CHE 102: Chemistry in Context

Amanda Nienow

Spring 2009

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Today: Feb 10, 2009

- Introductions
- Syllabus
  - Class website and other on-line resources
  - Course Goals
  - Activities for Participation Points
- Group Activity – Env Issues and Chemistry
- Chapter 1: The Air We Breathe

Group Activity

- Class – come up with a list of environmental issues
- Work in groups of 3-4
- List how chemistry is related to your environmental issue or why it might be important in solving the problem…

Key Environmental Topics

- Global Warming
    - Sea level
    - Extinction
    - Natural Disasters
- Natural Disasters
- Energy
    - Nuclear
    - Oil
    - Wind Turbine
    - E85
    - Hybrid
    - Diesel
    - Biomass/Switch Grass
    - Solar/Fuel Cells
- Forest Fires
- Deforestation
- Desertification
- Water Pollution
- Recycling
    - Landfills
    - Packaging
    - Plastics
    - Biodegradable Materials
- Biological/Chemical Warfare
- Acid rain
- Particulate Matter
- Toxic Gases
- North Atlantic Conveyor
- Disease
    - Bird Flu
    - Trees: Dutch Elm
    - Superbugs
- Drug-resistance
- Sewage
- Water
    - Hg
- Oil spills
- Winter Road Maintenance
- Agriculture
    - Organic
    - Slash and burn
    - Pesticides
    - Soil Pollution
- Industrialization
    - 3rd World pollution
- Kyoto protocol
- Water shortage
- Transportation
    - Auto emissions
    - Hydrogen
- Ozone depletion
- Overpopulation
- Green Construction
- Bisphenol A
- Carbon Footprint
- Waste Management
- Non-native Species

Focus topics

- Energy
  - Fuels
  - Transportation
  - Alternative technology
- Global Climate Change
  - Data
  - Public policy
  - Economic impact
- Air
  - Acid rain
  - Mercury (Hg)
  - Ozone hole
- Water
  - Drinking water
  - Wastewater
  - Agriculture
- Human Activity
  - Population
  - Waste Control
  - Industrialization

- Select group of interest
- Gather with group members
- Select subtopic
- Think of pro-environment and “smokestack” orientation
- Scientific, quantitative, analytical

For Next Time (Thurs 2/12)

- Review/Print Class Slides
- Read Chapter 1
- Sign-Up for AQI updates for your chosen city
- Do “Consider This” 1.6 for Minneapolis area

For Next Tuesday (2/17)

- Prepare for Lab: Read “Some Notes About Laboratory Safety” and “Lab 1: What am I Breathing?” in Lab Manual

Chapter One

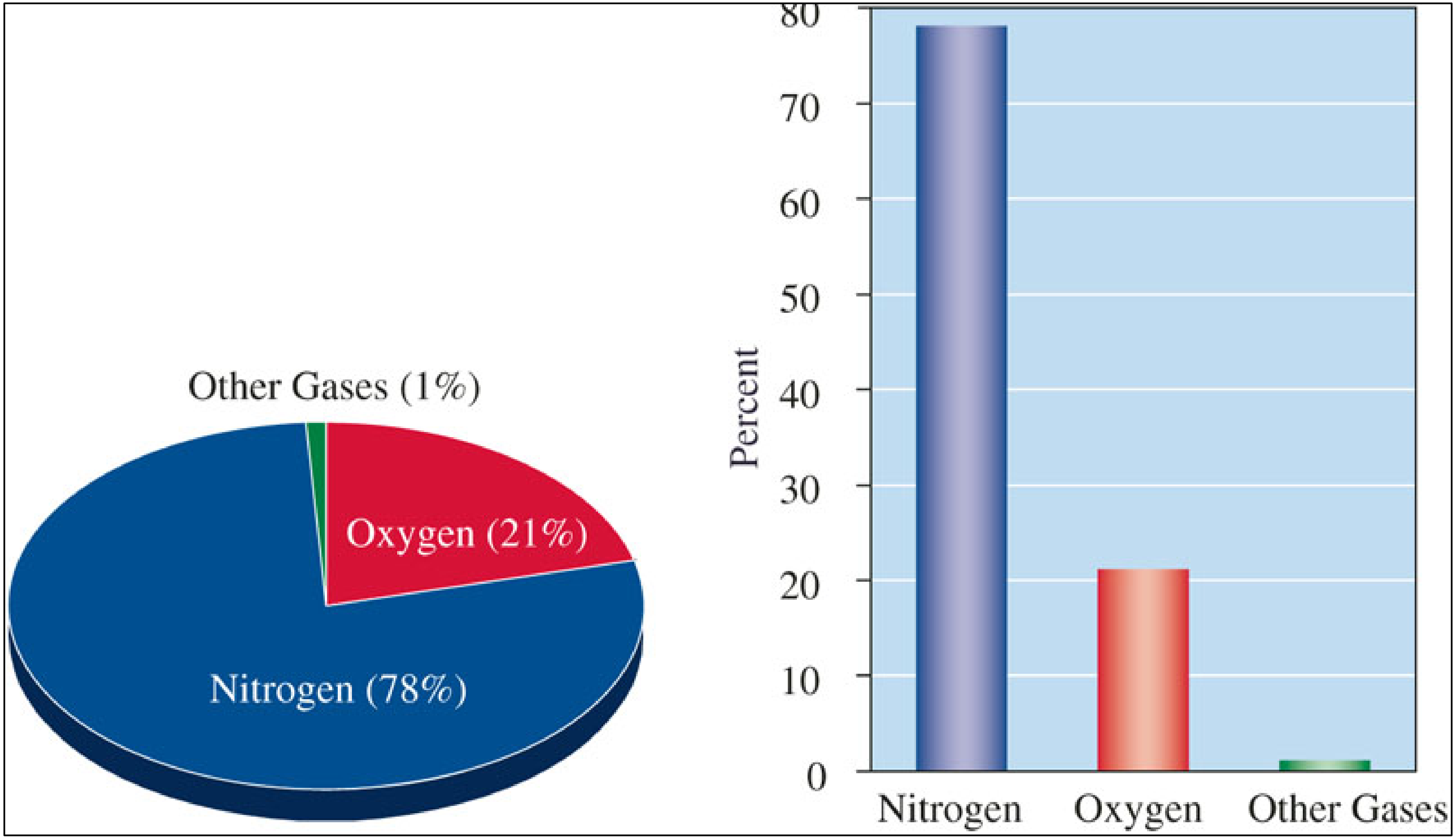
The Air We Breathe

What is in the air that we breathe?

Can air be dangerous to our health?

How can understanding *chemistry* help us decide?

The Composition of Our Air



It’s a <u>mixture</u> – a physical combination of two or more substances present in variable amounts.

What's in a Breath?

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	0.0	4.0

What about “other”?

- Argon (Ar) inert gas 0.9 %
- Carbon dioxide (CO_2) 0.04 %
- Neon (Ne) 0.0018% 18.2 parts per million
- Helium (He) 0.00052% 5.2 parts per million
- Krypton (Kr) 1.1 parts per million
- Sulfur dioxide (SO_2) 1.0 parts per million
- Methane (CH_4) 2.0 parts per million
- Hydrogen (H_2) 0.5 parts per million
- Nitrous Oxide (N_2O) 0.5 parts per million
- Xenon (Xe) 0.09 parts per million
- Ozone (O_3) 0.07 parts per million
- Nitrogen dioxide - NO_2 0.02 parts per million
- Iodine (I) 20.01 parts per million
- Carbon monoxide (CO) trace
- Radon (Rn) trace
- Ammonia (NH_3) trace
- Lead (Pb) trace

Criteria Pollutants

Criteria Air Pollutants vs Toxic Air Pollutants

Criteria Air Pollutants

- O_3, SO_2, NO_2, PM, lead, CO
- standards set by EPA
- steps must be taken in non-attainment areas
- nationwide monitoring

Air Toxics

- hazardous air pollutants
- not classified as “Criteria”
- respiratory and heart effects, cancer
- Emissions are tabulated (TRI)
- Permits for facilities to release air toxics
- Few ambient monitoring sites

Concentration Terms

Parts per hundred (percent)

Atmosphere is 21% oxygen = 21 oxygen molecules
per 100 molecules and atoms in air

Parts per million (ppm)

Midday ozone levels reach about 0.4 ppm =

$$\frac{\text{0.4 ozone molecules}}{1 \times 10^6 \text{ molecules and atoms in air}}$$

Parts per billion (ppb)

Sulfur dioxide in the air should not exceed 30 ppb =

$$\frac{\text{30 sulfur dioxide molecules}}{1 \times 10^9 \text{ molecules and atoms in air}}$$

21% means 21 parts per hundred

means 210 parts per thousand

means 2,100 parts per ten thousand

means 21,000 parts per hundred thousand

means 210,000 parts per million

The difference between pph and ppm is a factor of 10,000

Try Chapter 1 Figures Alive! for practice

Scientific Notation: A review

$11000 = 1.1 \times 10^4$

$0.00021 = 2.1 \times 10^{-4}$

$0.001021 = 1.021 \times 10^{-3}$

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

$1730 = 1.73 \times 10^3$

$6.022 \times 10^{-23} = 0.000,000,000,000,000,000,000,06022$

$602,200,000,000,000,000,000,000 = 6.022 \times 10^{23}$

The Bad Gases

- Carbon monoxide
- Ozone
- Sulfur oxides and nitrogen oxides
- Particulate matter, PM

