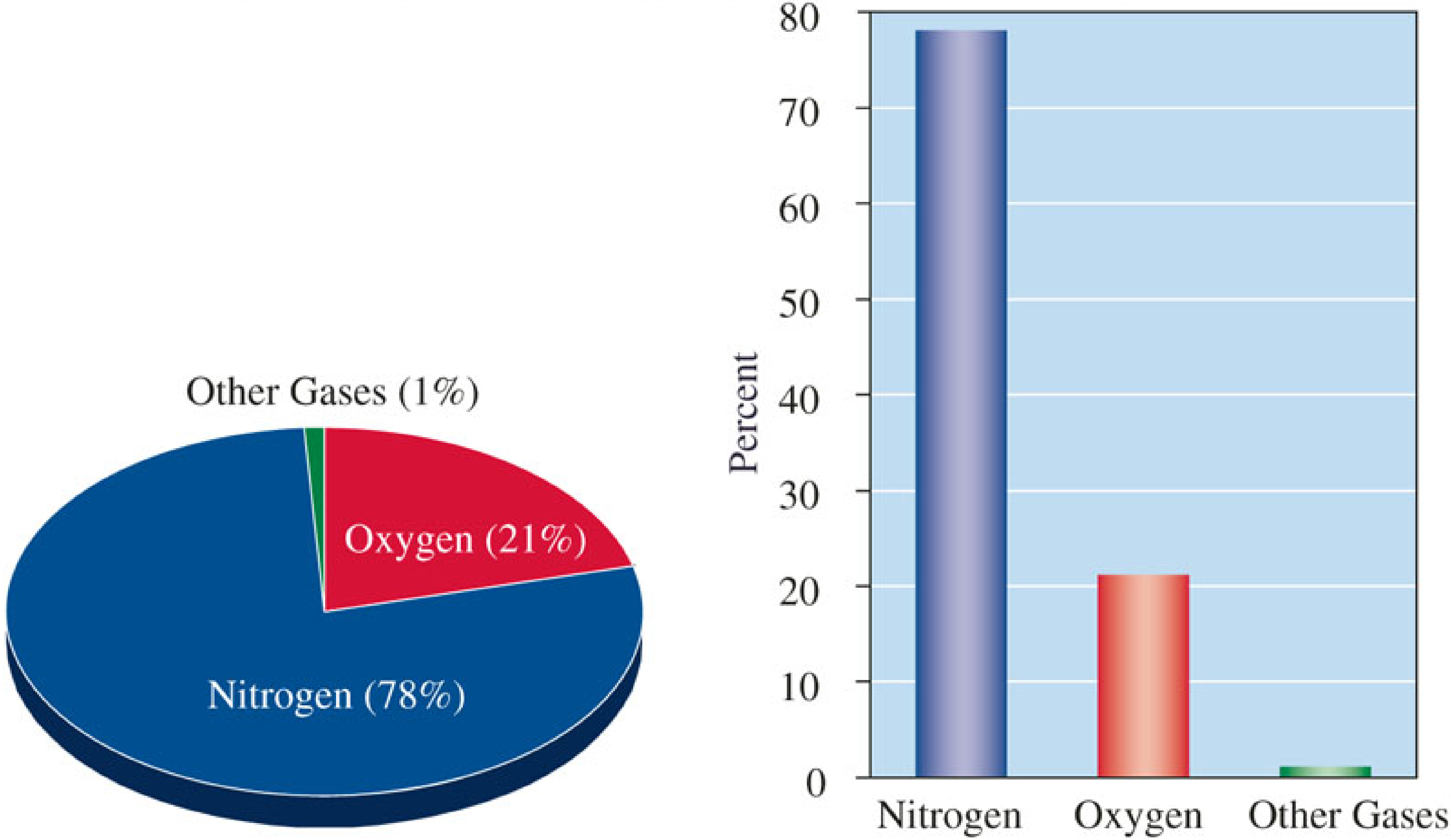
Chem L111

- How will L111 work?
- Every Tuesday, there will be a homework assignment due – you can’t do chemistry without problem solving
- Most Thursdays, there will be a short quiz – 15 minutes, multiple choice

Fig.01.04


Other Gases (1%)
Oxygen (21%)
Nitrogen (78%)
Percent
0
10
20
30
40
50
60
70
80
Nitrogen
Oxygen
Other Gases

