CHEM 103: Chemistry in Context

Unit 2.2

Energy:

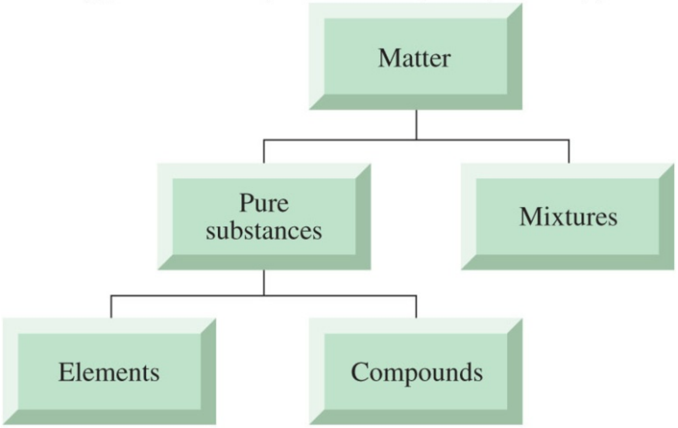
air pollution & water intro

Colorado State University

Unit 2.2 Plan

- reminder: air is a mixture
  - review periodic table, classification of matter
  - discuss pollutants
- what is the composition of air? need to get quantitative
  - review scientific notation and units
  - concentrations (especially %, ppm, ppb)
- where do the pollutants come from?
  - combustion: CO, CO_2, H_2O are the products
  - practice balancing equations
- linking our actions to pollution
  - example: tracking ozone in CA
- what to do about air pollution
  - Conservation
  - catalytic converters (go into more detail than the text provides)
- Water, unique compound
  - Hydrogen bonding
    - Specific heat
    - Boiling point elevation
    - Ice structure
  - Molecular solutions