We’ll take a closer look at each of these each in turn…

EPA’s Air Quality Index

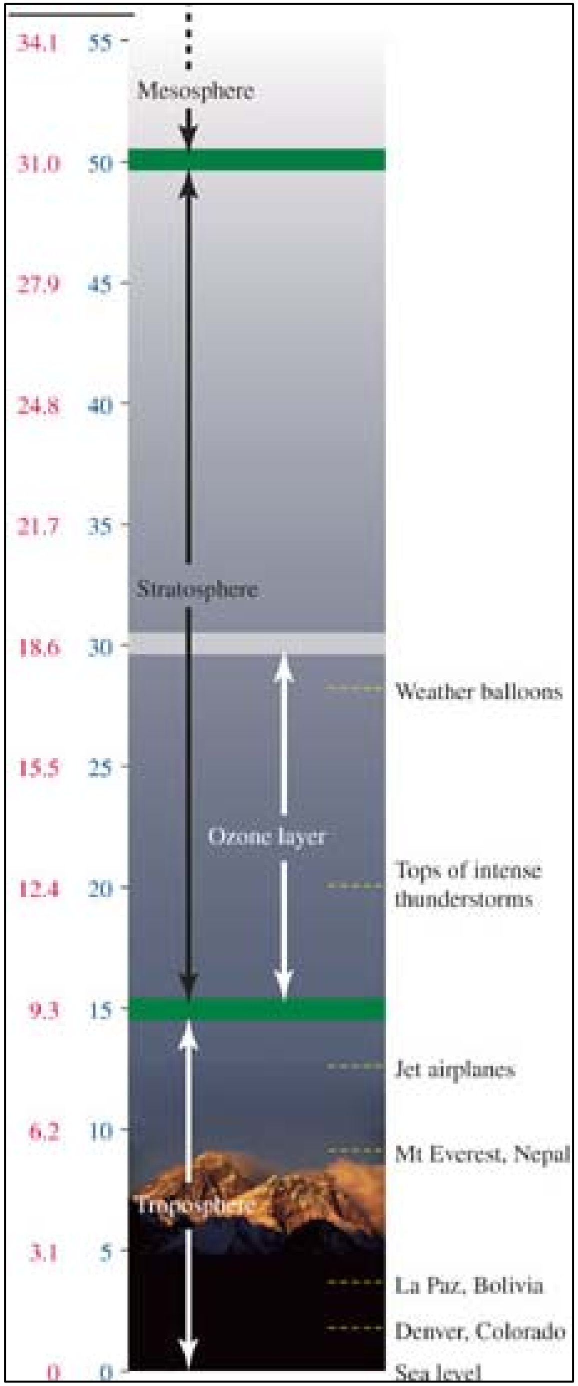
Air Quality Index (AQI) Values	**Levels of Health Concern**	**Colors**
When the AQI is in this range:	***...air quality conditions are:***	***...as symbolized by this color:***
0–50	Good	Green
51–100	Moderate	Yellow
101–150	Unhealthy for sensitive groups	Orange
151–200	Unhealthy	Red
201–300	Very unhealthy	Purple
301–500	Hazardous	Maroon

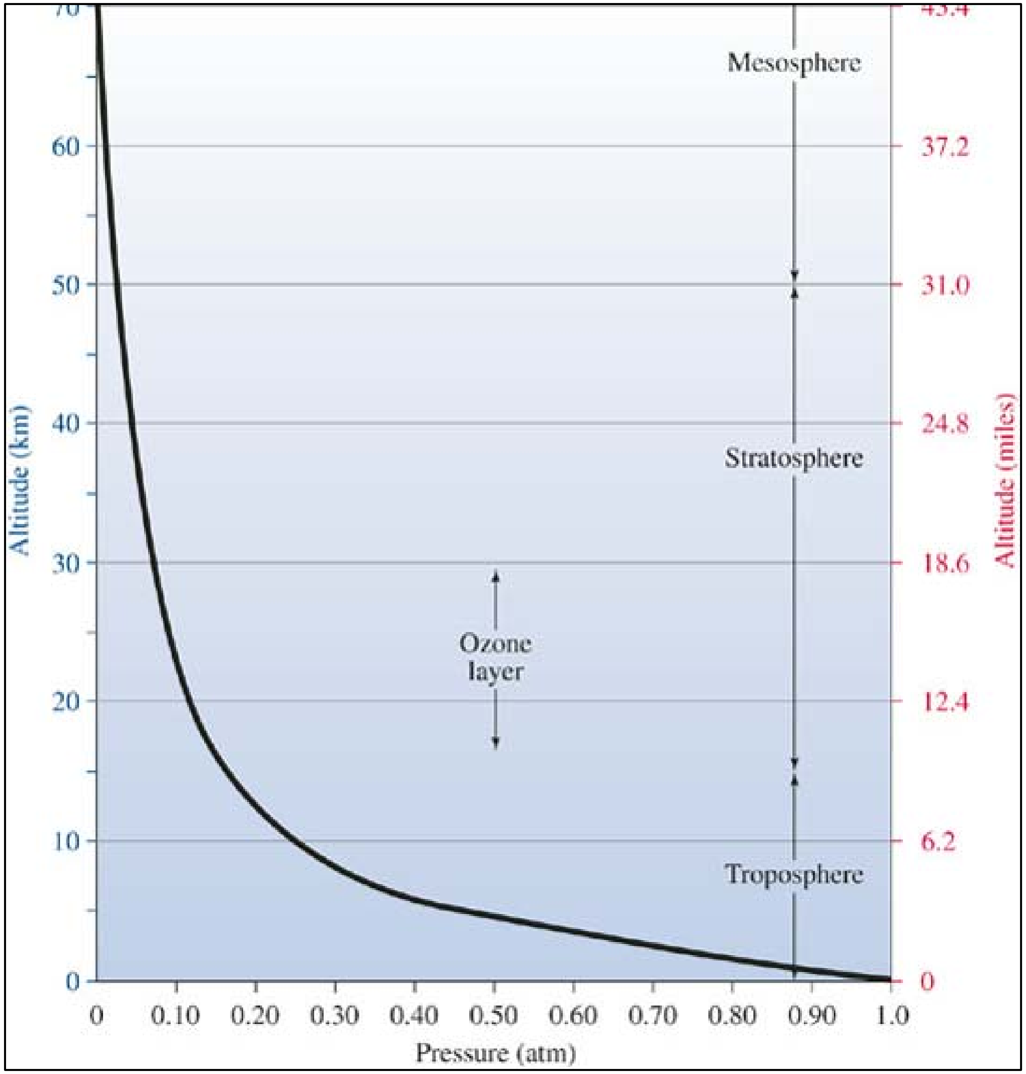
Table 1.4 Air Quality Index values for Houston

Year	Good (0–50)	Moderate (51–100)	Unhealthy for Sensitive Groups (101–150)	Unhealthy (>150)
1999	223	82	34	26
2000	166	147	37	16
2001	180	144	25	16
2003	196	136	24	9
2004	175	152	29	10
2005	138	180	39	7
2006	77	88	13	4

Variations reflect those in the local weather patterns. Regional events such as forest fires and volcanic eruptions can influence air quality.

