Air pollution I

Air pollution I

- Units for measuring air pollutants
- Types of air pollution problems
- Types of air pollutants
  - Carbon monoxide (CO)
  - Lead (Pb)
  - Nitrogen oxides
  - Photochemical oxidants
  - Sulfur oxides
  - Particulates
  - Other hazardous compounds

Today's goal


오 존 (O3)
0.002 ppm


미세먼지(PM-10)
newstown.co.kr


중 구
초미세먼지 (PM2.5)
3 μg/m³(기준 50 이하)


그야말로... 먼지_
초미세 먼지는?
미세한 먼지!
초미세
더 작은 먼지_

Units of measurement

- volume/volume units (for gas phase pollutants)
  - ppm = parts per million
  - ppb = parts per billion
  - ppt = parts per trillion
- mass/volume (for gas & particle phase pollutants)
  - usually $\mu g/m^3$

Unit conversion

Consider a pollutant "*i*"

Ideal gas law: $PV = nRT$

$$\frac{n_{air}}{V_{air}} = \frac{P_{air}}{RT} = \frac{mole_{air}}{m^3{}_{air}}$$

R = ideal gas constant = 8.21 x 10^{-5} m^3-atm/K-mole

$$ppm_i = \frac{moles\ of\ pollutant\ i}{moles\ of\ air} \times 10^6 = \frac{\mu mole_i}{mole_{air}}$$

So, $$\frac{\mu g_i}{m^3{}_{air}} = ppm_i \times MW_i \times \frac{P_{air}}{RT}$$

Unit conversion

Q: Convert 10 ppb of SO_2 to μg/m^3 at 20°C, 1 atm.

Air pollution problems

- Classification of air pollution problems by scales
  - **Microscale**: less than the size of a house or slightly bigger
  - **Mesoscale**: a few hectares to the size of a city or slightly bigger
  - **Macroscale**: size of a county to a country and to the globe

Microscale air pollution problems

- Indoor air pollution: pollutants from burners, ovens, heaters, cigarette smoke, and underground
- Cigarette smoke on streets

http://www.compacappliance.net

http://www.odamindia.org

http://www.edaily.co.kr

Mesoscale air pollution problems

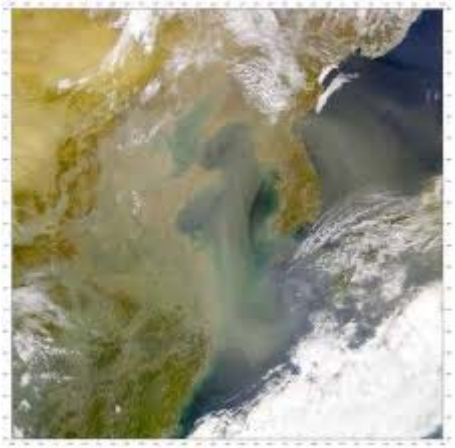
- Vehicle exhaust
- Smoke from power plants, factories, etc.
- Smog

http://web.ornl.gov

http://www.bbc.com

Macroscale air pollution problems

- Acid rain
- Yellow dust
- Ozone depletion
- Global warming



http://en.wikipedia.com

http://breitbart.com

Air pollutants (1) – Carbon monoxide (CO)

- Generated by incomplete combustion of carbon
- Natural sources: oxidation of methane (CH_4) in the atmosphere
- Anthropogenic sources: motor vehicles, fossil fuel burning, solid waste disposal, burning of plant materials
- Reacts with hemoglobin in the blood to form carboxyhemoglobin (CoHb)
- Carbon monoxide poisoning: lots of deaths in 1950s-1980s in Korea caused by indoor briquette burning

Air pollutants (2) – Lead

- A cumulative poison
- Usually occurs in the atmosphere as a particulate
- Natural sources: volcanic activity and airborne soil
- Anthropogenic sources: smelters and refining processes, and incineration of lead-containing wastes

- In the past, lead used to be added to gasoline → significant air pollution problems → lead addition currently prohibited

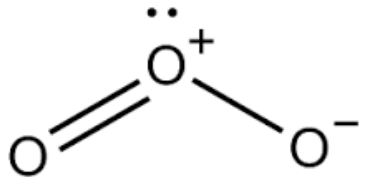
Air pollutants (3) – Nitrogen oxides

- NO, NO_2, N_2O, NO_3, N_2O_3, N_2O_4, N_2O_5
- NO_2 itself has adverse effects on respiratory tract
- NO and NO_2 are involved in the formation of photochemical smog and acid rain
- $NO_x = NO + NO_2$
- Anthropogenic sources: combustion processes in motor vehicles, power plants, and the industry
- N_2 is an inert gas, but reacts with oxygen at high temperature (>1600 K):

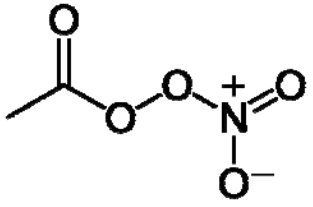
$$N_2 + O_2 \rightarrow 2NO$$

Air pollutants (4) – Photochemical oxidants

- Chemicals produced by reaction in the atmosphere in the presence of sunlight
- Classified as secondary pollutants
- **O_3** (major), peroxyacetyl nitrate (PAN), acrolein, peroxybenzoyl nitrates (PBzN), aldehydes, nitrogen oxides
- Toxic effects because of their oxidizing ability: cause eye, nose, and throat irritation, and affect lung function
- Major pollutants in photochemical smog