Composition of Air



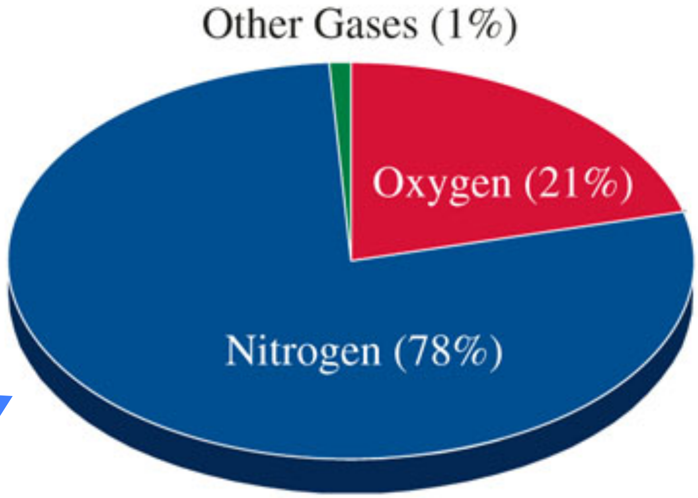
Matter

Pure substances

Mixtures

Elements

Compounds



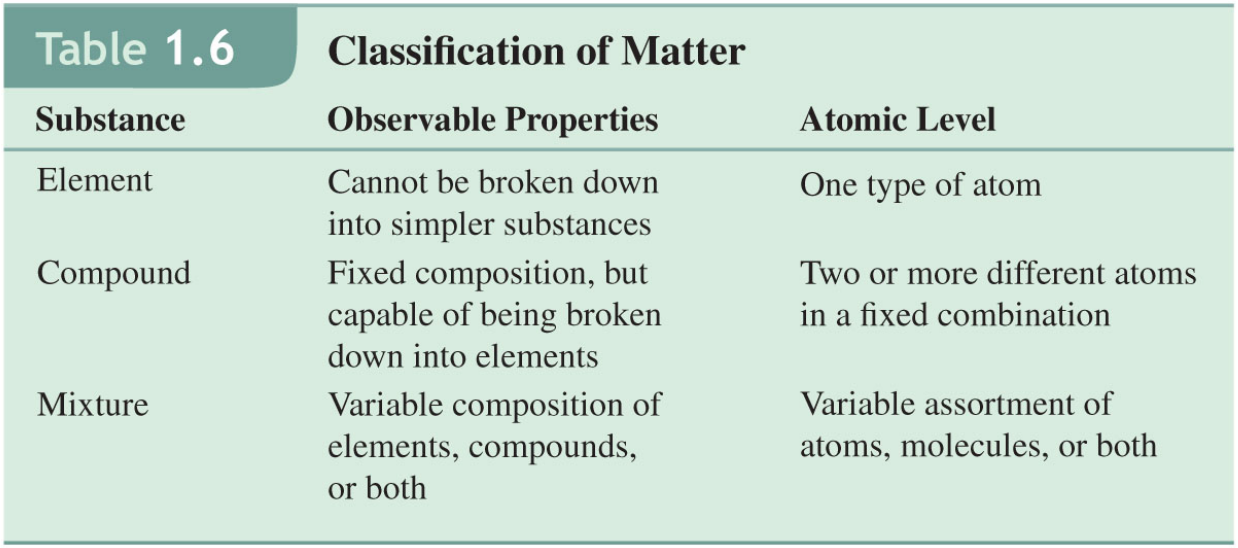


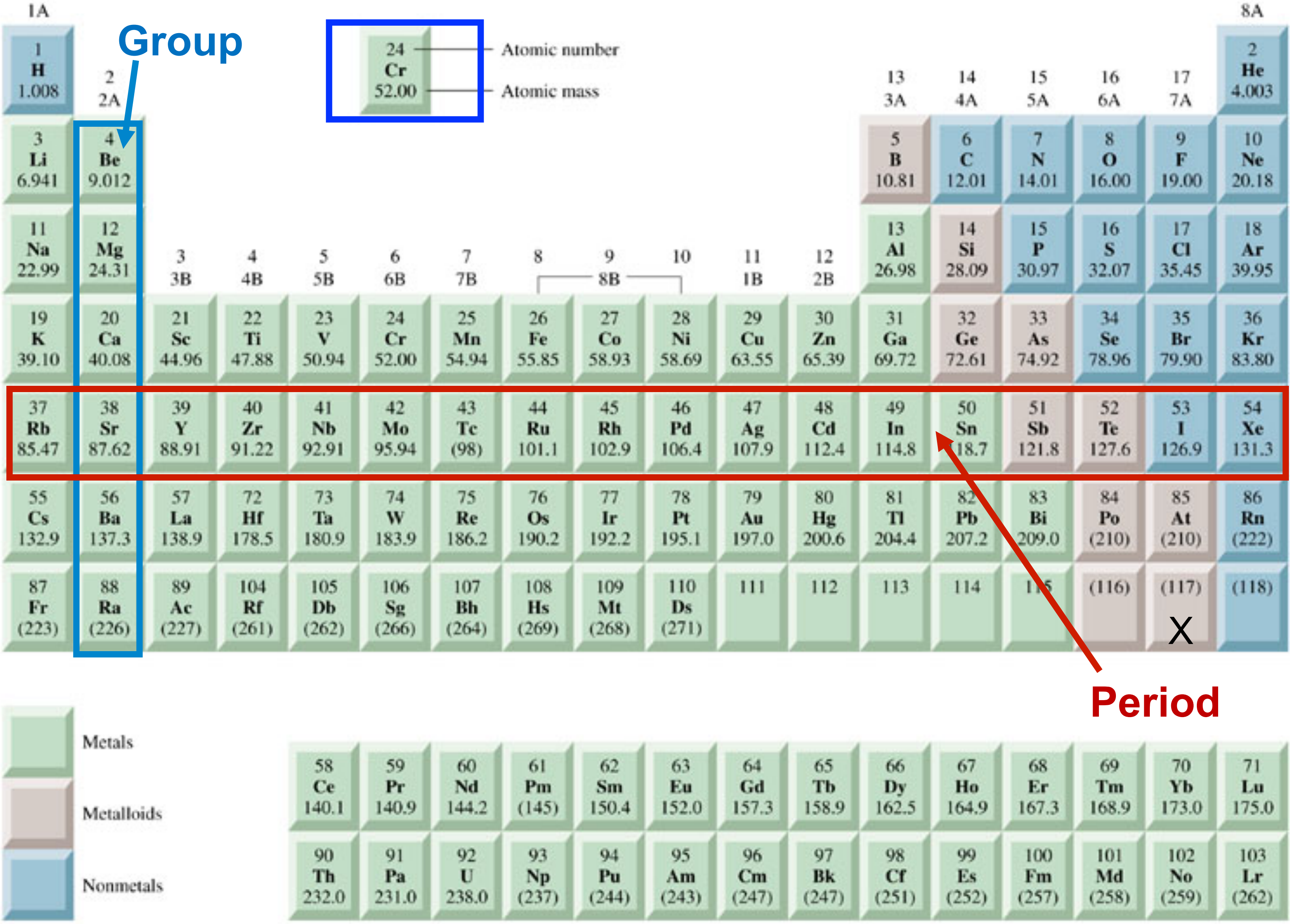
Table 1.6 **Classification of Matter**

Substance	Observable Properties	Atomic Level
Element	Cannot be broken down into simpler substances	One type of atom
Compound	Fixed composition, but capable of being broken down into elements	Two or more different atoms in a fixed combination
Mixture	Variable composition of elements, compounds, or both	Variable assortment of atoms, molecules, or both