Consider This - Solution

- Amount of air in one breath
  - $\sim$ 500 mL/breath
- Breaths per minute
  - $\sim$ 15 breaths/min
- Breaths per day

$$\frac{15 \text{ breaths}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{24 \text{ hr}}{1 \text{ day}} = \frac{21{,}600 \text{ breaths}}{1 \text{ day}}$$

- Amount we breathe per day

$$\frac{500 \text{ mL}}{1 \text{ breath}} \times \frac{21{,}600 \text{ breaths}}{1 \text{ day}} = \frac{10{,}800{,}000 \text{ mL}}{1 \text{ day}}$$

$$\frac{10{,}800{,}000 \text{ mL}}{1 \text{ day}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = \frac{10{,}800 \text{ L}}{1 \text{ day}} \approx 10{,}000 \, {}^{L}\!/_{day} = 10^4 \, {}^{L}\!/_{day}$$

Boston Air Quality

Brown Cloud Polluted Day
January 21, 1999

This is a typical "brown cloud" polluted day in Boston. Note how the brown cloud appears to envelop the city but quickly thins out at higher elevations. These events tend to occur on calm winter mornings during rush hour traffic. $PM_{2.5}$ and black carbon levels may be high; ozone will be low; RH may vary.

$PM_{2.5}$ = 40+ ug/m^3
RH = 69%

Risk Assessment

- Depends on two factors
  - **Toxicity** – the intrinsic health hazard of a substance
  - **Exposure** – the amount of the substance encountered

Table 1.5 National Ambient Air Quality Standards, 1999

Pollutant	Standard (ppm)	Approximate Equivalent Concentration of Standard ($\mu g/m^3$)
Carbon monoxide		
8-hr average	9	1×10^4
1-hr average	35	4×10^4
Nitrogen dioxide		
Annual average	0.053	100
Ozone		
1-hr average	0.12	235
8-hr average	0.08	157
Lead		
Quarterly average	…	1.5
Particulates*		
PM_{10}, 24-hr average	…	150
PM_{10}, annual average	…	50
$PM_{2.5}$, 24-hr average	…	65
$PM_{2.5}$, annual average	…	15
Sulfur dioxide		
Annual average	0.03	80
24-hr average	0.14	365
3-hr average	0.50	1300

… Data not available

* PM_{10} refers to airborne particles 10 μm in diameter or less, and $PM_{2.5}$ to those less than 2.5 μm. These two categories are monitored separately, and the standards for $PM_{2.5}$ are still controversial.

"Scientific notation" is used to represent numbers which are significantly larger or smaller than one, in order to eliminate the need to write a lot of zeroes.

In this table, the concentrations of CO are written in scientific notation:

$1 \times 10^4 = 10000$

$4 \times 10^4 = 40000$

SI Base Units

Name	Symbol	Unit of
meter	m	length
kilogram	kg	mass
second	s	time
kelvin	K	thermodynamic temperature
mole	mol	amount of substance

SI = Système Internationale

The Prefixes of the SI

exa	[E]	1 000 000 000 000 000 000	$= 10^{18}$	*(one quintillion)*
peta	[P]	1 000 000 000 000 000	$= 10^{15}$	*(one quadrillion)*
tera	[T]	1 000 000 000 000	$= 10^{12}$	*(one trillion)*
giga	[G]	1 000 000 000	$= 10^{9}$	*(one billion)*
mega	[M]	1 000 000	$= 10^{6}$	*(one million)*
kilo	[k]	1 000	$= 10^{3}$	*(one thousand)*
		1	$= 10^{0}$	*(one)*
milli	[m]	0.001	$= 10^{-3}$	*(one thousandth)*
micro	[μ]	0.000 001	$= 10^{-6}$	*(one millionth)*
nano	[n]	0.000 000 001	$= 10^{-9}$	*(one billionth)*
pico	[p]	0.000 000 000 001	$= 10^{-12}$	*(one trillionth)*
femto	[f]	0.000 000 000 000 001	$= 10^{-15}$	*(one quadrillionth)*
atto	[a]	0.000 000 000 000 000 001	$= 10^{-18}$	*(one quintillionth)*

Calculation

$$10{,}800 \text{ L air per day} \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 10.8 \text{ m}^3 \text{ air per day}$$

$$\text{PM}_{2.5} = \frac{40\mu\text{g}}{\text{m}^3}$$

$$10.8 \text{ m}^3 \text{ air per day} \times \frac{40\mu\text{g PM}_{2.5}}{\text{m}^3} = 432\ \mu\text{g PM}_{2.5} \text{ per day}$$

Is this safe?

