

# Air pollution I

# Air pollution I

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- 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



# Units of measurement

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- 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

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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

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**Q:** Convert 10 ppb of SO<sub>2</sub> to μg/m<sup>3</sup> at 20°C, 1 atm.

# Air pollution problems

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- 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

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- 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

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



<http://web.ornl.gov>

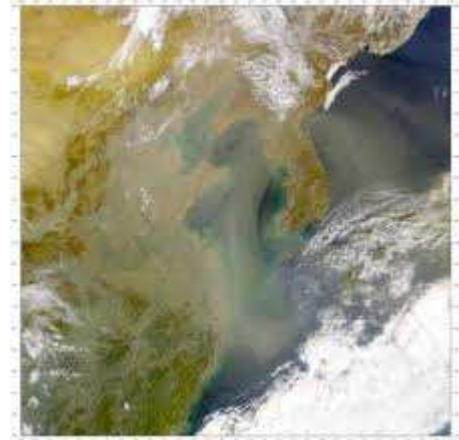


<http://www.bbc.com>

# Macroscale air pollution problems

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



<http://en.wikipedia.com>



<http://breitbart.com>

# Air pollutants (1) – Carbon monoxide (CO)

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- Generated by incomplete combustion of carbon
- Natural sources: oxidation of methane (CH<sub>4</sub>) 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

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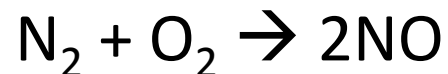
- A cumulative poison
- Usually occurs in the atmosphere as a particulate
- Natural sources: volcanic activity and airborne soil
- Anthropogenic sources: smelters and refining processes, and incineration of lead-containing wastes
- In the past, lead used to be added to gasoline → significant air pollution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



# Air pollutants (3) – Nitrogen oxides

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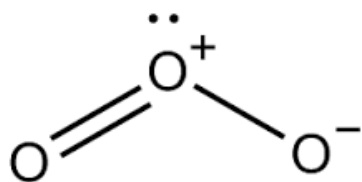
- NO, NO<sub>2</sub>, N<sub>2</sub>O, NO<sub>3</sub>, N<sub>2</sub>O<sub>3</sub>, N<sub>2</sub>O<sub>4</sub>, N<sub>2</sub>O<sub>5</sub>
- NO<sub>2</sub> itself has adverse effects on respiratory tract
- NO and NO<sub>2</sub> are involved in the formation of photochemical smog and acid rain
- NO<sub>x</sub> = NO + NO<sub>2</sub>
- Anthropogenic sources: combustion processes in motor vehicles, power plants, and the industry
- N<sub>2</sub> is an inert gas, but reacts with oxygen at high temperature (>1600 K):



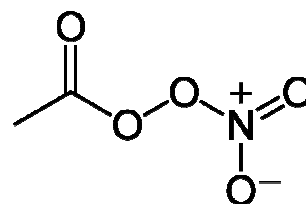
# Air pollutants (4) – Photochemical oxidants

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- 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

