Dalton's Atomic Theory (1808)

- 1. Elements are composed of extremely small particles called *atoms*.
- 2. All *atoms* of a given element are identical, having the same size, mass and chemical properties.
- **3.** Compounds are composed of atoms of more than one element.
- 4. A *chemical reaction* involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.

Types of Radioactivity



Wilhelm Rontgen (1895) discovered:

Alpha particles Beta particles Gamma rays

All radioactive substances emit one or more of these particles/ray.

(uranium compound)

α

β

γ

Ernest Rutherford's Experiment (1908 Nobel Prize in Chemistry)



Atoms' positive charge is concentrated in the nucleus
 proton (p) has opposite (+) charge of electron (-)

Rutherford's Model of the Atom



atomic radius ~ 100 pm nuclear radius ~ 5×10^{-3} pm





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Chadwick's Experiment (1932) (1935 Noble Prize in Physics)

Chadwick discovered neutrons within atoms:

- 1. Neutrons have no charge
- 2. Neutrons are almost identical in mass to protons
- 3. Neutrons are concentrated in the atom's nucleus along with protons

Thus, nucleus is very dense but rest of atom is largely empty space (just a few electrons). 5

Properties of Subatomic Particles

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Table 2.1 Mass and Charge of Subatomic Particles

Particle	Mass (g)	Coulomb	Charge Unit
		Churge	Churge
Electron*	9.10938×10^{-28}	-1.6022×10^{-19}	-1
Proton	1.67262×10^{-24}	$+1.6022 \times 10^{-19}$	+1
Neutron	1.67493×10^{-24}	0	0

*More refined measurements have given us a more accurate value of an electron's mass than Millikan's.

Protons and neutrons are both 1840 times more massive than electrons.

Atomic Number, Mass Number, and Isotopes

Atomic number (Z) = number of protons in nucleus

Mass number (A) = number of protons + number of neutrons

= atomic number (Z) + number of neutrons

Isotopes are atoms of the same element (X) with different numbers of neutrons in their nuclei

 $\begin{array}{ll} \text{Mass Number} \rightarrow A \\ \text{Atomic Number} \rightarrow Z \end{array} \ \leftarrow \ \text{Element Symbol} \end{array}$

 $^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

The Isotopes of Hydrogen



Give the number of protons, neutrons, and electrons in each of the following species:

(a) $\frac{20}{11}$ Na	11 p⁺, 9 n, 11 e⁻
(b) $\frac{22}{11}$ Na	11 p⁺, 11 n, 11 e⁻
(c) ¹⁷ 0	8 p⁺, 9 n, 8 e⁻
(d) carbon-14	6 p⁺, 8 n, 6 e⁻
(e) ¹⁰⁸ Pd	46 p⁺, 62 n, 46 e

Balancing Nuclear Reactions

	proton ¹ ₁ p or ¹ ₁ H	neutron ¹ ₀ n	electron $_{-1}^{0}e$ or $_{-1}^{0}\beta$	positron $_{+1}^{0}e$ or $_{+1}^{0}\beta$	∝ particle $\frac{4}{2}$ He or $\frac{4}{2}$ ∝
Mass	1	1	0	0	4
Charge	e 1	0	-1	+1	2

Balancing Nuclear Equations

1. Conserve mass number (A).

The sum of protons plus neutrons in the products must equal the sum of protons plus neutrons in the reactants.

2. Conserve atomic number (Z) or nuclear charge.

The sum of nuclear charges in the products must equal the sum of nuclear charges in the reactants.

Balance the following nuclear equations (that is, identify the product X):

(a)
$${}^{212}_{84}Po \rightarrow {}^{208}_{82}Pb + X$$

(b) ${}^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + X$

Comparing Nuclear and Chemical Equations

Comparison of Chemical Reactions and Nuclear Reactions

Chemical Reactions	Nuclear Reactions
1. Atoms are rearranged by the breaking and forming of chemical bonds.	 Elements (or isotopes of the same elements) are converted from one to another.
 Only electrons in atomic or molecular orbitals are involved in the breaking and forming of bonds. 	2. Protons, neutrons, electrons, and other elementary particles may be involved.
3. Reactions are accompanied by absorption or release of relatively <u>small amounts of energy</u> .	 Reactions are accompanied by absorption or release of tremendous amounts of energy.
4. Rates of reaction are influenced by temperature, pressure, concentration, and catalysts.	4. Rates of reaction normally are not affected by temperature, pressure, and catalysts.