Air is a <u>mixture</u> – a physical combination of two or more substances present in variable amounts.

note: % = percent = # of parts per 100 = pph

The Periodic Table



24
Cr
52.00

Atomic number
Atomic mass

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	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 Chemistry of Breathing

N_2 →

O_2

Ar →

CO_2

H_2O →

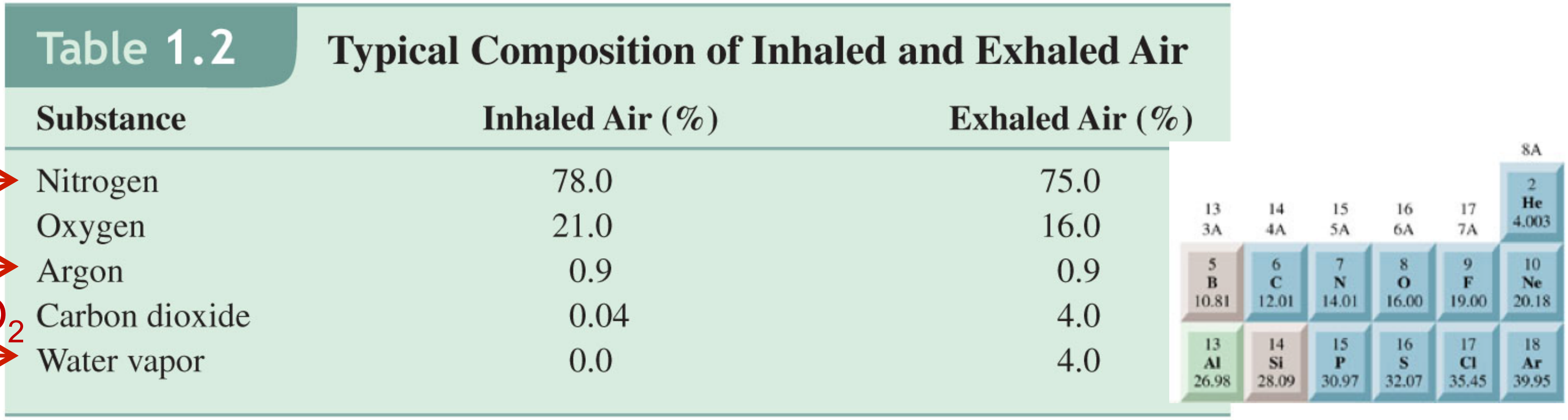


Table 1.2 Typical Composition of Inhaled and Exhaled Air

Substance	Inhaled Air (%)	Exhaled Air (%)
Nitrogen	78.0	75.0
Oxygen	21.0	16.0
Argon	0.9	0.9
Carbon dioxide	0.04	4.0
Water vapor	0.0	4.0

					8A
13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.003
5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95

- Oxygen is consumed ("burned" with food), forming carbon dioxide and water

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

- Most of the water doesn't come from oxygen consumption, but from evaporation from the surface of the lungs
- Nitrogen doesn't react, it's just diluted by the presence of carbon dioxide and "extra" water
- Argon doesn't react either: our one digit representation just doesn't properly show the dilution

Words take up a lot of space and can be confusing…to focus ourselves we'll use formulas (elements are our alphabet) and equations (chemical sentences) to describe what's happening.