Calculation

$$10{,}800 \text{ L air per day } \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 10.8 \text{ m}^3 \text{ air per day}$$

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During Rush Hour - duration of 2.5 hours -

so how much breathed in?

Calculation

$$10{,}800 \text{ L air per day} \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 10.8 \text{ m}^3 \text{ air per day}$$

$$PM_{2.5} = \frac{40\mu g}{m^3}$$

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During Rush Hour - duration of 2.5 hours -

so how much breathed in?

$$2.5 \text{ hours} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{432 \ \mu g \text{ PM}_{2.5}}{1 \text{ day}}$$

$$= 45 \ \mu g \text{ PM}_{2.5} \text{ breathed during 'rush hour'}$$

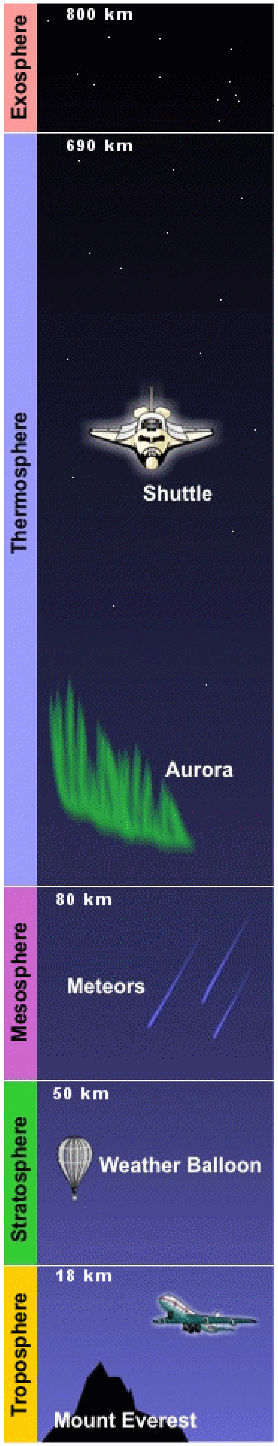
Is this safe?

Consider This - 1.12

A publication of the ACS, *Chemical Risk: A Primer*, states:

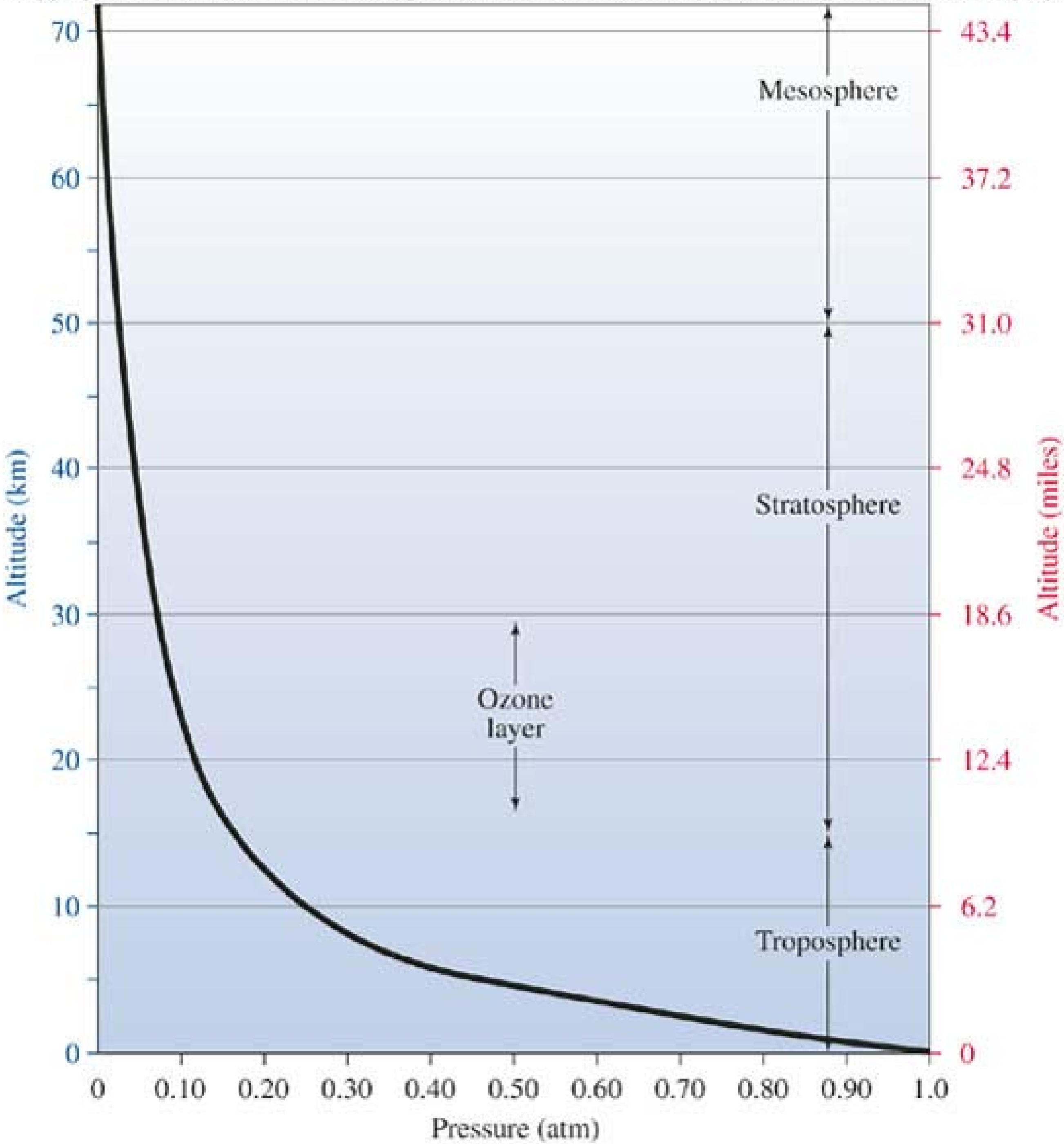
"The general public is uncomfortable with uncertainties. Too often we think in terms of absolutes and demand that the scientists and decision makers be held accountable for their risk decisions."

