of S)

= (4 x 30.97 amu) + (3 x 32.07 amu) = **220.09 amu**

(b) NH_4NO_3

formula mass = (2 x atomic mass of N) + (4 x atomic mass of H) + (3 x atomic mass of O)

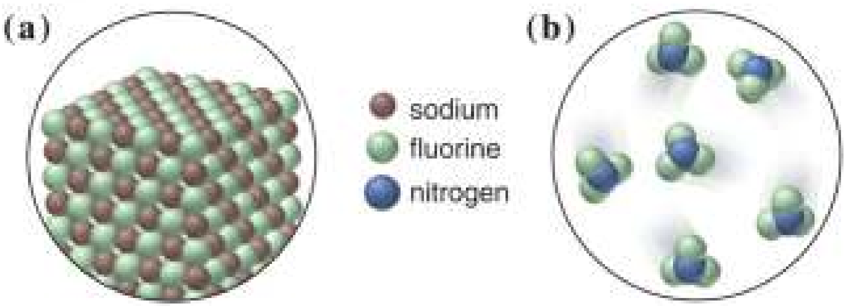
= (2 x 14.01 amu) + (4 x 1.008 amu) + (3 x 16.00 amu)

= **80.05 amu**

Sample Problem 2.16

Using Molecular Depictions to determine Formula, Name, and Mass for a compound

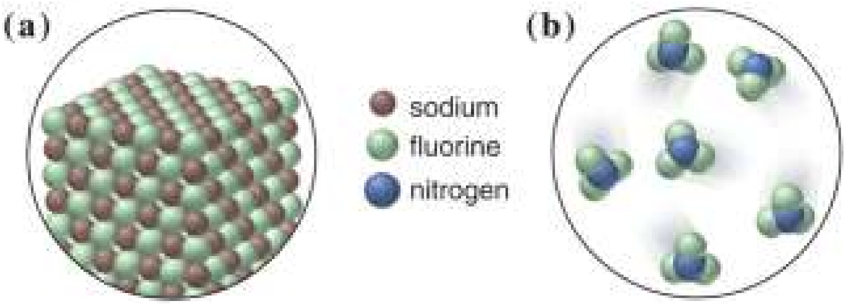
PROBLEM: Each scene represents a binary compound. Determine its formula, name, and molecular (formula) mass.



PLAN: Each compound contains only two elements. Find the simplest whole number ratio of atoms in each compound and use this formula to determine the name and the formula mass.

Sample Problem 2.16

SOLUTION:



(a) There is 1 brown Na^+ for every green F^-, so the formula is **NaF**, an ionic compound, which is named **sodium fluoride**.

Formula mass = (1 x atomic mass of Na) + (1 x atomic mass of F)
= 22.99 amu + 19.00 amu = **41.99 amu**

(b) There are 3 green F for every blue N, so the formula is **NF_3**, a covalent compound, which is named **nitrogen trifluoride**.

Molecular mass = (1 x atomic mass of N) + (3 x atomic mass of F)
= 14.01 amu + (3 x 19.00) = **71.01 amu**

Representing Molecules with Formulas and Models

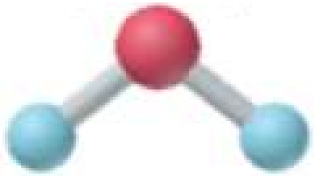
H_2O

Molecular formula for water.

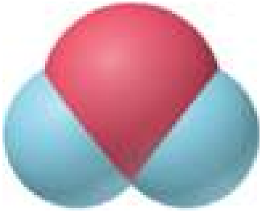
H:O:H

H—O—H

Structural formulas for water.



Ball-and-stick model for water.



Space-filling model for water.