Other Stuff in the Air

Carbon monoxide-disrupts delivery of oxygen

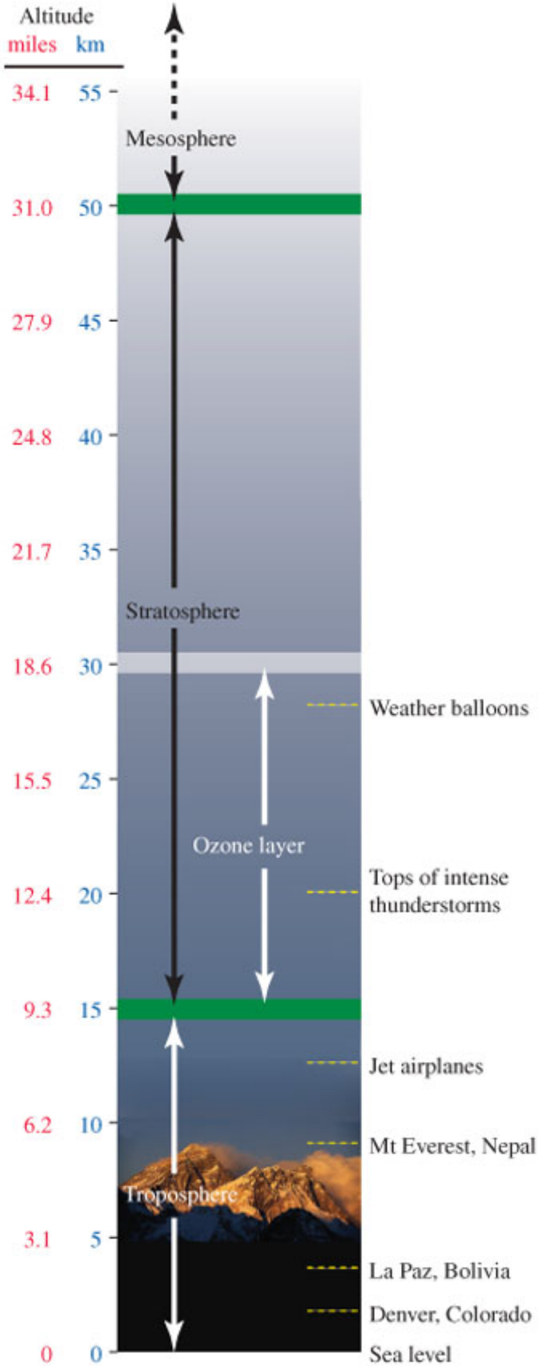
Nitrogen dioxide-respiratory irritant (reacts with lung tissue)

Sulfur dioxide-respiratory irritant (reacts with lung tissue)

Ozone-respiratory irritant (reacts with lung tissue) in troposphere…but essential for life in the stratosphere

PM_x-particulate matter
respiratory irritant
(reacts with lung tissue,
depending upon size)

note: CO, NO_2, SO_2, O_3 are all compounds with fixed chemical formulas; PM_x is not a compound because it has a variable composition



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Review of Scientific Notation and Units

(For further review, see Appendix 2)

number of students at CSU: ~28000 = 2.8×10^4

$PM_{2.5}$ is particulate matter with a diameter of 2.5 microns (µm) = 2.5×10^{-6} m

mass of a hungry mosquito is 1.021 mg = 1.021×10^{-3} g

number of yards in a mile = 1760 = 1.76×10^3

one atom of carbon has a mass of (weighs) 1.995×10^{-23} g

= 0.000,000,000,000,000,000,000,01995 g

an important big # is 602,200,000,000,000,000,000,000 = 6.022×10^{23}

(units Appendix 1)

m 10^{-3}
c 10^{-2}
k 10^{3}
m 10^{-3}
µ 10^{-6}
M 10^{6}

Note: same number of *significant figures* on both sides of each example.

%, ppm, scientific notation

% = parts per 100, but it is not always so convenient (preference for whole numbers)… (ratio x100)

ppm = parts per million (ratiox1,000,000 or 1x10^6)

Example: pre-industrial concentration of CO_2 in air = 0.015-0.028 %

ppm? $0.015\% \Rightarrow 0.00015 \Rightarrow 1.5\times10^{-4}$ $\quad 1.5\times10^{-4}\times1\times10^{6}=1.5\times10^{2} \Rightarrow 150\text{ ppm}$

The largest freshman class ever at Colorado State University has helped push enrollment to an all-time high of 26,735 students this fall.

Scientific notation? 2.6735×10^{4}

MilkyWay candy bar weighs 58.1 g & contains 11g fat. %? $\frac{11\text{ g}}{58.1\text{ g}}=0.1893287$

It contains 5 mg Cholesterol. ppm? $\Rightarrow 0.19\times10^{2}=19\%$

$$\frac{5\text{ mg}}{58.1\text{ g}}\times\frac{1\text{ g}}{1000\text{ mg}}=0.08606\times10^{-3}=9\times10^{-5}\times10^{6}=9\times10^{1}=90\text{ ppm}$$

More examples

186,000 scientific notation

0.00345 scientific notation

ppm?