The Modern Periodic Table

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kali N	Ikali E	1										13 3 \	14 4A	15 5A	16 6A	aloge	oble (
Net a	art	1										i	6 C	7 N	8 0		Gas
Na	N	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 	10	11 1B	12 2B	Gr	14 Si	15 P	16 S		Ar
19 1 5	leta	21 Sc	22 T i		eric	<mark>bd</mark> -	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	dnc	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	s ^e r	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	4) 11	50 Sn	51 Sb	52 Te	53 1	54 Xe
55 Cs	56 Fa	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113	114 Fl	115	116 Lv	117	118
	Metals			58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
	Metallo	oids		90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Nonmetals

D D

ΙZ

Classification of the Elements

				1		Copyright 6	McGraw-Hill	Zinc	nission required	for reproduction	on or display.						
1 1A				Repres	entative its			Cadmin	um 'y								18 8A
1 H	2 2A			Noble	gases			Lantha	nides			13 3A	14 4A	15 5A	16 6A	17 7A	2 He
3 Li	4 Be			Transit metals	ion			Actinid	les			5 B	6 C	7 N	8 0	9 F	10 Ne
11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 	10	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113	114 Fl	115	116 Lv	117	118

1								10	07.	54. S				
	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Molecules

A *molecule* is an aggregate of two or more atoms in a definite arrangement held together by chemical forces.

A diatomic molecule contains only two atoms:

 H_2 , N_2 , O_2 , Br_2 , HCl, CO



Permission required for

diatomic elements

A *polyatomic molecule* contains more than two atoms:

 O_3 , H_2O , NH_3 , CH_4

lons

An *ion* is an atom, or group of atoms, that has a net positive or negative charge.



Common Ions Shown on the Periodic Table

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1 1A																	18 8A
	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	
Li+													C4-	N ³⁻	02-	F-	
Na ⁺	Mg ²⁺	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 	10	11 1B	12 2B	Al ³⁺		P ³⁻	S ²⁻	CI-	
K +	Ca ²⁺				Cr ²⁺ Cr ³⁺	Mn ²⁺ Mn ³⁺	Fe ²⁺ Fe ³⁺	Co ²⁺ Co ³⁺	Ni ²⁺ Ni ³⁺	Cu ⁺ Cu ²⁺	Zn ²⁺				Se ²⁻	Br-	
Rb ⁺	Sr ²⁺									Ag ⁺	Cd ²⁺		Sn ²⁺ Sn ⁴⁺		Te ²⁻	I-	
Cs ⁺	Ba ²⁺									Au ⁺ Au ³⁺	Hg ₂ ²⁺ Hg ²⁺		Pb ²⁺ Pb ⁴⁺				
5.																	

Ionic Compounds

Ionic compounds consist of a combination of cations and anions.

- The formula is usually the same as the empirical formula.
- The sum of the charges on the cation(s) and anion(s) in each formula unit must equal zero.

The ionic compound NaCl



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Molecular Compounds

Molecular compounds

- Nonmetals or nonmetals + metalloids
- Common names

- H₂O, NH₃, CH₄

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Table 2.4 Greek Prefixes Used in Naming Molecular Compounds

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

Examples of Molecular Compounds

- HI hydrogen iodide
- NF₃ nitrogen trifluoride
- SO₂ sulfur dioxide
- N₂Cl₄ dinitrogen tetrachloride
- NO₂ nitrogen dioxide
- N₂O dinitrogen monoxide

Flowchart for Naming Compounds

Copyright @ MoGrew-Hill Education. Permission required for reproduction or display. Compound Ionic Molecular Cation: metal or NH⁺ · Binary compounds Anion: monatomic or of nonmetals polyatomic Naming · Use prefixes for Cation has more Cation has both elements present only one charge than one charge (Prefix "mono-" usually omitted for · Other metal cations Alkali metal cations the first element) · Alkaline earth metal cations · Add "-ide" to the • Ag⁺, Al³⁺, Cd²⁺, Zn²⁺ root of the second element Naming Naming · Name metal first · Specify charge of · Name metal first metal cation with · If monatomic anion. Roman numeral add "-ide" to the in parentheses root of the element · If monatomic anion, add "-ide" to the name · If polyatomic anion, root of the element use name of anion name · If polyatomic anion, (see Table 2.3) use name of anion

(see Table 2.3)

Organic Chemistry

Organic chemistry is the branch of chemistry that deals with carbon compounds.