Do you agree or disagree with these statements?

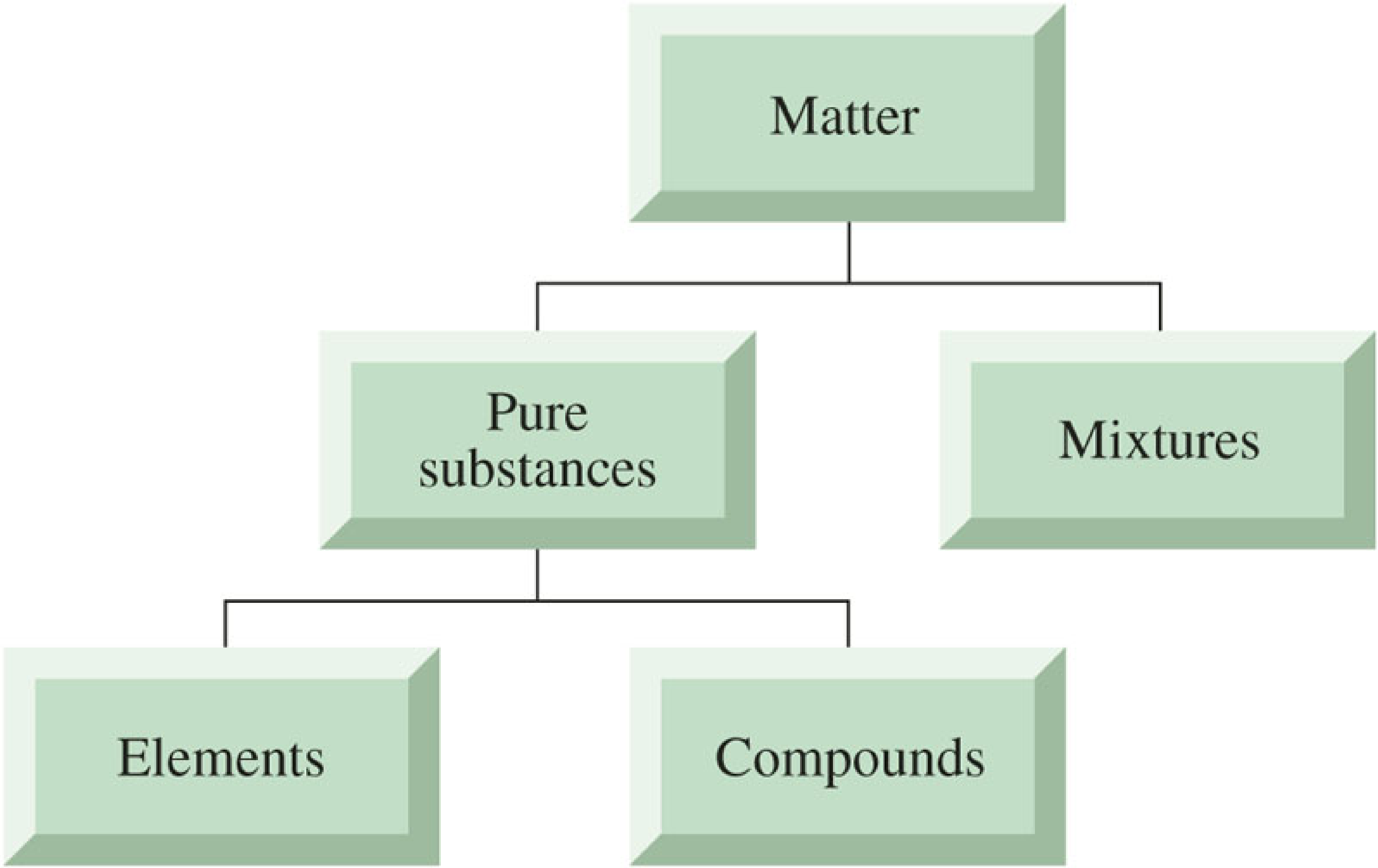


- **Exosphere**: above the ionosphere, where the atmosphere thins out into space.
- **Thermosphere**: from 80–85 km to 640+ km, temperature increasing with height.
  - **Ionosphere**: the region containing ions: approximately the mesosphere and thermosphere up to 550 km.
- **Mesopause**: Boundary
- **Mesosphere**: from about 50 km to the range of 80 km to 85 km, temperature decreasing with height.
- **Stratopause**: Boundary
- **Stratosphere**: from that 7–17 km range to about 50 km, temperature increasing with height.
  - **Ozone Layer**: approximately 10 - 50 km, where stratospheric ozone is found. Note that even within this region, ozone is a minor constituent by volume
- **Tropopause**: Boundary
- **Troposphere**: The troposphere is the lowest layer of the atmosphere starting at the surface going up to between 7 km at the poles and 17 km at the equator with some variation due to weather factors. In the troposphere, on average, temperature decreases with height due to expansive cooling.

http://en.wikipedia.org/wiki/Earth's_atmosphere
Layers of Atmosphere leading to space. (NOAA) from U.S. National Weather Service (NOAA)



70
60
50
40
30
20
10
0
Altitude (km)
43.4
37.2
31.0
24.8
18.6
12.4
6.2
0
Altitude (miles)
Mesosphere
Stratosphere
Ozone layer
Troposphere
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.0
Pressure (atm)


Matter
Pure substances
Mixtures
Elements
Compounds

- Matter - commonly referred to as the substance of which physical objects are composed
  - Mixtures (the atmosphere)
  - Pure Substances
- Elements – substances that cannot be broken down into simpler ones by any chemical means
- Chemical symbols – one- or two-letter abbreviations for the elements
- Periodic Table – an orderly arrangement of all the elements base on similarities of their properties

24 **Cr** 52.00	
24	Atomic number
52.00	Atomic mass

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	2 **He** 4.003
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
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
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
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
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** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)	110 **Ds** (271)	111	112	113	114	115	(116)	(117)	(118)

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
90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	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** (262)

Metals

Metalloids

Nonmetals

The 1–18 group designation has been recommended by the International Union of Pure and Applied Chemistry (IUPAC) but is not yet in wide use. In this text we use the standard U.S. notation for group numbers (1A–8A and 1B–8B). No names have been assigned for elements 111–115. Elements 116–118 have not yet been synthesized.

- Horizontal Columns – Periods
- Vertical Columns – Groups
  - Alkali Metals
  - Alkaline Earth Metals
  - Halogens
  - Noble gases – inert
- Metals – elements that are shiny and conduct electricity and heat well
- Nonmetals – elements that have varied appearances and don’t conduct well

Pure Substances

- Elements – pure substances made up of a single element
  - Only ~100 exist
- Compounds – pure substances made up of two or more elements in a fixed, characteristic chemical combination
  - Over 20 million compounds have been isolated, identified and characterized.