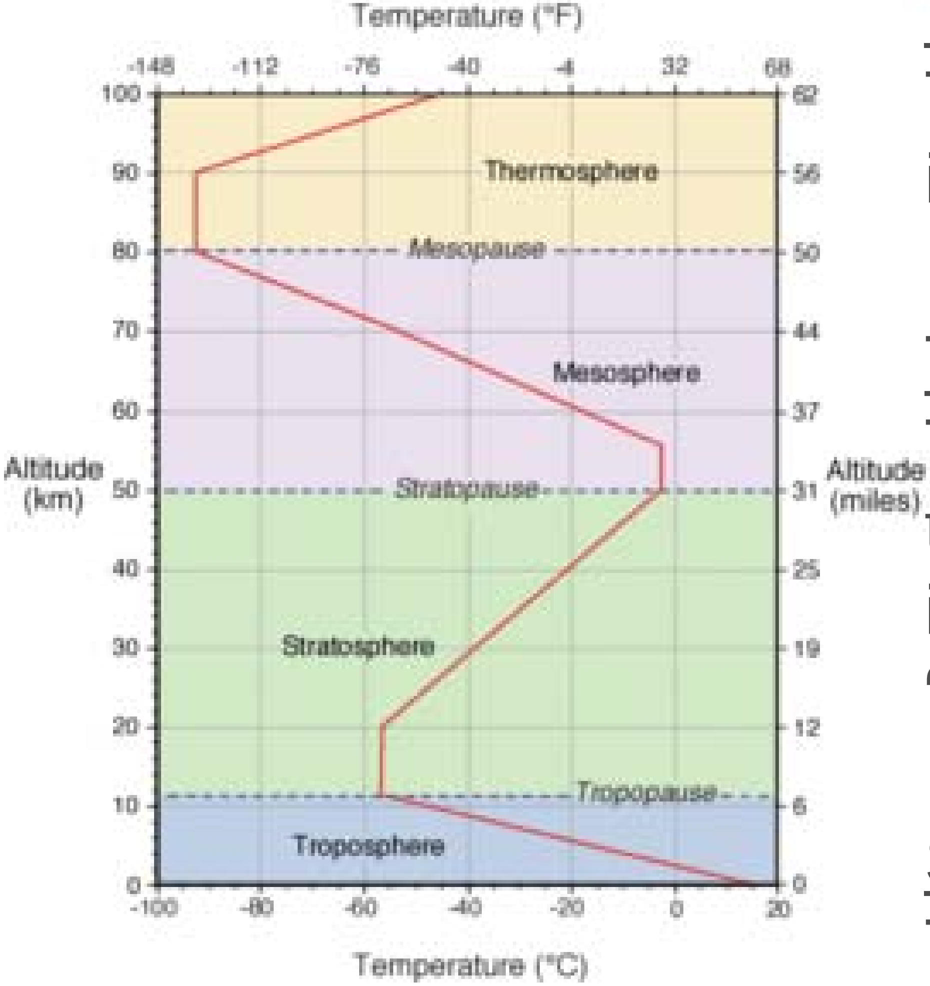
The Regions of the Lower Atmosphere





Atmospheric pressure changes with altitude

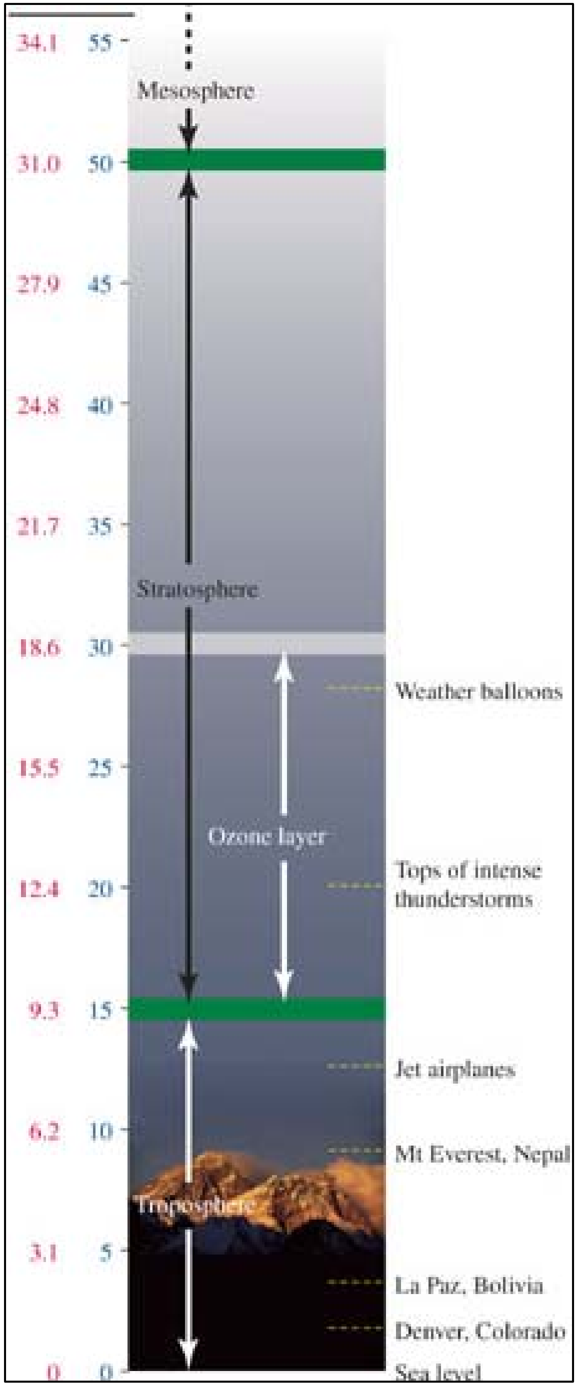
Temperature in the Atmosphere



Troposphere = where we live
Temperature decreases with increasing altitude

Temperature inversion
Temporarily, the temperature in the troposphere increases with increasing altitude… forms a "cap" so pollution can't escape

Stratosphere
Temperature increases with increasing altitude



The Regions of the Atmosphere

Have you ever been in a plane landing in Denver, CO?

You may have experienced being thrust forward as the plane uses more energy to stop. There are fewer air molecules at that height, reducing the amount of friction, so a greater amount of energy is needed to stop the plane.

Why does it take longer to cook an egg in Denver than it does in New Orleans?

There is less air pressure at higher altitudes. Water boils when the vapor pressure of the water molecules exceeds that of the localized air pressure. Because there is less air pressure at higher altitudes, more energy must be supplied (longer time) to get the temperature of the water high enough to cook the egg.

Today: Feb 12, 2009

- Projects: Meet with Focus Groups
- Chapter 1 Notes (Con’t)
- In-class Worksheet
- Further discussion/description of AQI monitoring
- Newspaper Presentation by Dr. Nienow
- Discussion of Lab

Key Environmental Topics

- Global Warming
    - Sea level
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•Select group of interest

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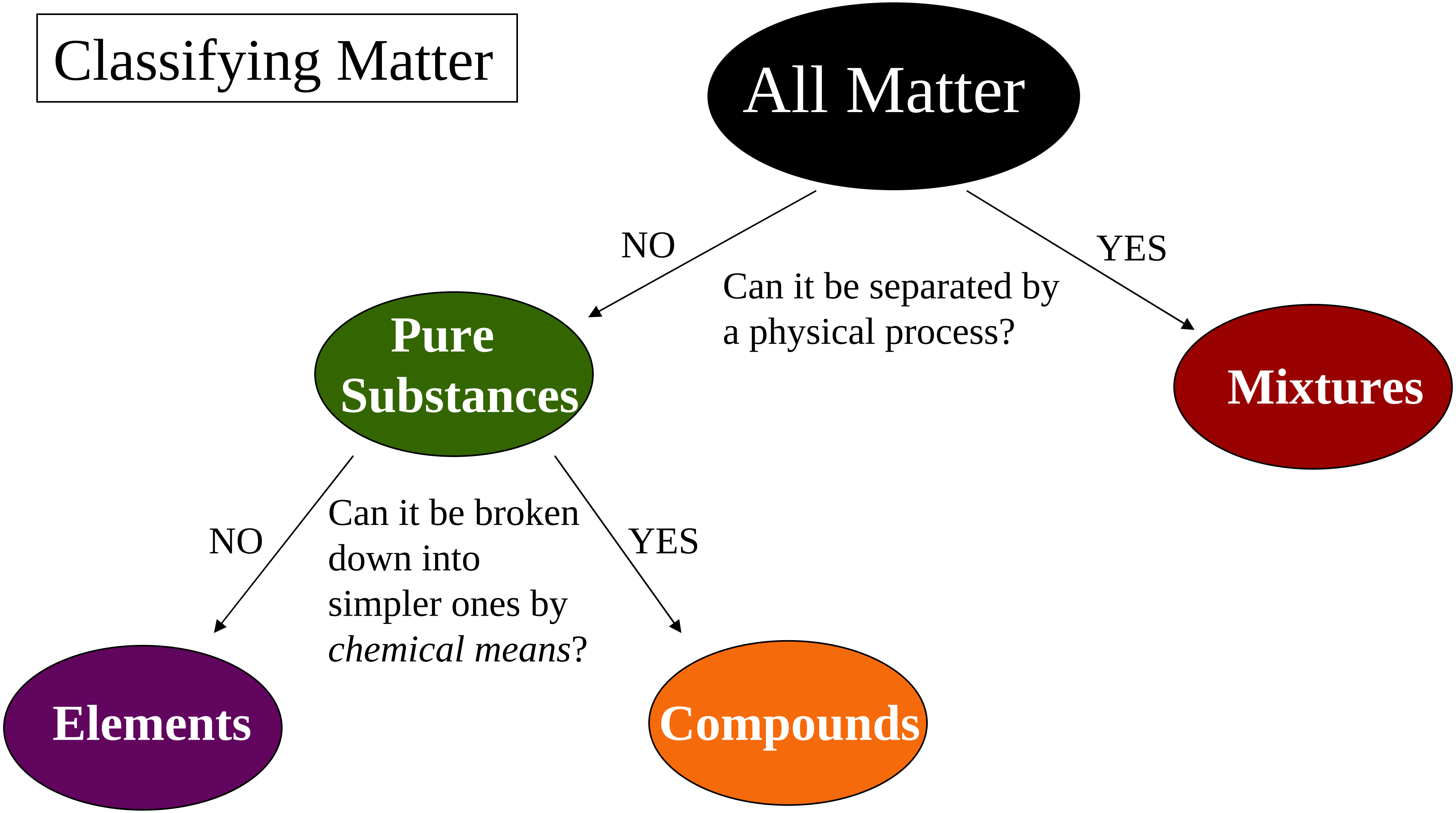
•Select subtopic

•Think of pro-environment and “smokestack” orientation

•Scientific, quantitative, analytical

Classifying Matter



All Matter

Can it be separated by a physical process?

NO

Pure Substances

YES

Mixtures

Can it be broken down into simpler ones by *chemical means*?

NO

Elements

YES

Compounds

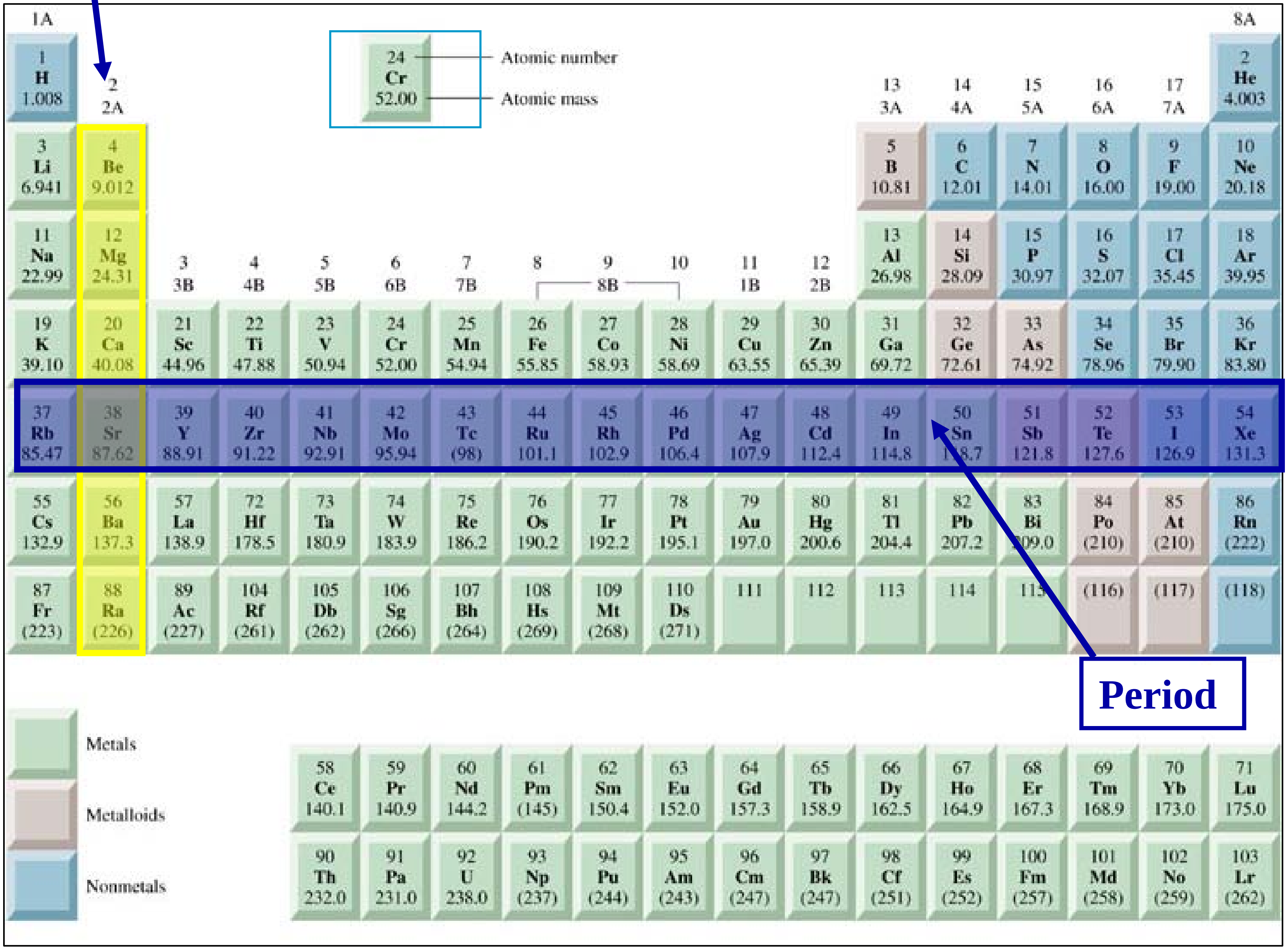
Classifying Matter

Classify each of these as an element, a compound, or a mixture:

carbon dioxide	**compound**
nickel	**element**
cocaine	**compound**
water	**compound**
fluorine	**element**
table salt	**compound**
soap	**mixture**
sea water	**mixture**

