Unit 8: Pollution: module 4.43 Photochemical smog, thermal inversions

Module 43: Photochemical smog, thermal inversions, particulates

Two types:

- Photochemical smog: LA smog, brown smog, caused by surface ozone reactions
- Sulfurous smog: grey smog, VOG (includes bits of volcanic glass)

Here's how they look:



(a) (b)

FIGURE 43.2 There are two different types of smog. (a) Los Angeles–type brown smog. The smog seen here, photographed in Los Angeles, September 2020, is also a result of nearby wildfires. (b) London-type smog, gray smog, also known as industrial smog. The smog seen here was photographed in 2014. *(a: Citizen of the Planet/Alamy Stock Photo; b: Dinendra Haria/Alamy Stock Photo)*

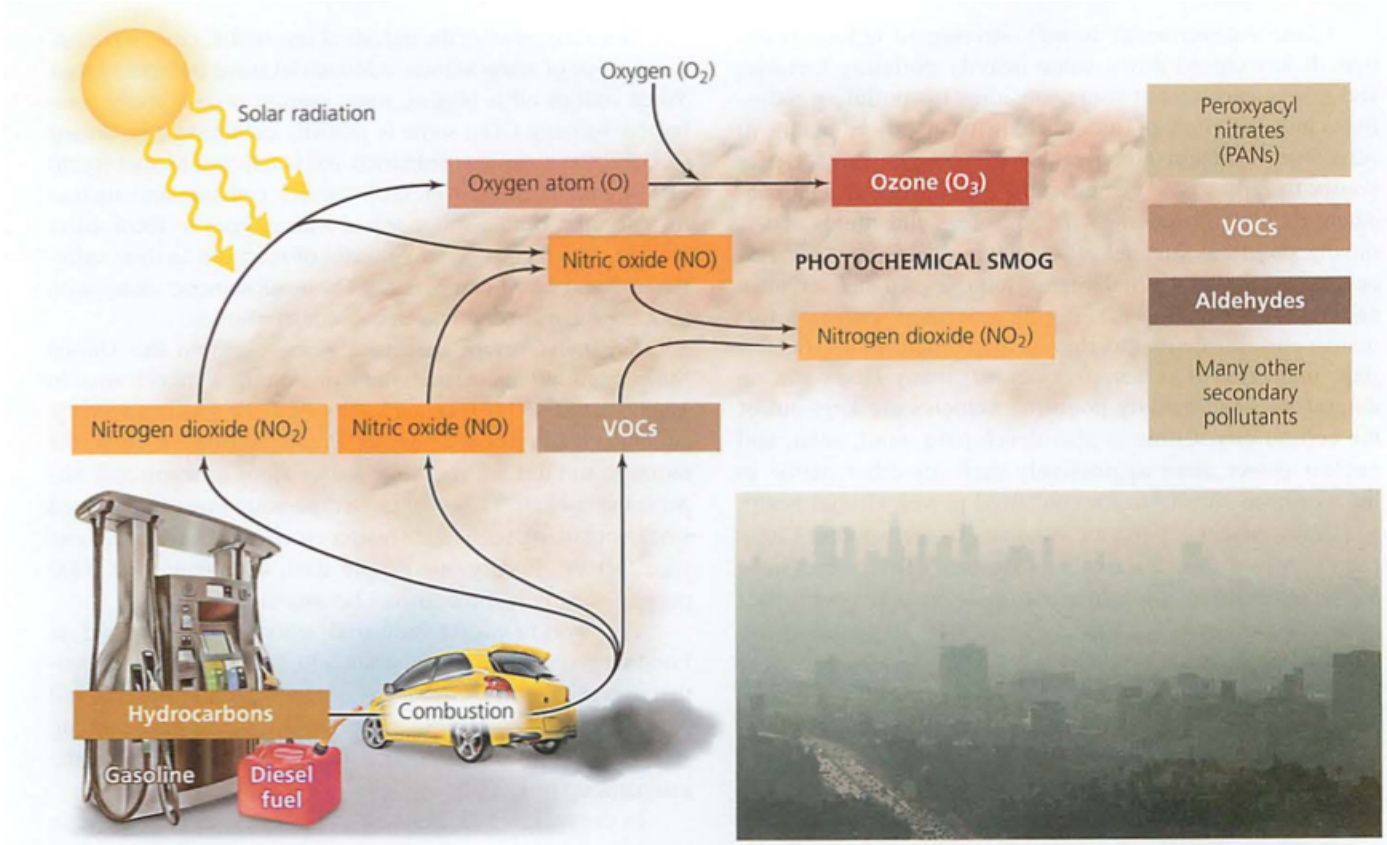
Smog and other photochemical reactions:

Primary and secondary pollutants:

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- **Secondary pollutants: need a chemical reaction (often energy from sunlight) to form (see figures above)**
- **Example: PhotoChemical Smog: Photo (light) Chemical (reaction) smog**
- **See PANs: Peroxyacyl nitrates: formed from VOCs, NOx**

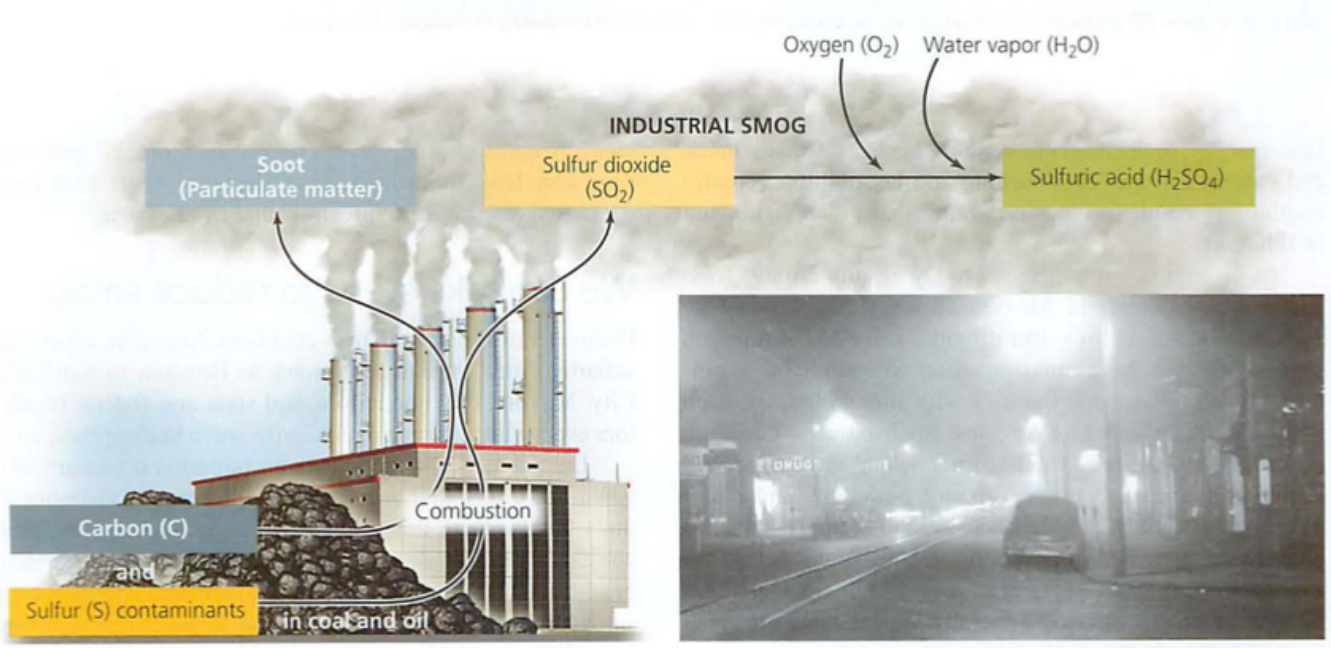
  https://en.wikipedia.org/wiki/Peroxyacyl_nitrates



(a) Formation of photochemical smog

(b) Photochemical smog over Los Angeles

FIGURE 17.17 Photochemical smog results when pollutants from automobile exhaust react amid exposure to sunlight. Nitrogen dioxide, nitric oxide, and VOCs initiate a series of chemical reactions **(a)** that produce a toxic brew of secondary pollutants, including ozone, peroxyacyl nitrates (PANs), and aldehydes. Photochemical smog is common over Los Angeles **(b)** and many other urban areas, especially those with hilly topography or frequent inversions.