Representing Molecules with Formulas and Models

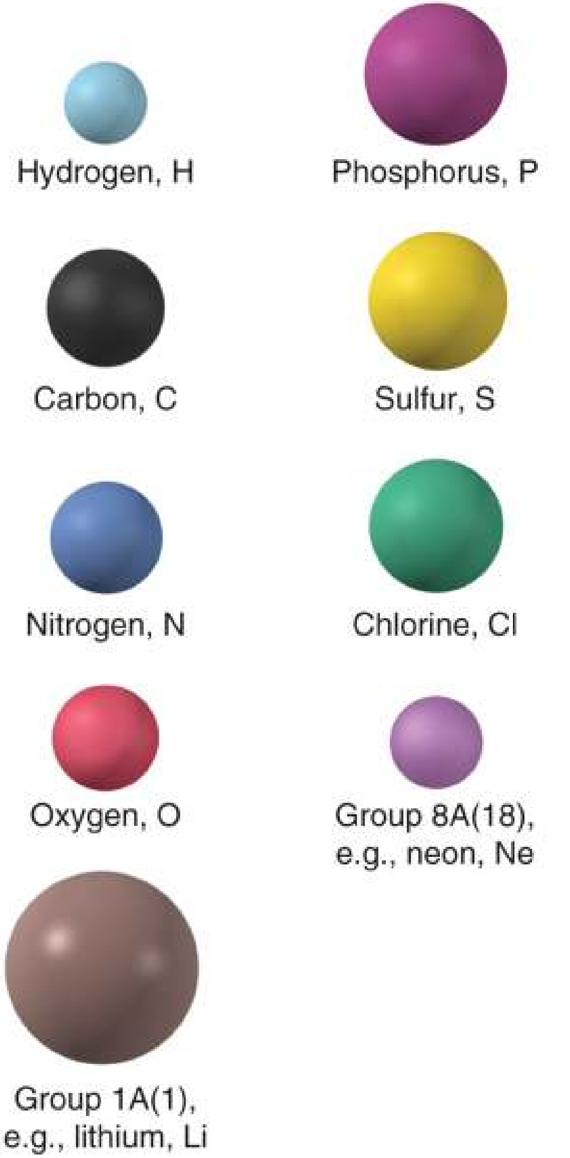
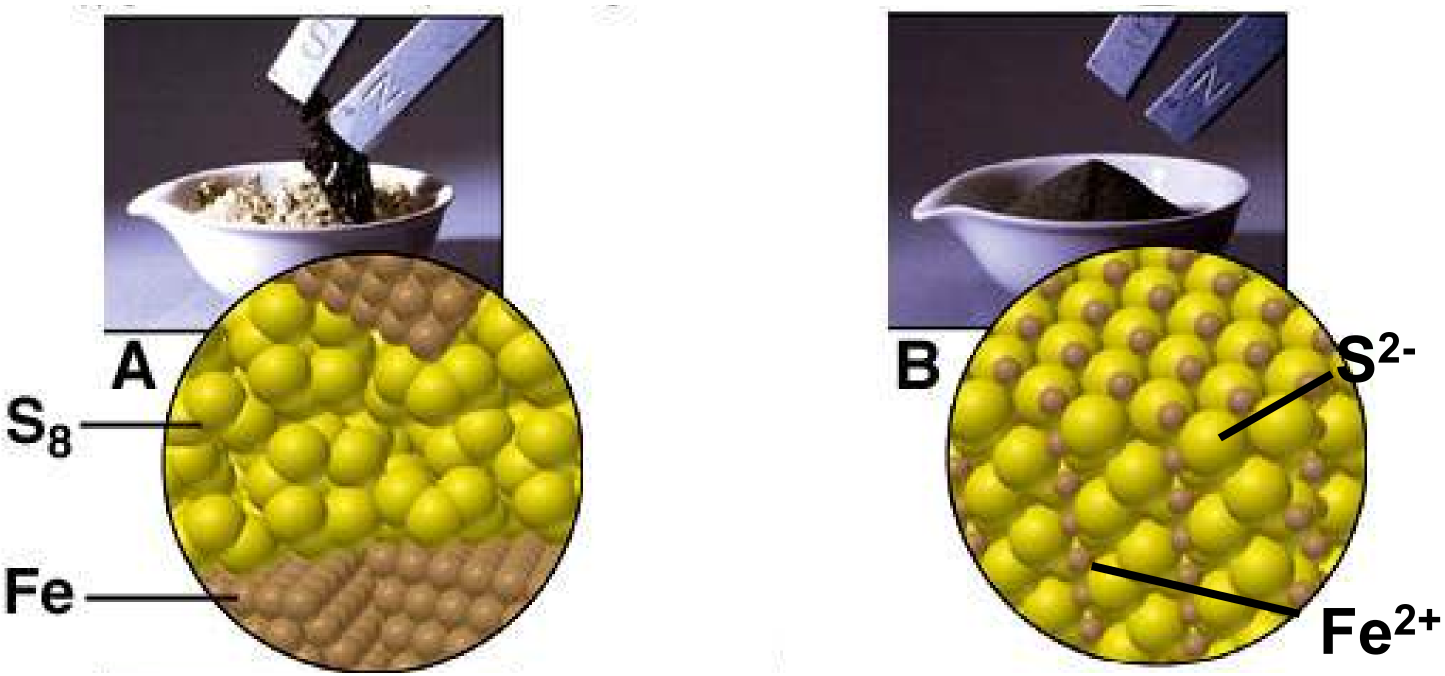


Figure 2.17 The distinction between mixtures and compounds.



A physical mixture of Fe and S_8 can be separated using a magnet.

Fe and S have reacted chemically to form the compound FeS. The elements cannot be separated by physical means.

Mixtures

A ***heterogeneous mixture*** has one or more visible boundaries between the components.
Examples: milk, coffee and soup.

A ***homogeneous mixture*** has no visible boundaries because the components are mixed as individual atoms, ions, and molecules.
example: NaCl in water and sugar in water.

A homogeneous mixture is also called a ***solution***.
Solutions in water are called ***aqueous solutions***.