The Periodic Table

Group



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

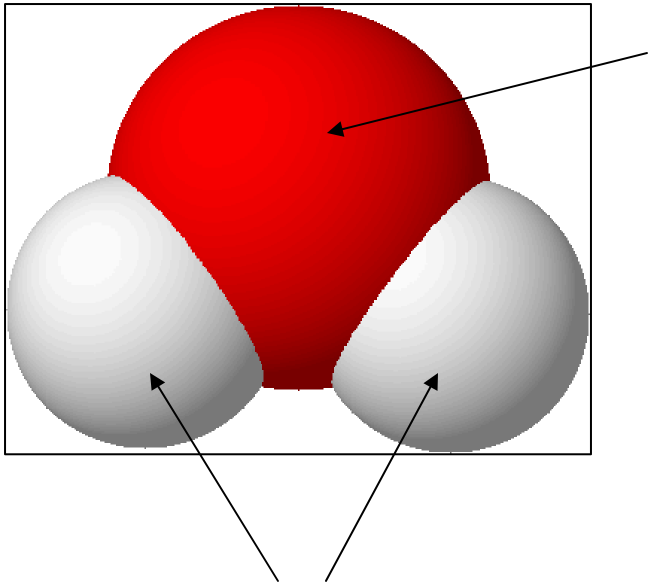
🟫 Metalloids

🟦 Nonmetals

Period

http://www.privatehand.com/flash/elements.html

A space filling model for a water molecule, H_2O

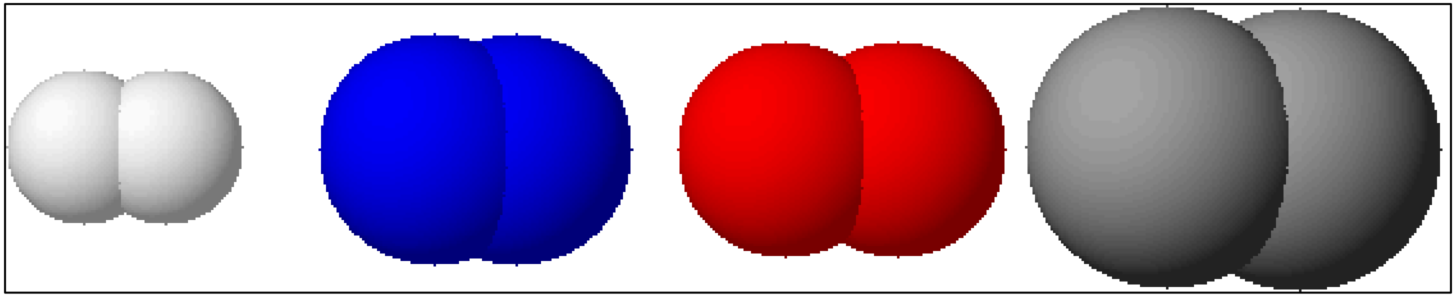


Two hydrogen atoms

A molecule is a fixed number of atoms held together by chemical bonds in a certain spatial arrangement.

The chemical formula symbolically represents the type and number of each element present.

Many nonmetals occur as diatomic (made up of two atoms) molecules.



H_2 N_2 O_2 Cl_2

Naming Binary Compounds

2. Prefixes are used to designate the number of each type of element:

number of atoms	prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

Naming Binary Compounds of Nonmetals

2. Prefixes are used to designate the number of each type of element:

N_2O = dinitrogen monoxide (laughing gas)

P_2O_5=diphosphorous pentoxide

Notice the dropped “a” from “penta” – when both the prefix and suffix (in this case “oxide”) end and start, respectively, in a vowel, the vowel of the prefix is typically dropped; pentoxide rather than pentaoxide.

Chemical reactions are characterized by the rearrangement of atoms when **reactants** are transformed into **products.**

$$C + O_2 \longrightarrow CO$$

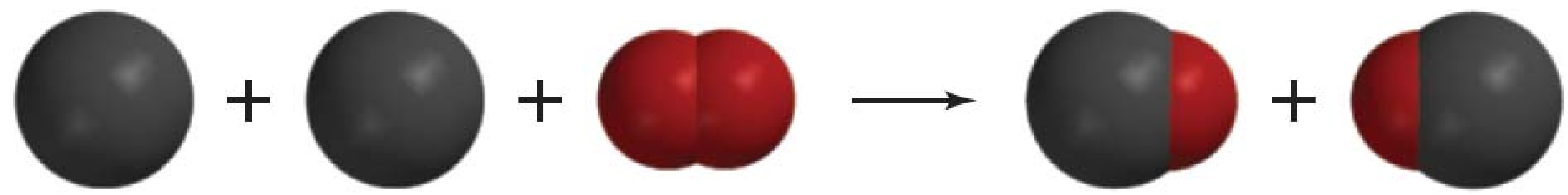
reactants **product**

This is an example of a **combustion reaction**

But the number of atoms on each side of the arrow must be equal (**Law of Conservation of Mass**).

$$\underbrace{2\,C + O_2}_{\substack{\text{2 carbon atoms}\\ \text{2 oxygen atoms}}} \longrightarrow \underbrace{2\,CO}_{\substack{\text{two carbon atoms}\\ \text{two oxygen atoms}}} \quad \text{(balanced)}$$

$$2\,C \quad + \quad O_2 \longrightarrow 2\,CO$$



Another look, pictorially – using space-filling models

Balancing equations:

-if an element is present in just one compound on each side, balance it *first*

-balance anything that exists as a free element *last*

-check when done – same number of atoms, and same total charge (if any) on both sides

$$\mathbf{C_3H_8 + O_2 \longrightarrow CO_2 + H_2O}$$

$$\boxed{\mathbf{C_3H_8 + 5\ O_2 \longrightarrow 3\ CO_2 + 4\ H_2O}}$$

3 C atoms	3 C atoms
8 H atoms	8 H atoms
10 O atoms	10 O atoms

Hydrocarbons

- Compounds of hydrogen and carbon
- Naming hydrocarbons: Mother Eats Peanut Butter

– Methane	1 Carbon
– Ethane	2 Carbons
– Propane	3 Carbons
– Butane	4 Carbons

Combustion Reactions

Reactions Unbalanced!

- Hydrocarbons combust in the presence of oxygen (and ignition source)

$CH_4 + O_2 \rightarrow CO_2 + H_2O$ Complete Combustion

$CH_4 + O_2 \rightarrow CO + H_2O$ Incomplete Combustion

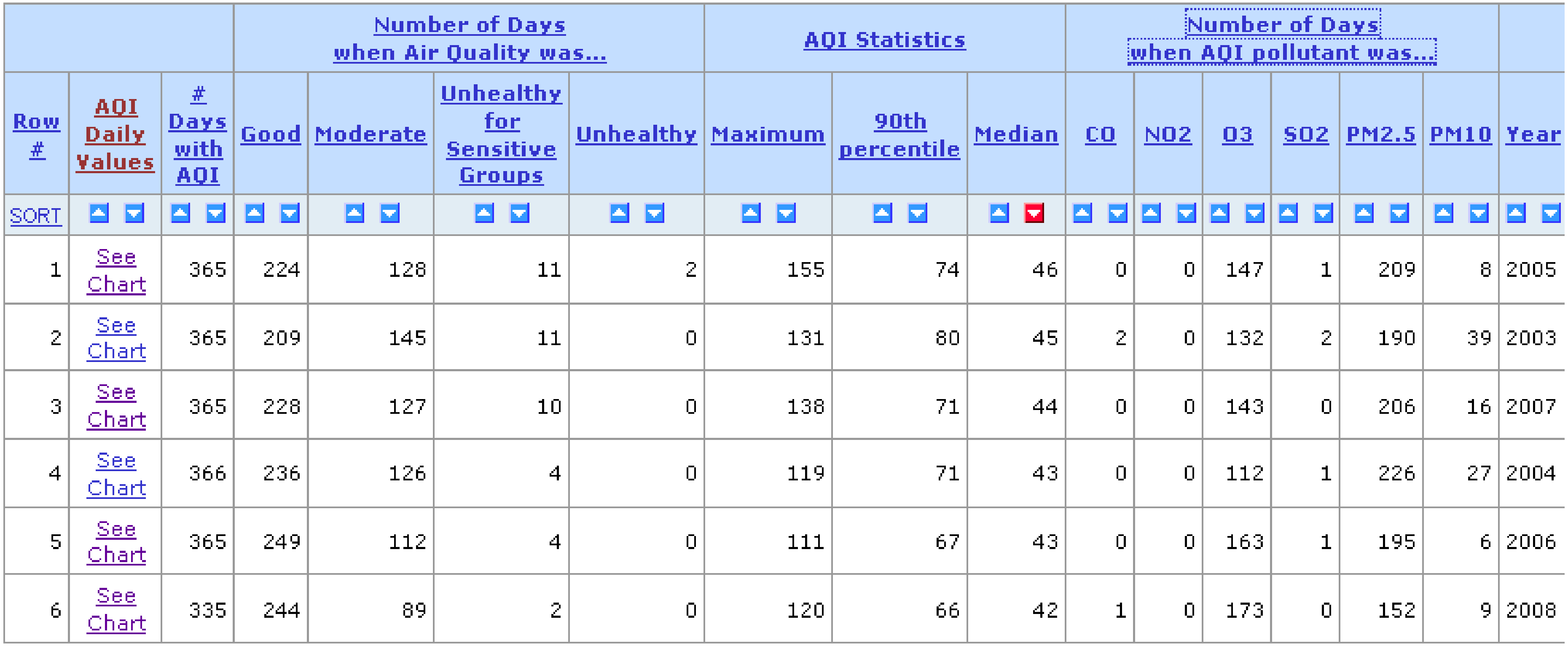
$CH_4 + O_2 \rightarrow C + H_2O$ “Very” Incomplete Combustion

Soot

In an automobile engine, some combination of these reactions occurs.