(a) Formation of industrial smog

(b) Donora, Pennsylvania, at midday in its 1948 smog event

FIGURE 17.16 Industrial smog results from fossil fuel combustion. When coal or oil is burned in a power plant or factory, soot (particulate matter of carbon) is released, and sulfur contaminants give rise to sulfur dioxide, which may react with atmospheric gases to produce further compounds **(a).** Carbon monoxide and carbon dioxide are also emitted. Under certain weather conditions, industrial smog can blanket whole regions, as it did in Donora, Pennsylvania **(b),** shown in the daytime during its deadly 1948 smog episode.

Thermal inversions: London fog, US, Donora, PA 1948 k.20, sick 7000

- 1952 London 4000-12,000 dead, three nights
- Mexico city 1996 300 dead, 400K sick
- How?
- Normally, the sun heats the surface, warming the air there, which rises. Cooler air aloft then falls to replace this rising air.

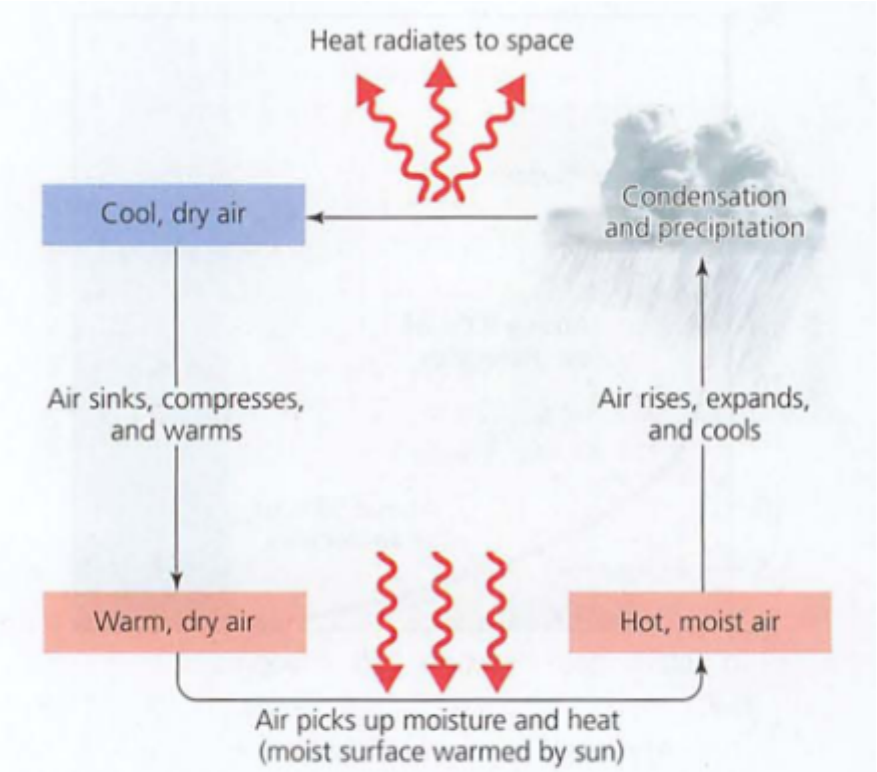


FIGURE 17.4 Convective circulation helps drive weather. Air heated near Earth's surface picks up moisture and rises. Once aloft, this air cools, and moisture condenses, forming clouds and precipitation. Cool, drying air begins to descend, compressing and warming in the process. Warm, dry air near the surface then picks up moisture, beginning the cycle anew.