Your Turn 1.15

- Classifying Pure Substances
  - Using your everyday knowledge of materials, classify each of these as an element, a compound, or as a mixture.
    a. Rubbing Alcohol (Isopropanol)
    b. Copper
    c. U.S. penny coin
    d. 14kt gold
    e. Nitrogen dioxide
    f. Shampoo

Atoms and Molecules

- An **atom** (Greek from *non* and *divisible*) is a submicroscopic structure found in all ordinary matter around us.
  - The word *atom* originally meant a smallest possible particle of matter, not further divisible.
  - Later, those objects to which the name atom had been assigned were found to be further divisible into smaller subatomic particles, but the word atom nonetheless continues to refer to them.
  - Atoms are canonically distinguished from ions by their balanced electrical charge. When this charge is disrupted, the particle is then considered to be an atomic ion rather than an atom.
- Most atoms are composed of 3 types of massive subatomic particles which govern their external properties:
  - electrons, which have a negative charge;
  - protons, which have a positive charge; and
  - neutrons, which have no charge.

- Pure elements have all the same kind of atom.
  - Pure elements can also be made up of molecules.
  - Ar (g), Fe (s), Hg (l), N_2 (g)
  - N_2 (g), O_2 (g), and H_2 (g) are examples of elements made up of diatomic molecules.
- Pure compounds have different kinds of atoms, but all the same kind of molecules.
  - Molecule – a combination of a fixed number of atoms held together in a certain spatial arrangement.
  - Chemical formula – a symbolic way to represent the elementary composition of a substance
  - H_2O, CH_4, NO_2, CO_2, CO

Your Turn 1.16

- Elements and Compounds
  - Name the element(s) present in each of these substances. Identify each substance as an element or a compound.
    a. Water, H_2O
    b. Methane, CH_4
    c. Iodine, I_2
    d. Nitrogen dioxide, NO_2
    e. Glucose, $C_6H_{12}O_6$
    f. Methyl bromide, CH_3Br

Most Prominent Gases in the Air

Name	Chemical Formula	Element or Compound	Atom or Molecule
Nitrogen	N_2		
Oxygen	O_2		
Argon	Ar		
Water	H_2O		
Carbon Dioxide	CO_2		
Methane	CH_4		
Krypton	Kr		

Naming Binary Compounds

- The name of the more metallic element comes first, followed by the name of the less metallic element, modified to end in the suffix “ide”.
- Example: sodium and chlorine combine to give the common compound
  - sodium chloride or NaCl or table salt.

Your Turn 1.17

- Naming Simple Compounds
  - Name the compound that contains each pair of elements.
    a. Chlorine and Calcium
    b. Oxygen and Magnesium
    c. Potassium and Iodine
    d. Hydrogen and Sulfur

Your Turn 1.18

- More Naming Exercises
  - Name the compound that has each of these formulas.
    a. AgCl
    b. Fe_2O_3
    c. NaH
    d. $CuCl_3$

Naming Compounds

Table 1.7 Prefixes Used in Naming Compounds

Prefix	Meaning	Prefix	Meaning
Mono	One	Hexa-	Six
Di- or Bi-	Two	Hepta-	Seven
Tri-	Three	Octa-	Eight
Tetra-	Four	Nona-	Nine
Penta-	Five	Deca-	Ten

- CO: carbon monoxide
- CO_2: carbon dioxide
- NO_2: nitrogen dioxide
- N_2O_4: dinitrogen tetraoxide
- NO:
- SO_2:

Chemical Reactions

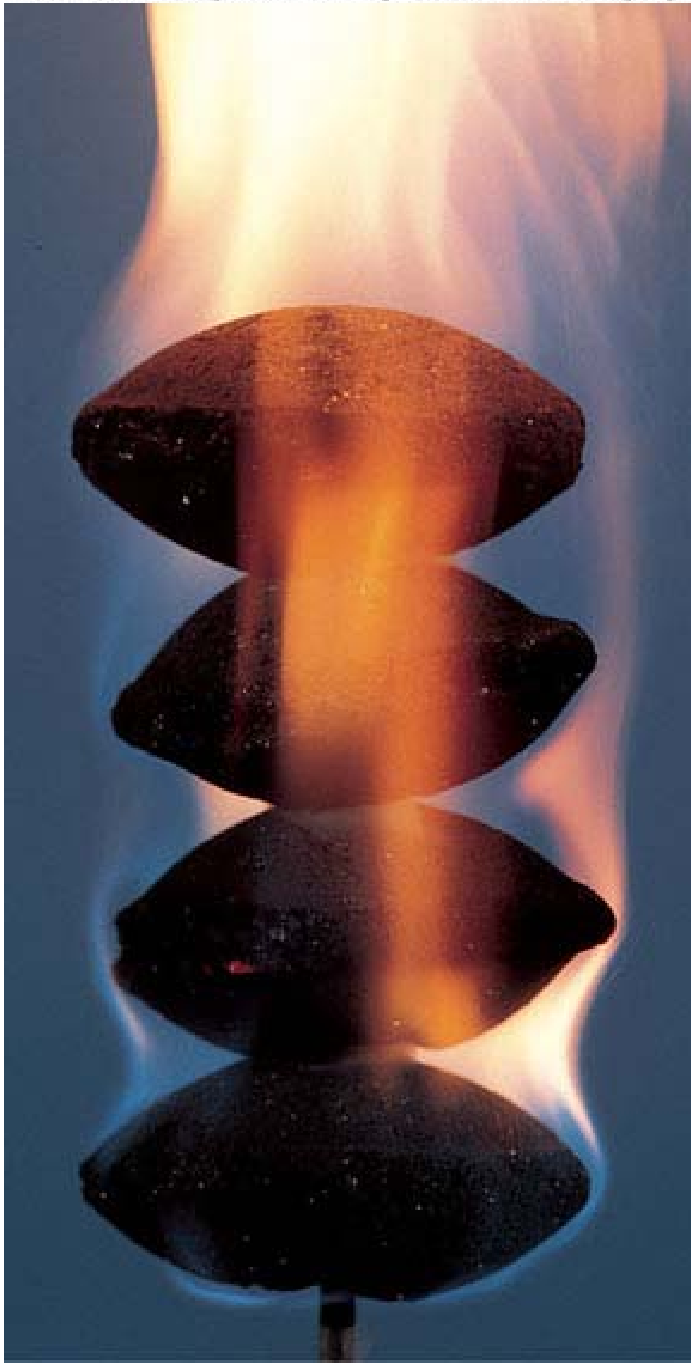
- A process whereby substances described as *reactants* are transformed into different substances called *products*.

  Reactant(s) → Product(s)

  carbon + oxygen → carbon dioxide

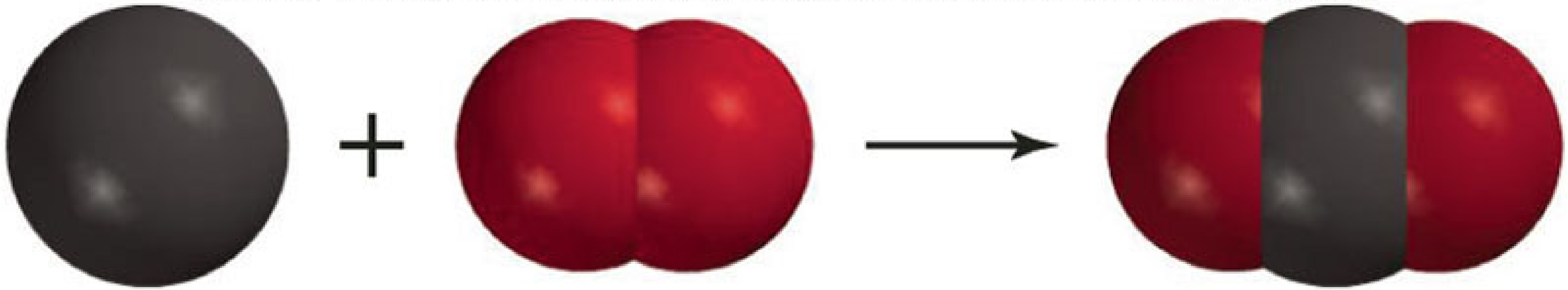
- Represented by a **chemical equation** which uses the chemical formulas of the reactants and products.

  $C + O_2 \rightarrow CO_2$



Combustion

- The rapid combination of oxygen with a substance.
- A major type of chemical reaction.
- When elemental carbon or carbon-containing compounds burn in air, oxygen combines with the carbon to form CO_2 or CO (or both).