Consider This 1.6 … MSP

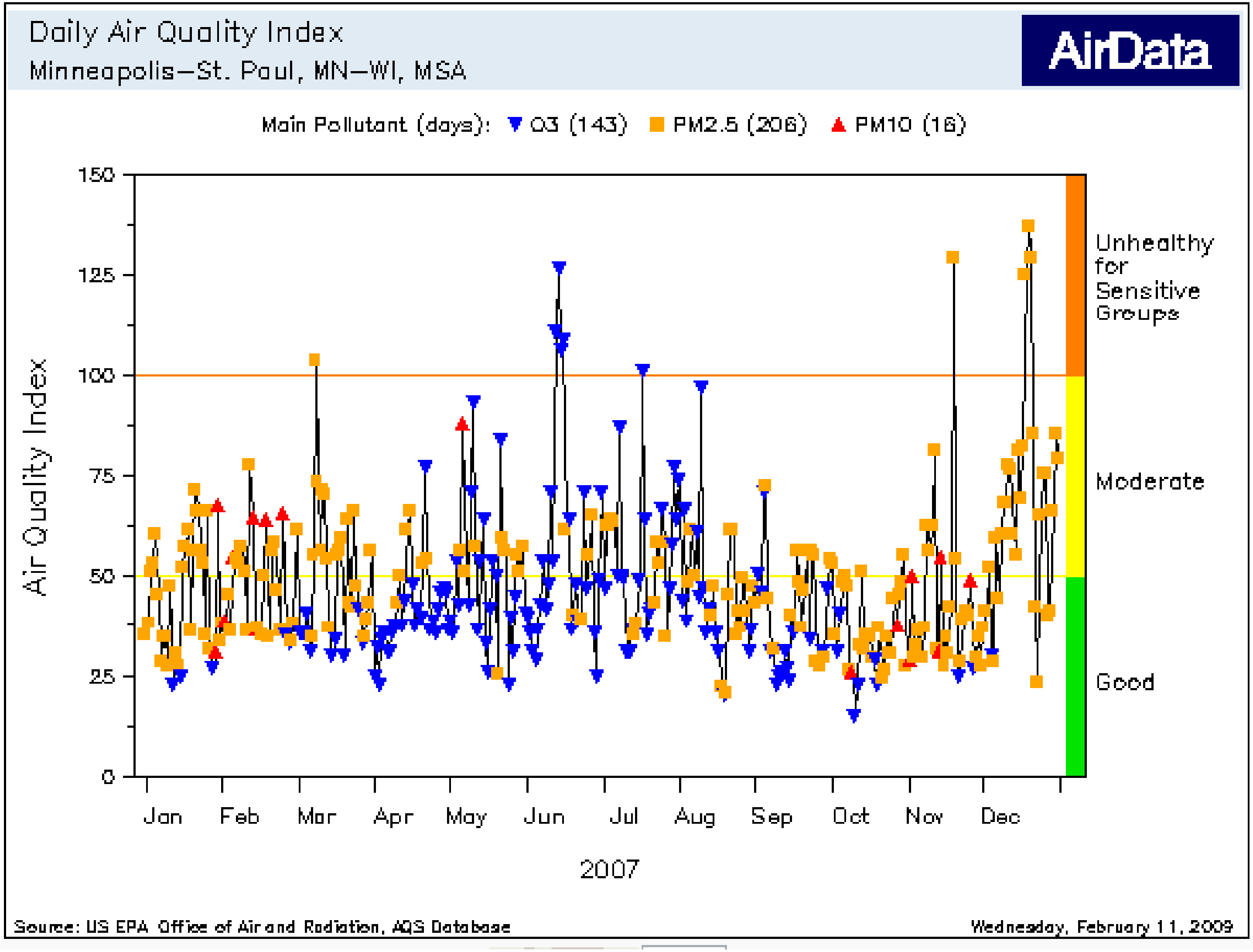
- Does MSP have better or worse Air Quality than Houston?
- What are the major pollutants for MSP?



			Number of Days when Air Quality was...				AQI Statistics			Number of Days when AQI pollutant was...						
Row #	AQI Daily Values	# Days with AQI	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Maximum	90th percentile	Median	CO	NO2	O3	SO2	PM2.5	PM10	Year
SORT	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼	▲ ▼
1	See Chart	365	224	128	11	2	155	74	46	0	0	147	1	209	8	2005
2	See Chart	365	209	145	11	0	131	80	45	2	0	132	2	190	39	2003
3	See Chart	365	228	127	10	0	138	71	44	0	0	143	0	206	16	2007
4	See Chart	366	236	126	4	0	119	71	43	0	0	112	1	226	27	2004
5	See Chart	365	249	112	4	0	111	67	43	0	0	163	1	195	6	2006
6	See Chart	335	244	89	2	0	120	66	42	1	0	173	0	152	9	2008

Consider This 1.6… MSP

See zoom and pan instructions below this image.



Source: US EPA Office of Air and Radiation, AQS Database

Wednesday, February 11, 2009

2007

For Next Time (Tues 2/17)

- Read Chapter 1
- Start AQI monitoring and prepare 2-3 minute summary of your city
- Prepare for Lab: Read “Some Notes About Laboratory Safety” and “Lab 1: What am I Breathing?” in Lab Manual
- Start working on Homework 1 (Due 2/24)

For Next Thurs (Thurs 2/19)

We will meet in the library next Thurs at 2:30 pm

Today: Feb 17, 2009

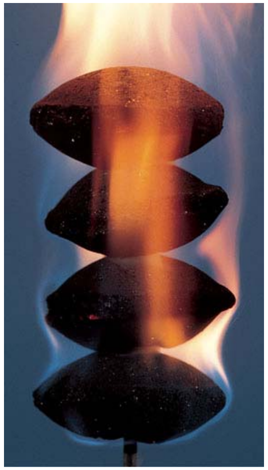
- Newspaper Presentations: Ally Pelton and Ricardo Torres
- Tips for AQI City “Presentations”
- Finish Chapter 1 Notes
- Lab 1: What am I Breathing?

The Bad Gases

- Carbon monoxide
- Sulfur oxides and nitrogen oxides
- Ozone
- Particulate matter, PM

We’ll take a closer look at each of these each in turn…

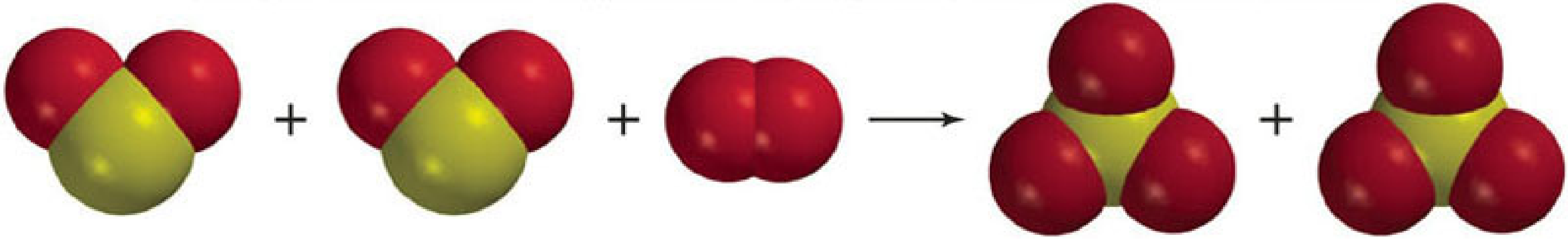
Direct Source of Sulfur Trioxide



$$\text{Coal} + O_2 \longrightarrow SO_2$$

(1-3% sulfur)

$$2\,SO_2 + O_2 \longrightarrow 2\,SO_3$$



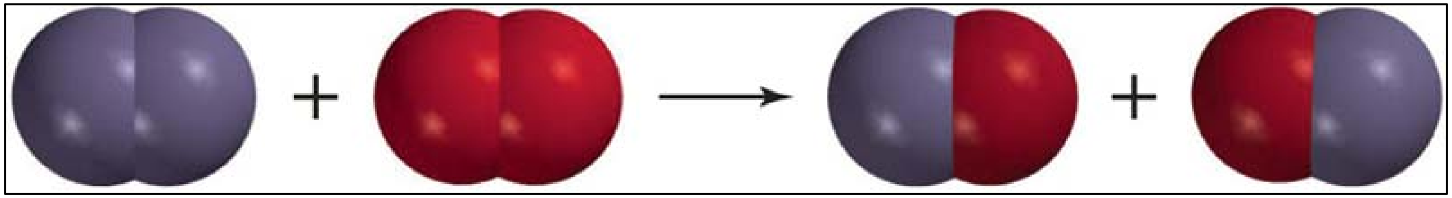
Good News: Since 1985 we have seen a 25% reduction in SO_2 emissions in the U.S.