%?

Other Stuff in the Air

What are the concentrations of these other things in the air? It’s time to get quantitative…

% = parts per 100, but it is not always so convenient (preference for whole numbers)…

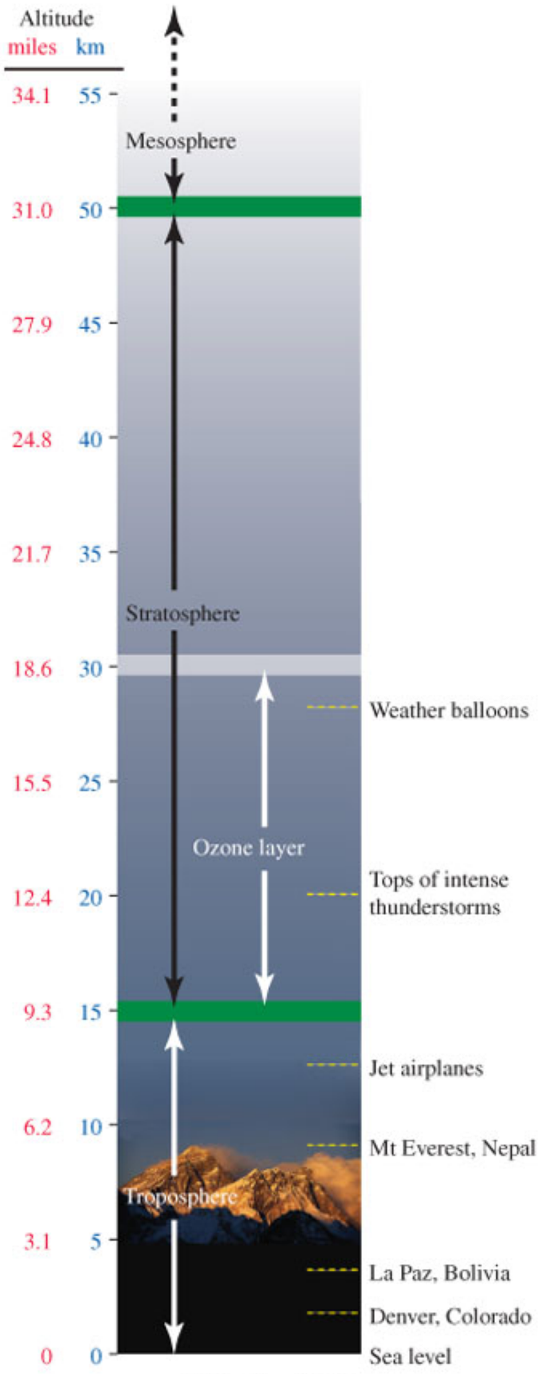
ppm = parts per million

Example: concentration of CO_2 in air = 0.0385 %

= 0.0385 parts per hundred
= 0.385 parts per thousand
= 3.85 parts per ten thousand
= 38.5 parts per hundred thousand
= 385 parts per million

A sample of air containing 1,000,000 molecules
Will contain 385 carbon dioxide molecules

Some things are present in parts per billion (ppb) concentrations…



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What’s Allowed in the Air?

- “Standard” represents a concentration based on # of equivalents
- “Approx. Eq. Conc.” accounts for the mass of the molecules
- Concentrations that are considered to be safe for the general population
- For comparison
  - O_2: 21% of air = 210,000 ppm
  - N_2: 78% of air = 780,000 ppm
- The standards vary quite a bit—why?