$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$

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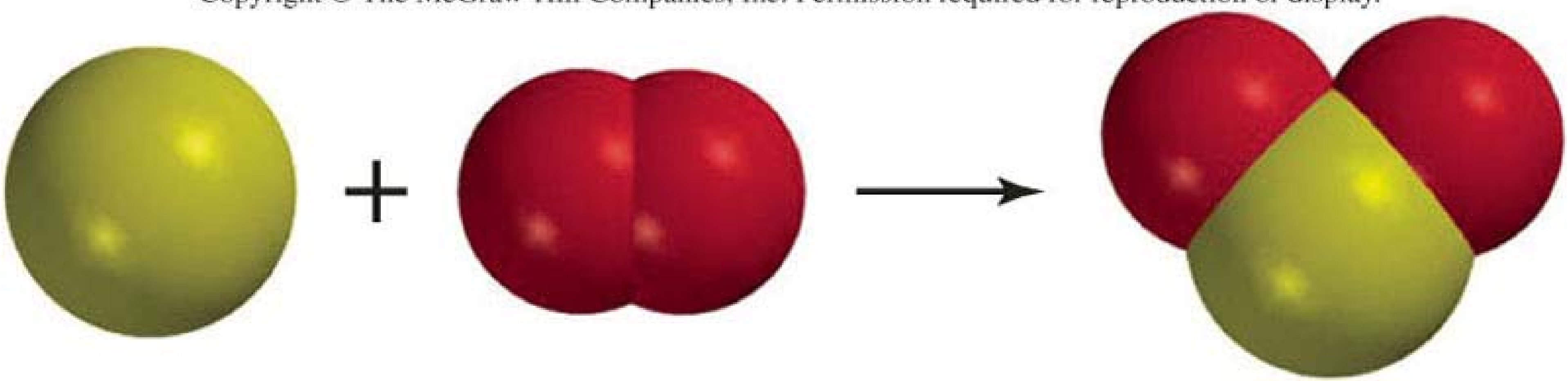


$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$

The **law of conservation of mass and matter** states that the mass of a system of substances is constant, regardless of the processes acting inside the system.

An equivalent statement is that matter changes form, but cannot be created or destroyed.

This implies that for any chemical process in a closed system, the mass of the reactants must equal the mass of the products.

Tbl.01.08

Table 1.8 Characteristics of Chemical Equations

Always Conserved

Identity of atoms in reactants = Identity of atoms in products
Number of atoms in reactants = Number of atoms in products
Mass of all reactants = Mass of all products

May Change

Number of molecules in reactants may differ from number of molecules in products
Physical states (*s*, *l*, or *g*) of reactants may differ from physical states of products

Balancing Chemical Reactions

Carbon and oxygen combine to give carbon monoxide

Carbon = C (s)

Oxygen = O_2 (g)

Carbon Monoxide = CO (g)

C (s) + O_2 (g) → CO (g)

Is this reaction **Mass Balanced**?

Balancing Chemical Reactions

$$C\ (s) + O_2\ (g) \rightarrow CO\ (g)$$

Reactants : 1 atom of carbon and 2 atoms of oxygen

Products : 1 atom of carbon and 1 atom of oxygen

Where does the other oxygen atom go?

Balancing Chemical Reactions

$C\ (s) + O_2\ (g) \rightarrow 2\ CO\ (g)$

Reactants still : 1 atom of carbon and 2 atoms of oxygen

Now products : 2 atoms of carbon and 2 atoms of oxygen

Now the Oxygens match, but what about the Carbon?

Balancing Chemical Reactions

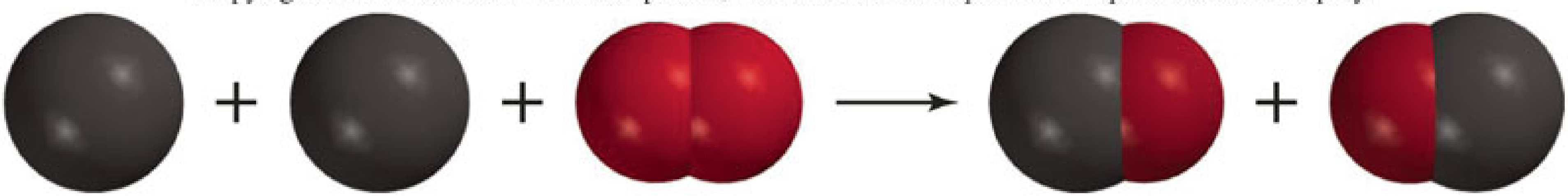
$2\ C\ (s) + O_2\ (g) \rightarrow 2\ CO\ (g)$

Now reactants : 2 atoms of carbon and 2 atoms of oxygen

Products : 2 atoms of carbon and 2 atoms of oxygen

Now the both the Oxygens and the Carbon match.

Fig.01.p035a



$$C + C + O_2 \rightarrow CO + CO$$