Direct Source of Nitrogen Oxides

N_2 + O_2 + high temp $\longrightarrow$ 2 NO

(nitrogen oxide)

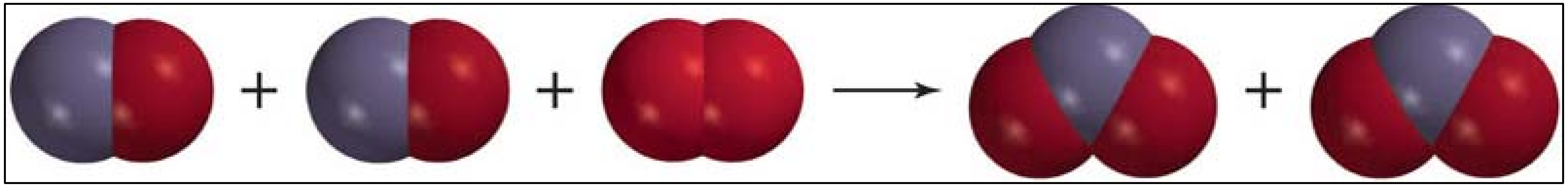
High temperatures from auto engine or coal-fired power plant



NO is very reactive:

Simplified version of chemistry that occurs

$2\ NO + O_2 \longrightarrow 2\ NO_2$

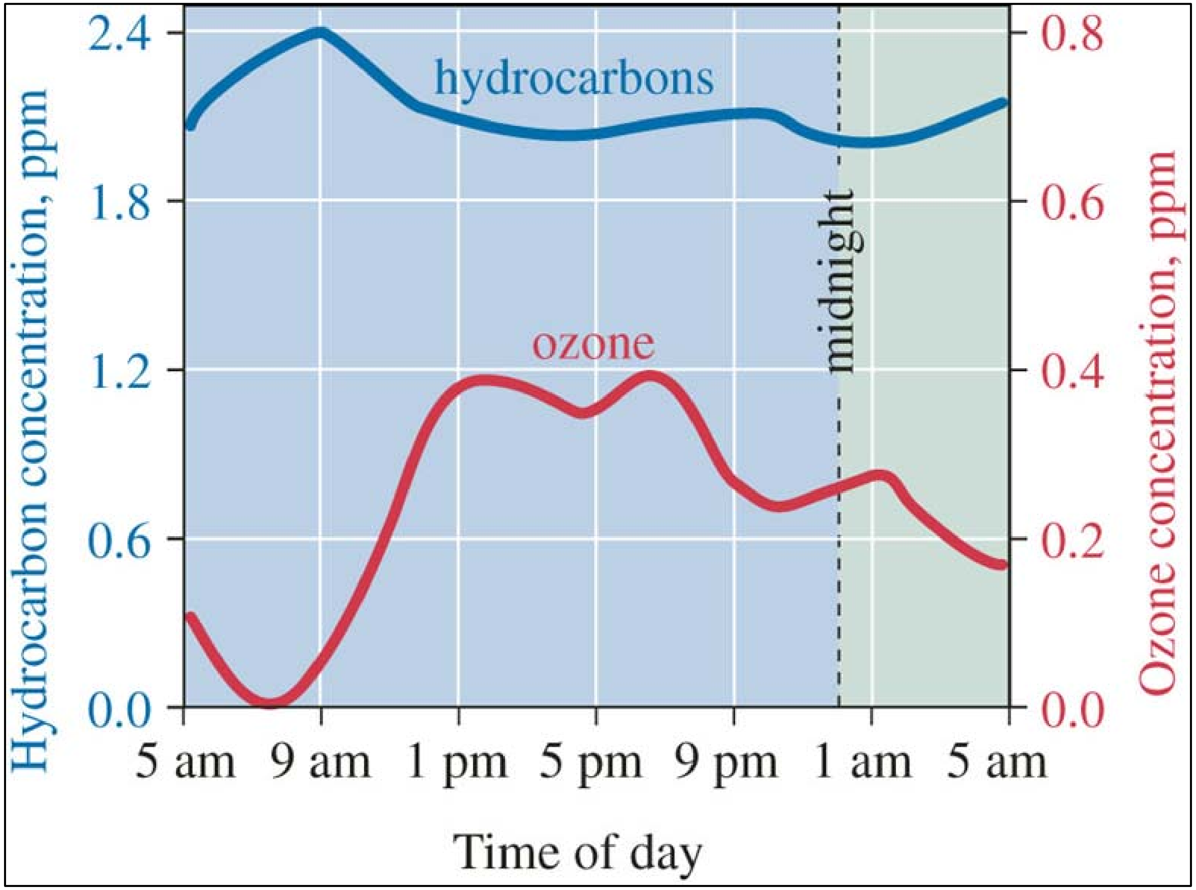


Formation of Tropospheric Ozone

$$NO_2 \xrightarrow{\text{sunlight}} NO + O$$

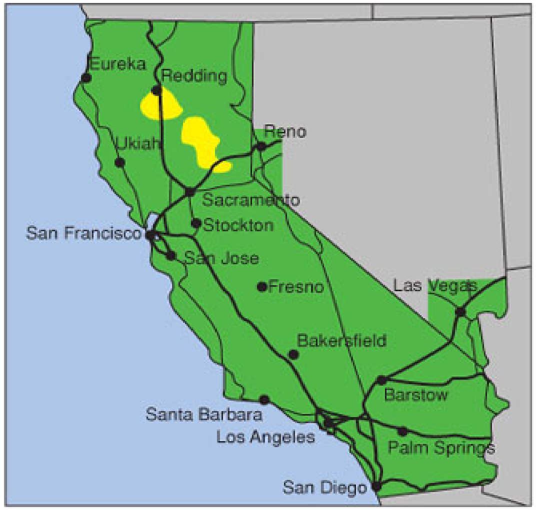
$$O + O_2 \longrightarrow O_3$$

O_3 is not directly emitted, it is a **secondary pollutant**- produced from other pollutants.

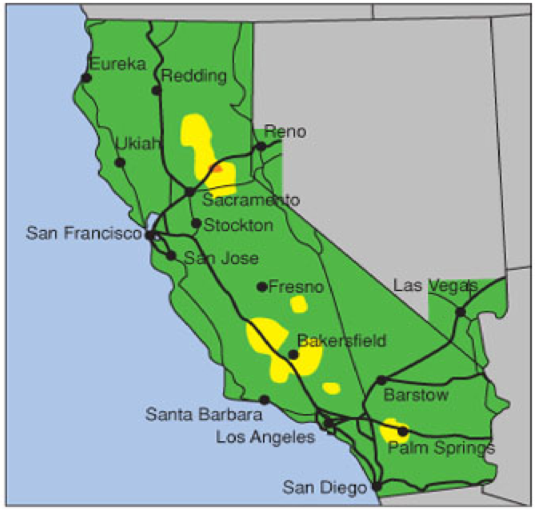


Ozone maps for California, July 2006

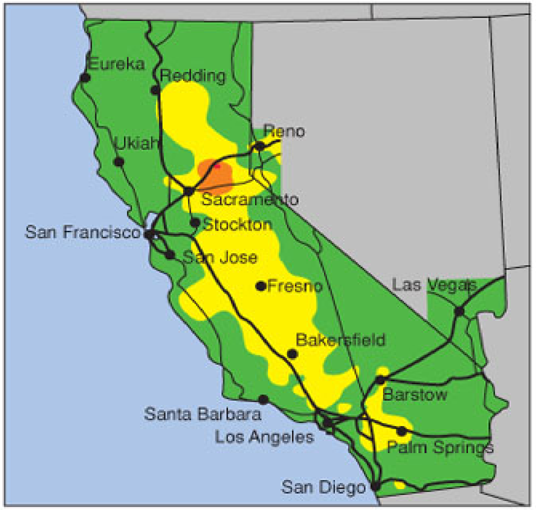
6 AM



10 AM



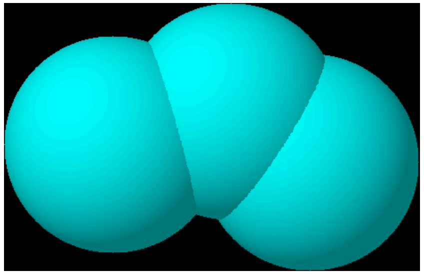
Noon



4 PM

10 PM

Ozone (O_3)



If one breath of air contains 2 x 10^{22} molecules and atoms, and the acceptable ozone level is 0.12 ppm, how many molecules of O_3 are in each breath?

$$2 \text{ x } 10^{22} \ \cancel{\text{molecules and atoms in a breath of air}} \ \text{x} \left(\frac{0.12 \ O_3 \ \text{molecules}}{1 \text{ x } 10^{6} \ \cancel{\text{molecules and atoms in air}}} \right)$$

$$\boxed{= 2 \text{ x } 10^{15} \ O_3 \ \text{molecules in a breath}}$$

How many oxygen *atoms* are in each breath?

$$2 \text{ x } 10^{15} \ \cancel{O_3 \ \text{molecules}} \ \text{x} \left(\frac{3 \ O \ \text{atoms}}{1 \ \cancel{O_3 \ \text{molecules}}} \right) = 6 \text{ x } 10^{15} \ O \ \text{atoms}$$

What is Particulate Matter (PM)?

- Mixture of solid particles and liquid droplets composed of many individual chemicals
  - Generally a solid core with chemicals on the surface