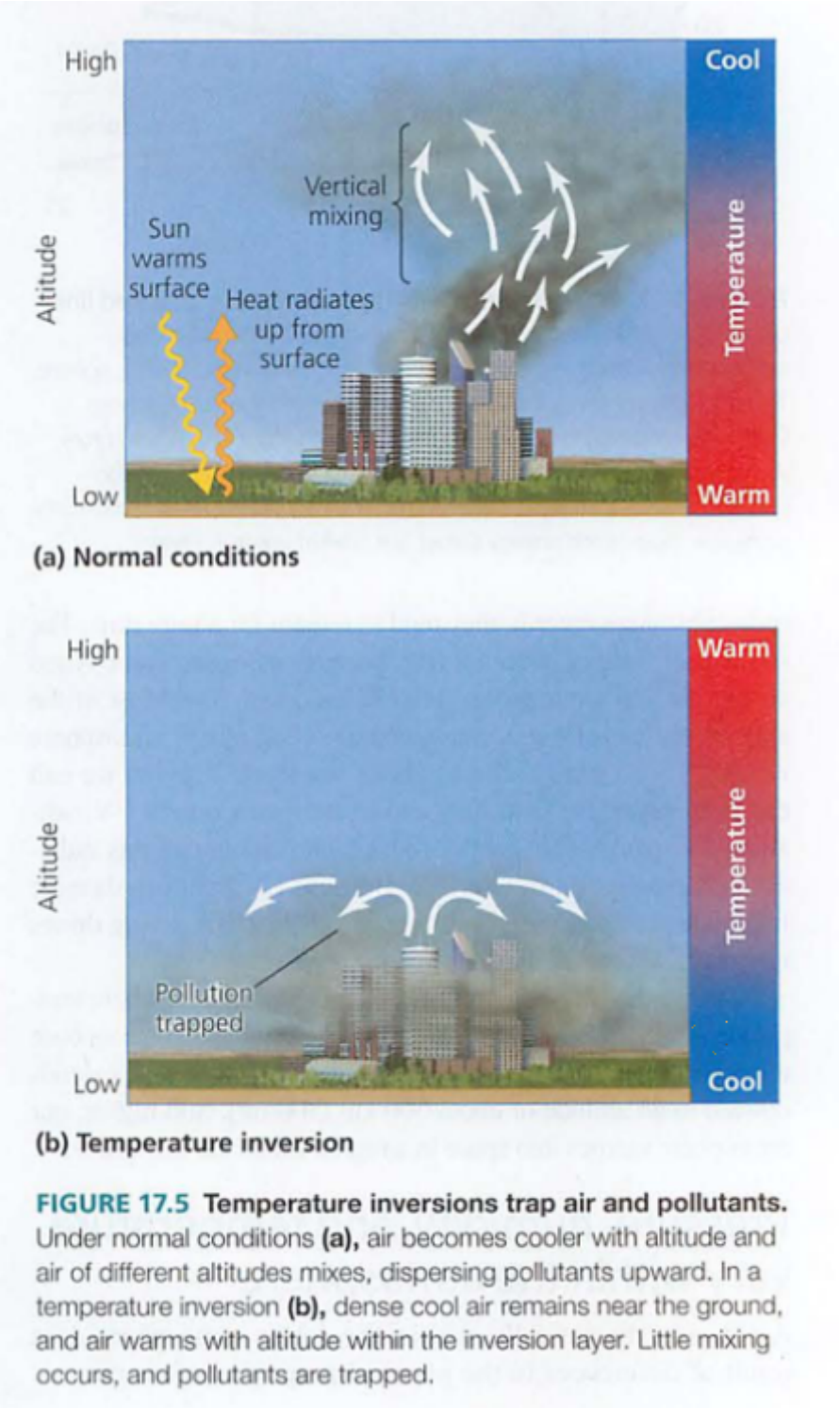


FIGURE 17.5 Temperature inversions trap air and pollutants. Under normal conditions **(a),** air becomes cooler with altitude and air of different altitudes mixes, dispersing pollutants upward. In a temperature inversion **(b),** dense cool air remains near the ground, and air warms with altitude within the inversion layer. Little mixing occurs, and pollutants are trapped.

In an inversion, warmer air aloft traps the air at the surface (no temperature difference, so no convection), causing the pollution to be trapped in the lower levels. Most dangerous in valleys or bowl shaped cities (London, Mexico City, Denver, Donora).

Los Angeles has severe smog in the daytime, when hotter air draws in ocean air ("onshore breeze"), but the cycle reverses at night when the water is warmer than the land, so they have an "offshore breeze". Surfers like the first one.