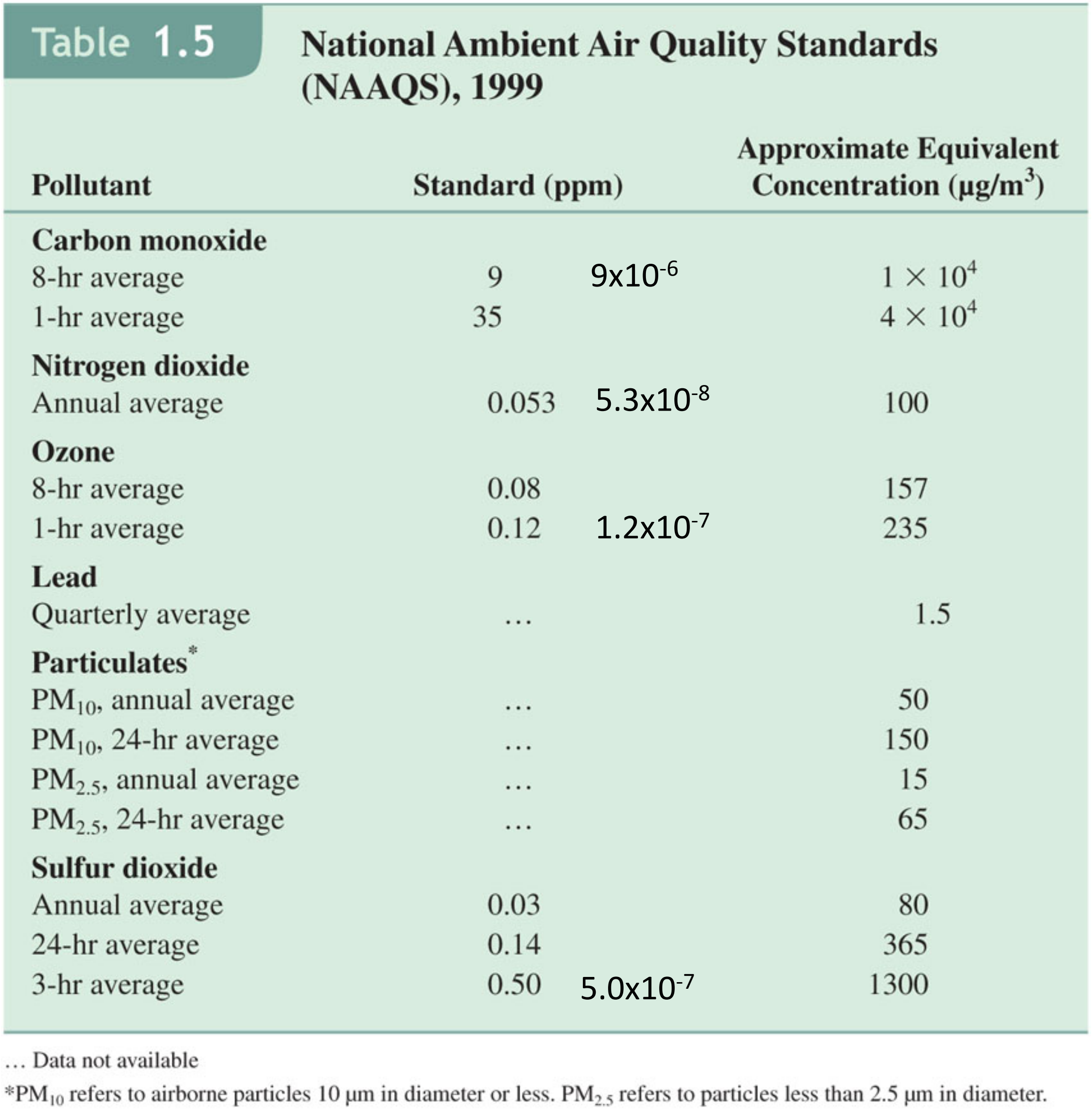

Table 1.5 National Ambient Air Quality Standards (NAAQS), 1999

Pollutant	Standard (ppm)		Approximate Equivalent Concentration (μg/m^3)
Carbon monoxide			
8-hr average	9	$9\text{x}10^{-6}$	1×10^4
1-hr average	35		4×10^4
Nitrogen dioxide			
Annual average	0.053	$5.3\text{x}10^{-8}$	100
Ozone			
8-hr average	0.08		157
1-hr average	0.12	$1.2\text{x}10^{-7}$	235
Lead			
Quarterly average	…		1.5
Particulates*			
PM_{10}, annual average	…		50
PM_{10}, 24-hr average	…		150
$PM_{2.5}$, annual average	…		15
$PM_{2.5}$, 24-hr average	…		65
Sulfur dioxide			
Annual average	0.03		80
24-hr average	0.14		365
3-hr average	0.50	$5.0\text{x}10^{-7}$	1300

… Data not available

*PM_{10} refers to airborne particles 10 μm in diameter or less. $PM_{2.5}$ refers to particles less than 2.5 μm in diameter.

Risk Assessment

Risk Assessment – evaluating scientific data and making predictions in an organized manner about the *probabilities* of an occurrence.

Toxicity – intrinsic health hazard of a substance.

Exposure – the amount of the substance encountered.

Example: carbon monoxide exposure and toxicity