- PM_{10} - particulate matter < 10 micrometers

- $PM_{2.5}$ - particulate matter < 2.5 micrometers

Diameter of average human hair is 100 micrometers

5

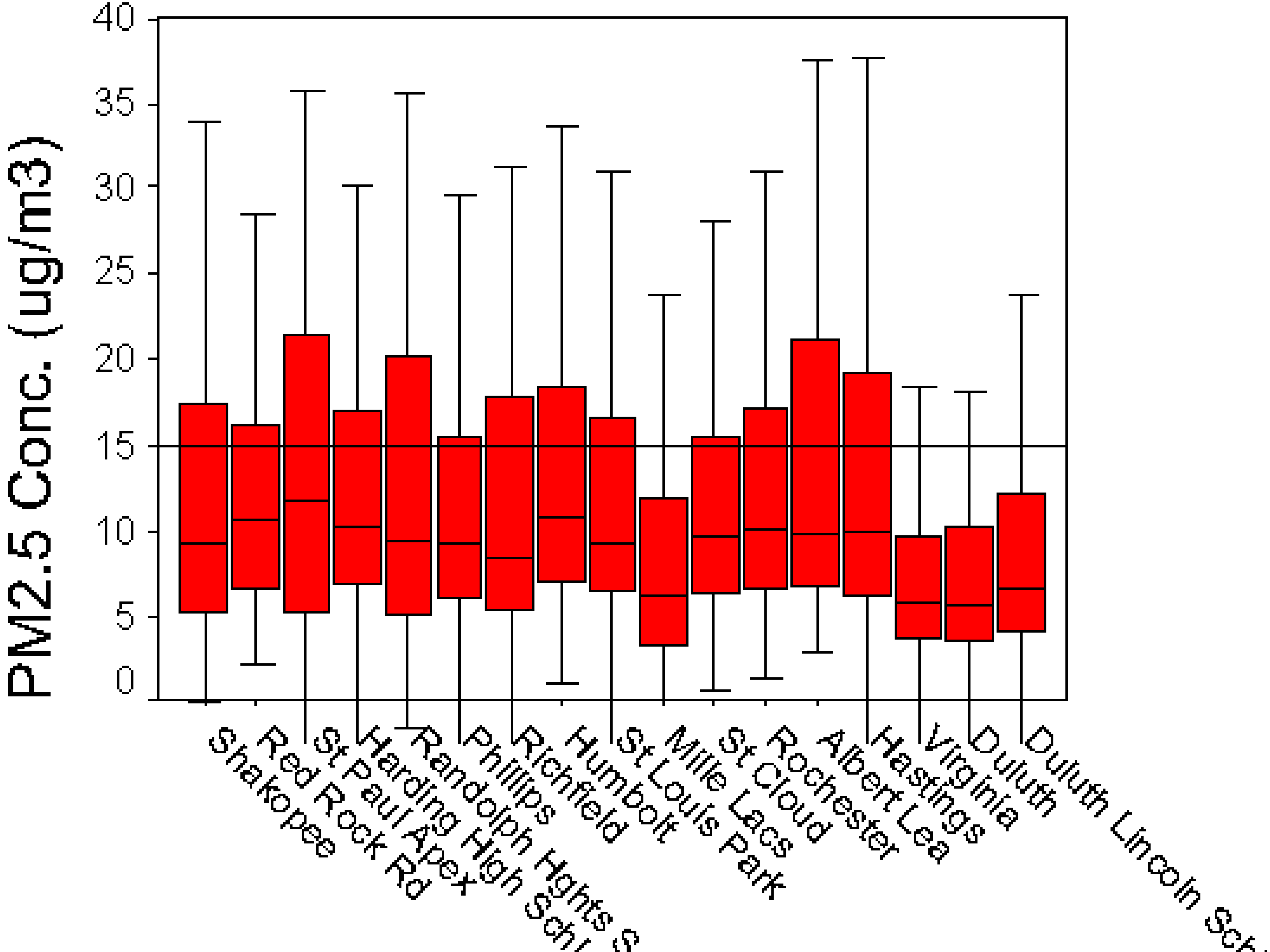
35

National Ambient Air Quality Standards (NAAQS)

- PM$_{2.5}$
  - –15 $\mu g/m^3$ annual average
  - –65 $\mu g/m^3$ 24-hour average
- PM$_{10}$
  - –50 $\mu g/m^3$ annual average
  - –150 $\mu g/m^3$ 24-hour average

Albert Lea Air Toxic Site

PM2.5 Conc. in MN (4/00-3/01)



PM Impact Estimates

- 60,000 - 70,000 premature U.S. deaths/year

Harvard Center for Risk Analysis (2001)

- Appears air pollution (especially PM) contributes to ≅ 4% of U.S. deaths & if so, this risk is more than 100 times the risk of all other EPA-regulated pollutants

Wilson & Spengler (1996)

- $730 million/year direct public health costs attributed to Twin Cities traffic

most from PM-associated mortality

UMN Center for Transportation Studies (2000)

Major US Sources of Fine PM

- Coal combustion in power plants and boilers
- Gasoline and diesel combustion--on- & off-road vehicles
- Waste, wood and other biomass burning
- Fugitive dust from road surfaces, construction & agriculture
- Livestock

Green Chemistry

- Designing of chemical products and processes that reduce or eliminate the use or generation of hazardous substances

- Presidential Green Chemistry Challenge Award: 1996-present
  - New dry-cleaning methods
  - New materials for disposable diapers
  - Cheaper, less wasteful, and less toxic production of chemicals (like ibuprofen, pesticides, etc).

Air Toxics in MN

Criteria Air Pollutants vs Toxic Air Pollutants

Criteria Air Pollutants

- O_3, SO_2, NO_2, PM, lead, CO
- standards set by EPA
- steps must be taken in non-attainment areas
- nationwide monitoring

Air Toxics

- hazardous air pollutants
- not classified as "Criteria"
- respiratory and heart effects, cancer
- Emissions are tabulated
- Permits for facilities to release air toxics
- Few ambient monitoring sites

Air toxics exceeding health benchmarks in MN

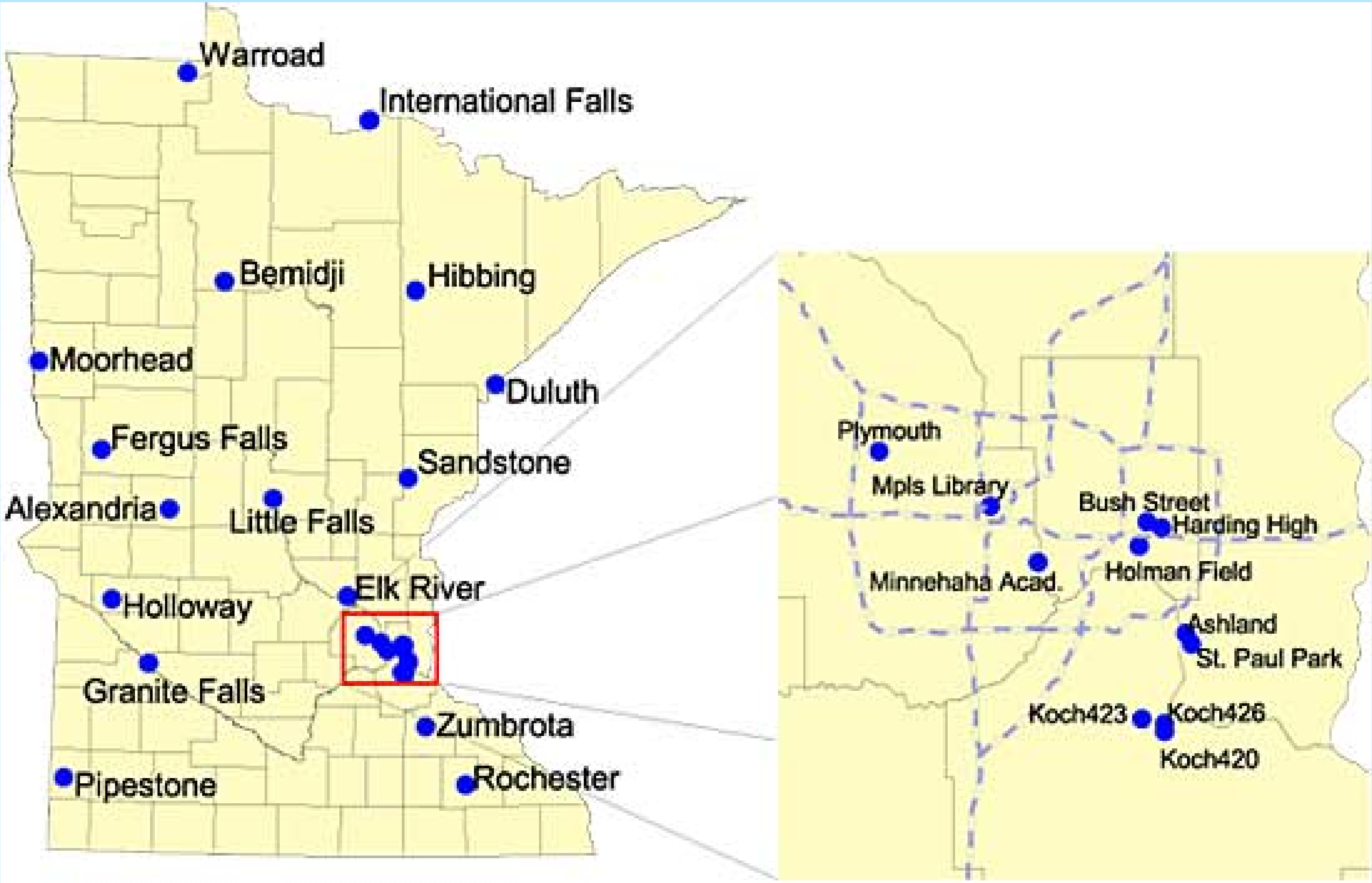
- Formaldehyde
- Benzene
- Carbon Tetrachloride
- Chloroform

- Ethylene dibromide
- 1,3 –butadiene
- Acrolein
- Arsenic
- Nickel
- Chromium
- Particulate organic matter (POM)

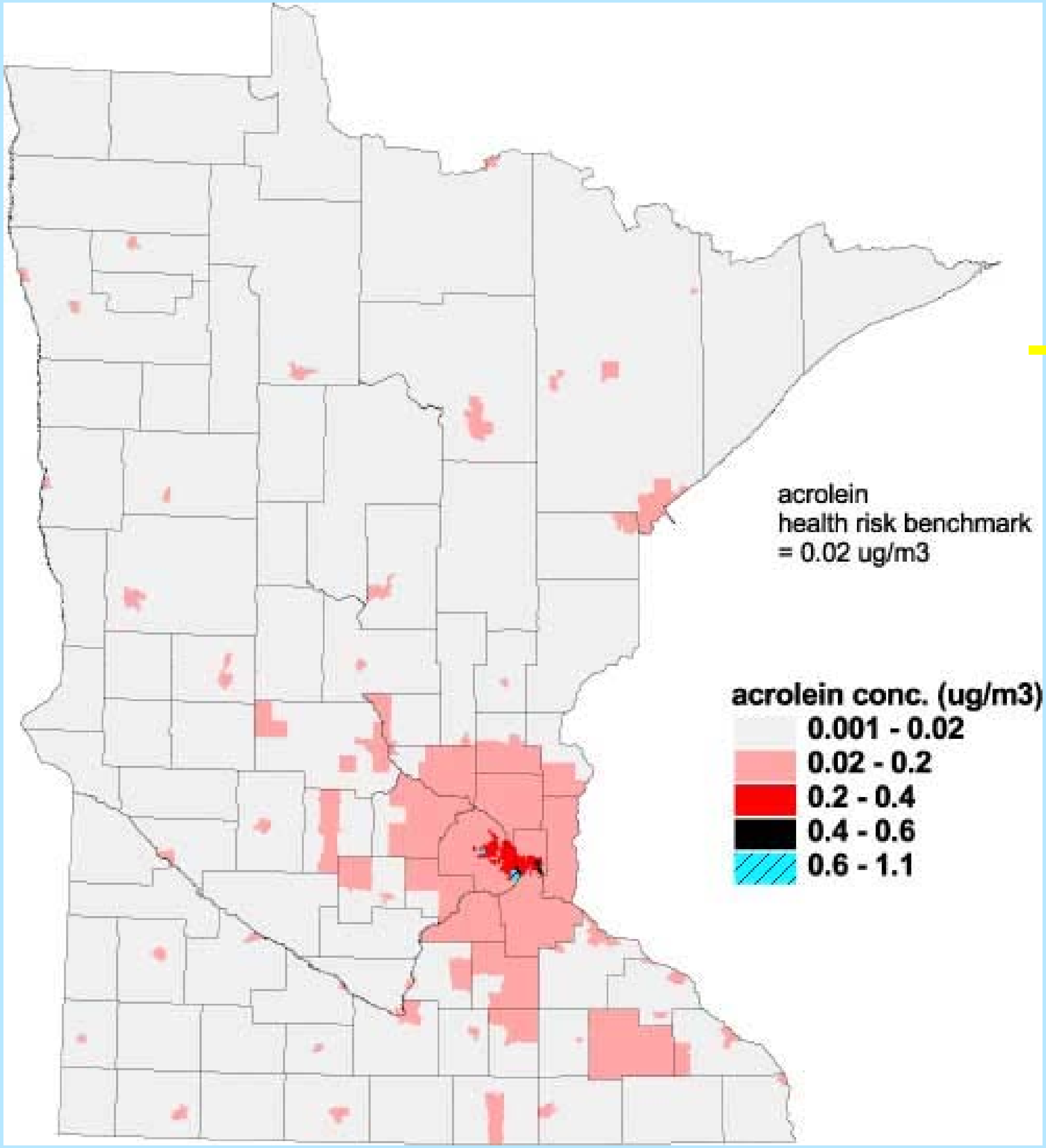
Cumulative Exposure Project (CEP) for air toxics