Another diagram:

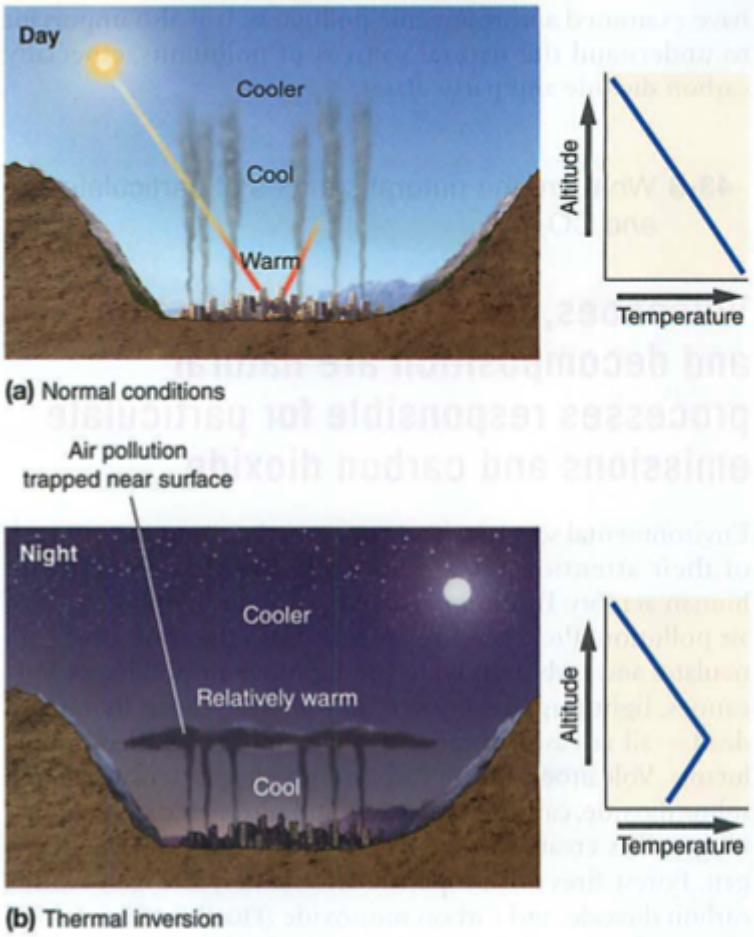
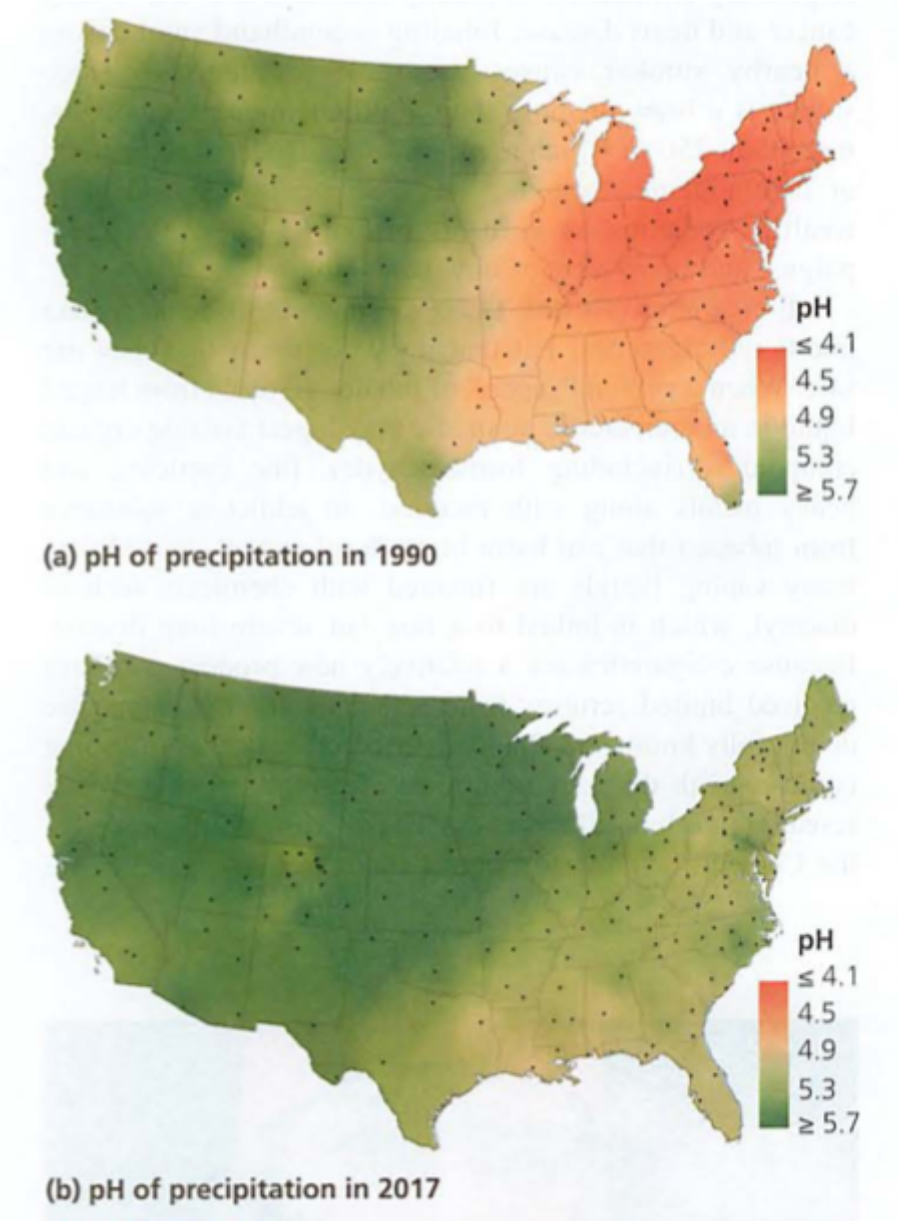