ozone

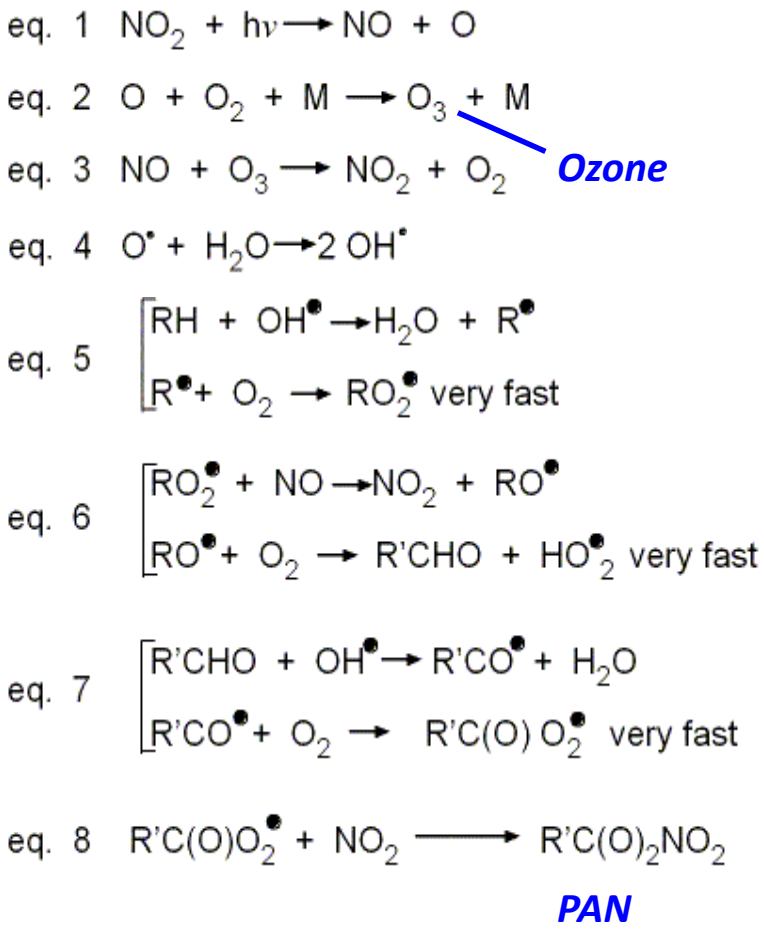


PAN

Primary vs. secondary pollutants

- **Primary pollutants**
  - Pollutants that are emitted directly from sources

- **Secondary pollutants**
  - Pollutants that are formed in the atmosphere by chemical reactions between primary pollutants and chemical species normally found in the atmosphere



Air pollutants (5) – Sulfur oxides

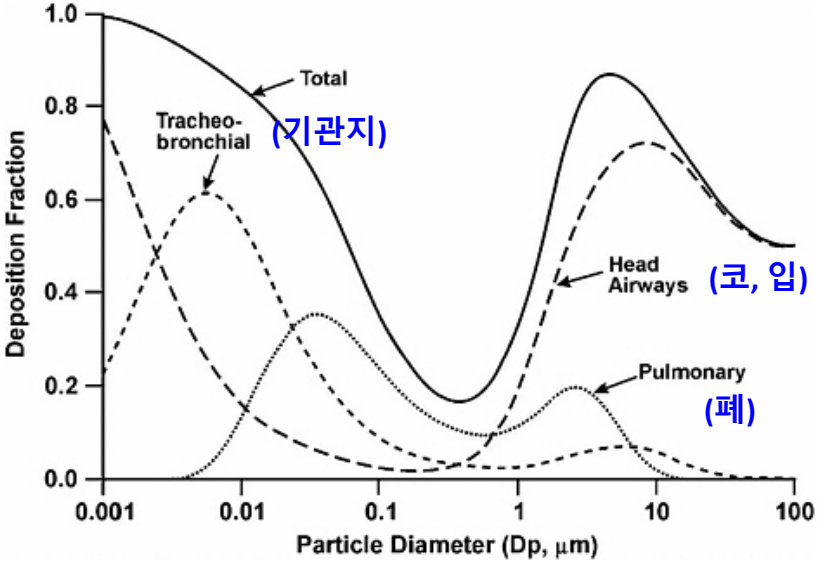
- SO_2, SO_3, SO_4^{2-}
- Called SO_x
- Sources
  - Direct emission of SO_x from power plants, industry, volcanoes, and the oceans (as a primary pollutant)
  - Oxidation of H_2S produced by natural biological processes or the industry (as a secondary pollutant)
- Involved in “London-type smog” and acid rain

Air pollutants (6) – Particulates

- Particles suspended in the air
- Natural sources: sea salt, soil dust, volcanic particles, smoke from forest fires
- Anthropogenic sources: fossil fuel burning, industrial processes
- Damage respiratory organs

Fine particulates, finer particulates

- Large particles are trapped at the upper respiratory system, but small particles go deeper → small particles are more significant!
- Korean government regulate "PM_{10}" and "$PM_{2.5}$"
  - PM_{10}: particulate matter less than 10 μm size
  - $PM_{2.5}$: particulate matter less than 2.5 μm size



Deposition of inhaled particles in the human

Raabe (1994) Internal Radiation Dosimetry

Other hazardous air pollutants

- Toxic organic compounds, heavy metals, arsenic, etc.
- Korean government regulates 35 hazardous air pollutants
- Some examples: cadmium, mercury, asbestos, dioxin, benzene

Reading assignment

Textbook Ch 12 p. 580-600

Unit conversion

Slide#6 solution)

10 ppb = 0.01 ppm

MW of SO_2 = 64.1

SO_2 conc. in µg/m^3

$$= 0.01\ ppm \times 64.1\ g/mole \times \frac{1\ atm}{8.21\times10^{-5}\ m^3-atm/K-mole\times 293\ K}$$

$$= \mathbf{26.6\ \mu g/m^3}$$