- EPA project to inform Americans about potential cancer risks due to breathing outdoor air
- EPA modeled concentrations of 148 toxics compounds in air throughout the U.S.
- Modeled concentrations can be compared to health standards
- Minnesota is one of the few states that monitors any of these compounds (MPCA monitors 75 air toxics)
- Minnesota's monitoring generally supported CEP modeled air toxic levels
- Outdoor air may represent minimum exposures

Monitoring Air Toxics in MN

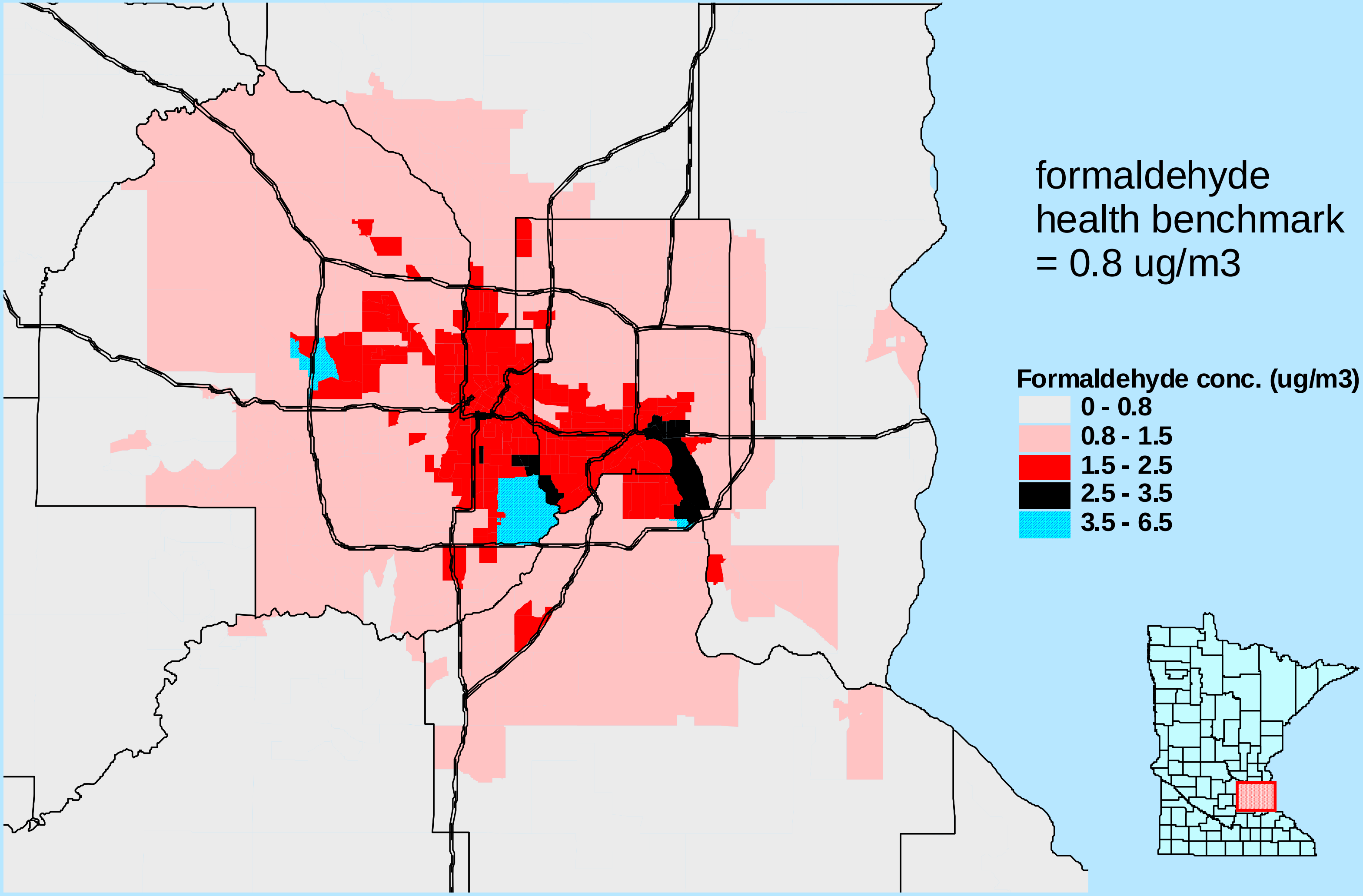


Example – Acrolein in MN



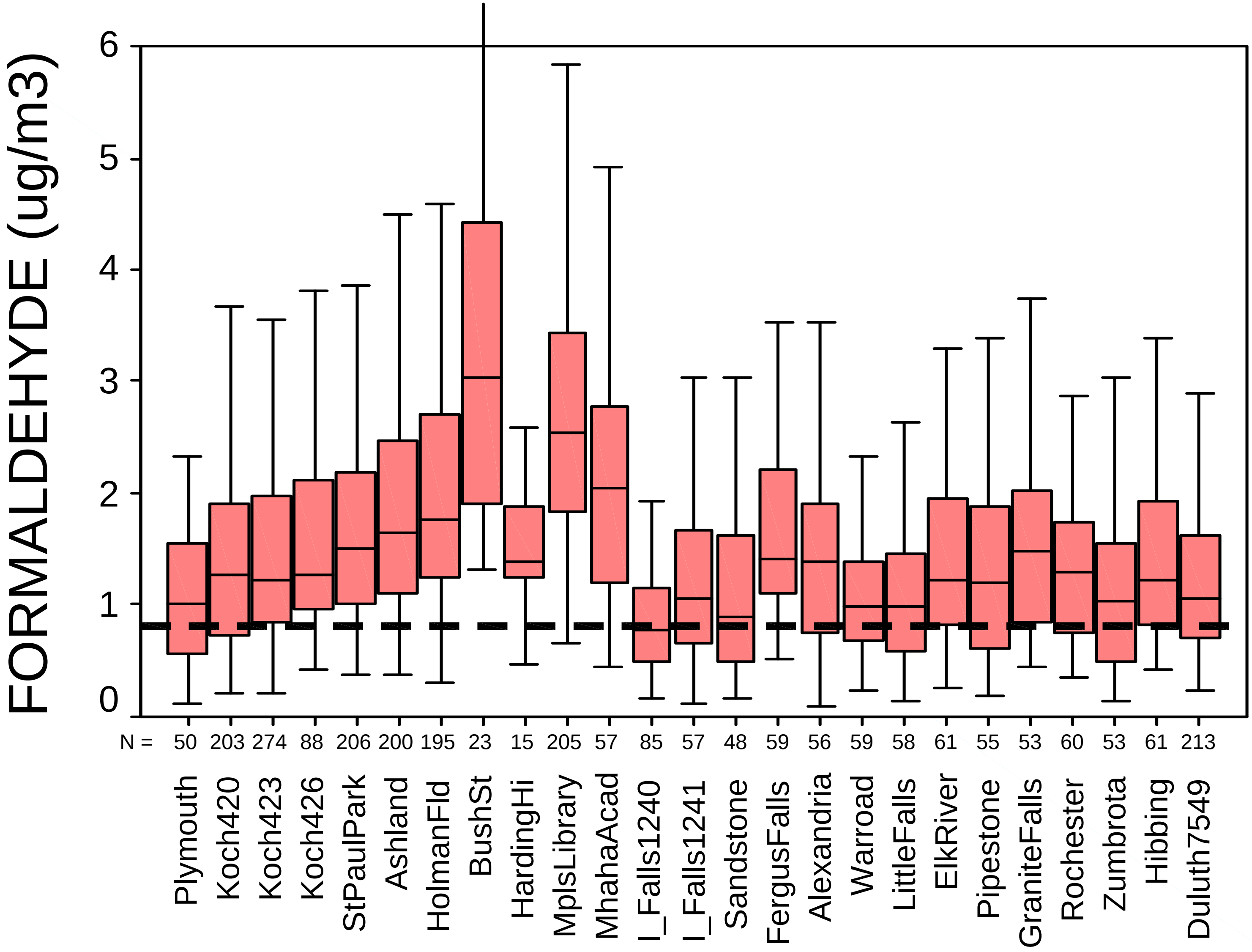
- Modeled concentrations

Metro Area - Formaldehyde Concentrations (EPA - CEP)



formaldehyde
health benchmark
= 0.8 ug/m3

Formaldehyde



Conclusions - Air Toxics

- CEP: Cumulative Exposure Project by EPA to identify excess cancer risk due to breathing outdoor air
- Mobile sources are the main source of risk
  - cars, trucks, etc.
  - greater risks in urban areas
- In Minnesota ten air toxics exceed health benchmarks
- Upper bound estimated cancer risks = 2 - 141 per 100,000 in MN due to air toxics

For Next Time (Thurs 2/19)

- Bring topic for project to library at 2:30
- Bring summary of city for AQI project to classroom at 3:30… 1-2 minutes only!
- Finish reading Chapter 1
- Start working on Homework #1 (Due 2/24)

For Next Tues (Tues 2/24)

- Homework #1 Due
- Start Reading Chapter 2
- Prepare for lab: Read Exp 4 in lab manual