FIGURE 43.4 A thermal inversion. (a) Under normal conditions, where temperatures decrease with increasing altitude, emissions rise into the atmosphere. (b) When a mid-altitude, relatively warm inversion layer blankets a cooler layer, emissions are trapped and accumulate.

Acid Rain and Acid deposition:



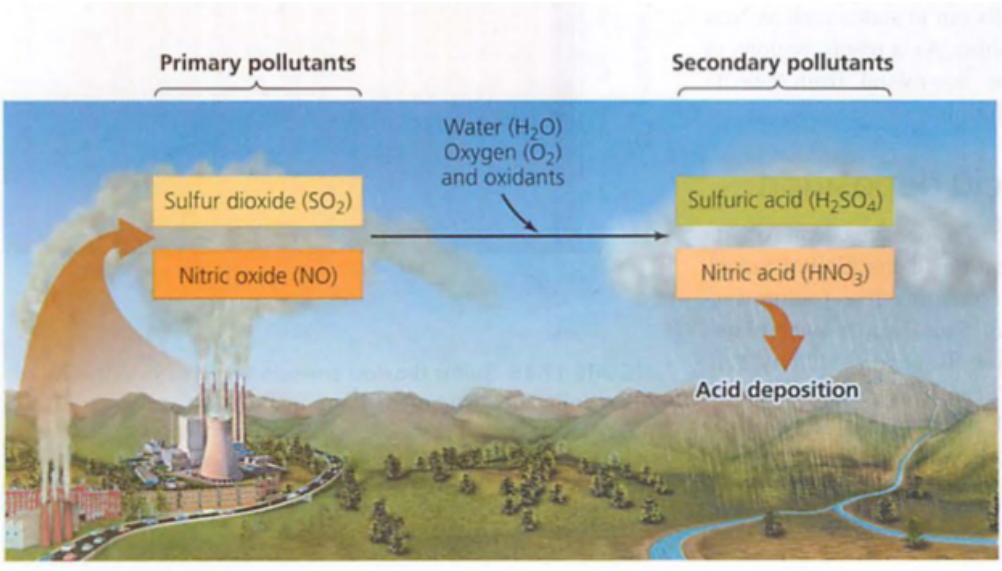


FIGURE 17.23 Acid deposition has impacts far downwind from where pollutants are released. Sulfur dioxide and nitric oxide emitted by industries, utilities, and vehicles react in the atmosphere to form sulfuric acid and nitric acid. These acidic compounds descend to Earth's surface in rain, snow, fog, and dry deposition.

- SO2 + O2, water = H2SO4 (sulfuric acid)
- NO3 + O2, water = HNO3 (nitric acid)
- “Acid snow” yes, acid snow...
- W. VA had rain more acidic than stomach acid in the 1970's

Important: Know how a power plant air scrubber works (just like the nuclear plant diagram)

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