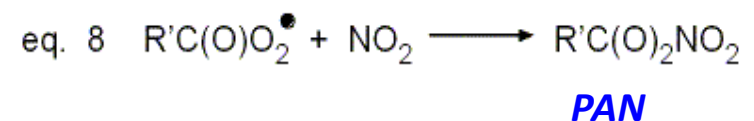
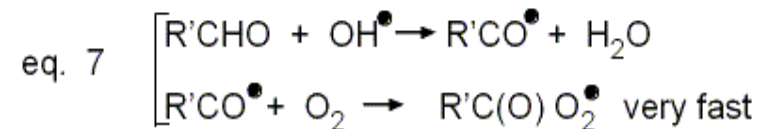
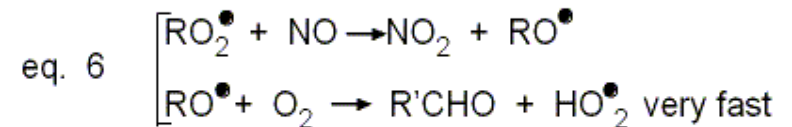
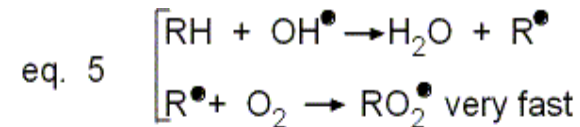
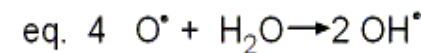
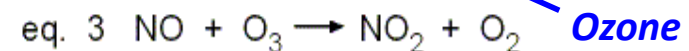
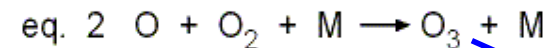
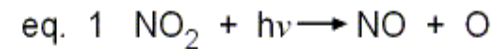
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- **Primary pollutants**

- 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

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- $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{SO}_4^{2-}$
- Called  $\text{SO}_x$
- Sources
  - Direct emission of  $\text{SO}_x$  from power plants, industry, volcanoes, and the oceans (as a primary pollutant)
  - Oxidation of  $\text{H}_2\text{S}$  produced by natural biological processes or the industry (as a secondary pollutant)
- Involved in “London-type smog” and acid rain



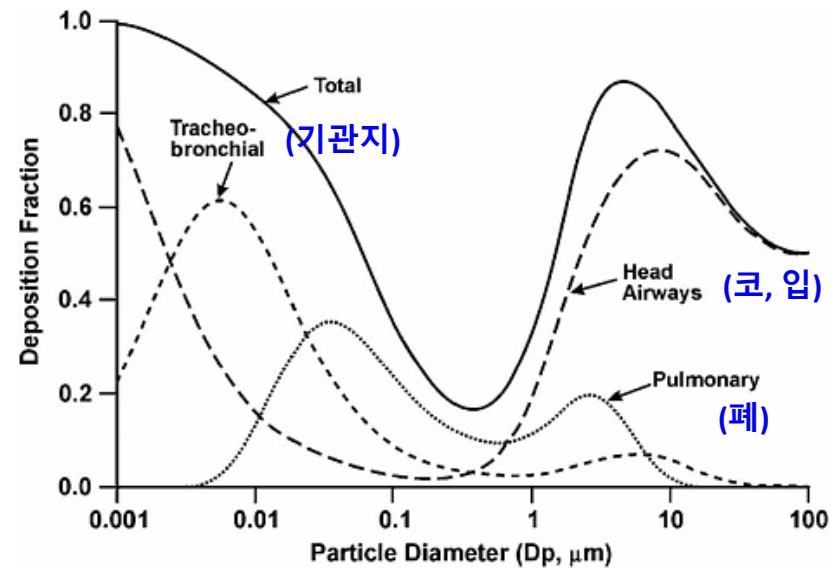
# Air pollutants (6) – Particulates

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- 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<sub>10</sub>” and “PM<sub>2.5</sub>”
  - PM<sub>10</sub>: particulate matter less than 10 μm size
  - PM<sub>2.5</sub>: particulate matter less than 2.5 μm size



Deposition of inhaled particles in the human  
*Raabe (1994) Internal Radiation Dosimetry*

# Other hazardous air pollutants

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

# Reading assignment

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Textbook Ch 12 p. 580-600

# Unit conversion

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**Slide#6 solution)**

*10 ppb = 0.01 ppm*

*MW of SO<sub>2</sub> = 64.1*

*SO<sub>2</sub> conc. in μg/m<sup>3</sup>*

$$= 0.01 \text{ ppm} \times 64.1 \text{ g/mole} \times \frac{1 \text{ atm}}{8.21 \times 10^{-5} \text{ m}^3\text{-atm/K-mole} \times 293 \text{ K}}$$

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