Organic compounds are comprised of: Carbon & hydrogen

May also contain: O, S, N, P, etc..

The first four hydrocarbons: methane CH_4 ethane C_2H_6 propane C_3H_8 butane C_4H_{10}

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Table 2.8	The First Ten St	raight-Chain Alkanes
Name	Formula	Molecular Model
Methane	CH4	×
Ethane	C_2H_6	
Propane	C ₃ H ₈	°e [®] e°
Butane	$C_4 H_{10}$	؞ڡٚۄڡٚۄ [؞]
Pentane	C3H13	، و فو فو م د
Hexane	C ₆ H ₁₄	ి కి కి కి కి కి
Heptane	$C_7 H_{\rm M}$	؞ ^ۿ ۄۿۄۿۄ؋
Octane	$\mathrm{C}_8\mathrm{H}_{18}$	`s ^s s ^s s ^s s ^s .
Nonanc	C ₉ H ₃₀	~9 ⁶ 9 ⁶ 9 ⁶ 9 ⁶ 9 ⁶ 9
Decane	$C_{10}H_{22}$	`**********

Elemental Gases

Elements that exist as gases at 25° C and 1 atmosphere

1A						Copyright C	McGraw-Hill 8	ducation. Perm	rission required	for reproductio	an or display.						8A
Н	2A	0										3A	4A	5A	6A	7A	He
Li	Be											В	С	N	о	F	Ne
Na	Mg	3B	4B	5B	6B	7B		— 8B —		1B	2B	Al	Si	Р	S	CI	Ar
к	Ca	Sc	Ti	v	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Мо	Te	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	I	Xe
Cs	Ba	La	Hf	Та	w	Re	Os	Ir	Pt	Au	Hg	ті	РЬ	Bi	Ро	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn		FI		Lv		

Common Gases

Table 5.1 Some Substances Found as Gases at 1 atm and 25°C Elements

H ₂ (molecular hydrogen)	N ₂ (molecular nitrogen)
0 ₂ (molecular oxygen)	0 ₃ (ozone)
F ₂ (molecular fluorine)	Cl ₂ (molecular chlorine)
He (helium)	Ne (neon)
Ar (argon)	Kr (krypton)
Xe (xenon)	Rn (radon)
Compounds	
HF (hydrogen fluoride)	HCI (hydrogen chloride)
HBr (hydrogen bromide)	HI (hydrogen iodide)
CO (carbon monoxide)	CO ₂ (carbon dioxide)
CH ₄ (methane)	C ₂ H ₂ (acetylene)
NH ₃ (ammonia)	N0 (nitric oxide)
NO ₂ (nitrogen dioxide)	N ₂ 0 (nitrous oxide)
SO ₂ (sulfur dioxide)	SF ₆ (sulfur hexafluoride)
H ₂ S (hydrogen sulfide)	HCN (hydrogen cyanide)*

Physical Characteristics of Gases

- Gases assume the volume and shape of their containers.
- Gases are the most compressible state of matter.
- Gases will mix evenly and completely when confined to the same container.
- Gases have much lower densities than liquids and solids.

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NO₂ gas

Pressure



Pressure (1)

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Ideal Gas Equation

$$PV = nRT$$

Standard Temperature and Pressure

The conditions 0 °C and 1 atm are called **standard temperature and pressure (STP).**

Experiments show that at STP, 1 mole of an ideal gas occupies 22.414 L.

$$PV = nRT$$
$$R = \frac{PV}{nT} = \frac{(1 \text{ atm})(22.414\text{L})}{(1 \text{ mol})(273.15 \text{ K})}$$

 $R = 0.082057 \,\mathrm{L} \cdot \mathrm{atm}/(\mathrm{mol} \cdot \mathrm{K})$



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The distribution of speeds for nitrogen gas molecules at three different temperatures

$$u_{\rm rms} = \sqrt{\frac{3RT}{\mathcal{M}}}$$

Distribution of Gas Speeds

The distribution of speeds of three different gases at the same temperature

