

Air pollution I

Air pollution

- Units for air pollutants
- Types of air pollution problems and air pollutants
- Air pollution problems
 - Indoor air pollution
 - Acid rain
 - Ozone depletion
 - Global warming
- Atmospheric distribution of air pollutants
- Air pollution control methods

Today's goal



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 $\mu\text{g}/\text{m}^3$

Unit conversion

Consider a pollutant “i”

Ideal gas law: $PV = nRT$

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

$R = \text{ideal gas constant} = 8.21 \times 10^{-5} \text{ m}^3\text{-atm/K-mole}$

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

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

Unit conversion

Q: Convert 10 ppb of SO₂ to μg/m³ at 20°C, 1 atm.

Air pollution problems

- Classification of air pollution problems
 - **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

Air pollution problems

- 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>

Air pollution problems

- Mesoscale air pollution problems
 - Vehicle exhaust
 - Smoke from power plants, factories, etc.
 - Smog



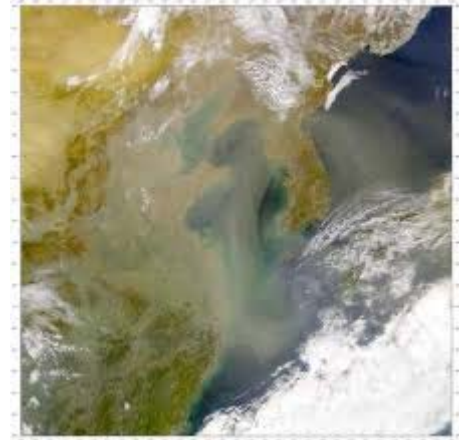
<http://web.ornl.gov>



<http://www.bbc.com>

Air pollution problems

- Macroscale air pollution problems
 - Acid rain
 - Yellow dust
 - Ozone depletion
 - Global warming



<http://en.wikipedia.com>



<http://breitbart.com>

Air pollutants

- **Carbon monoxide (CO)**
 - Generated by incomplete combustion of carbon
 - Natural sources: oxidation of methane (CH₄) 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

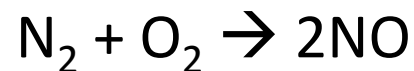
- **Lead (Pb)**
 - A cumulative poison
 - Usually occurs in the atmosphere as a particulate
 - Natural sources: volcanic activity and airborne soil
 - Anthropogenic sources: smelters and refining processes, and incineration of lead-containing wastes
 - In the past, lead used to be added to gasoline → significant air pollution problems → lead addition currently prohibited



Air pollutants

- **Nitrogen oxides**

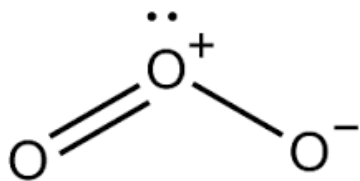
- NO, NO₂, N₂O, NO₃, N₂O₃, N₂O₄, N₂O₅
- NO₂ itself has adverse effects on respiratory tract
- NO and NO₂ are involved in the formation of photochemical smog and acid rain
- NO_x = NO + NO₂
- Anthropogenic sources: combustion processes in motor vehicles, power plants, and the industry
- N₂ is an inert gas, but reacts with oxygen at high temperature (>1600 K):



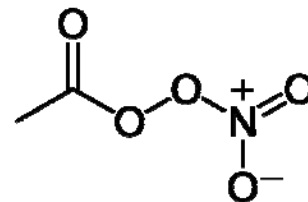
Air pollutants

- **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



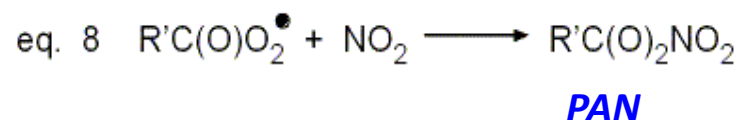
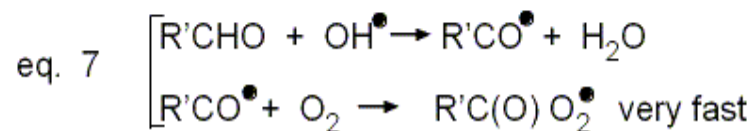
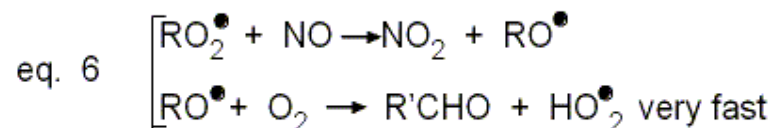
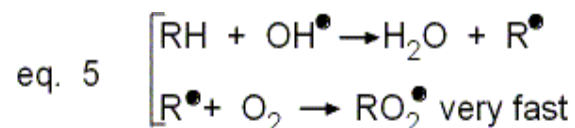
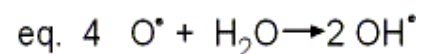
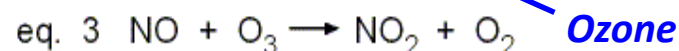
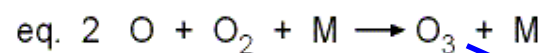
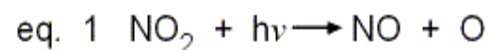
ozone



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

- 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 smog” and acid rain

Air pollutants

- **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

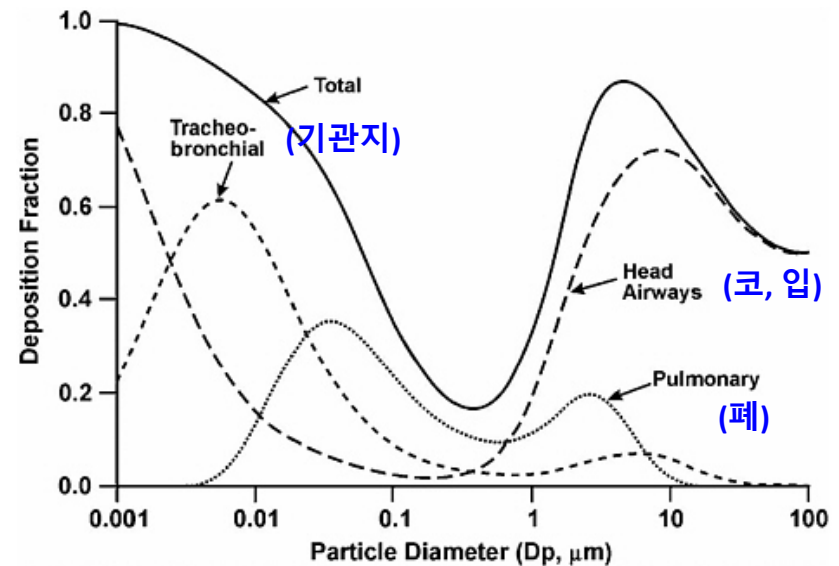
Air pollutants

- Particulates

- Large particles are trapped at the upper respiratory system, but small particles go deeper → small particles are more significant!

- Korean government regulate “PM₁₀” and “PM_{2.5}”

- PM₁₀: 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

Air pollutants

- **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. 587-605