Acid Rain

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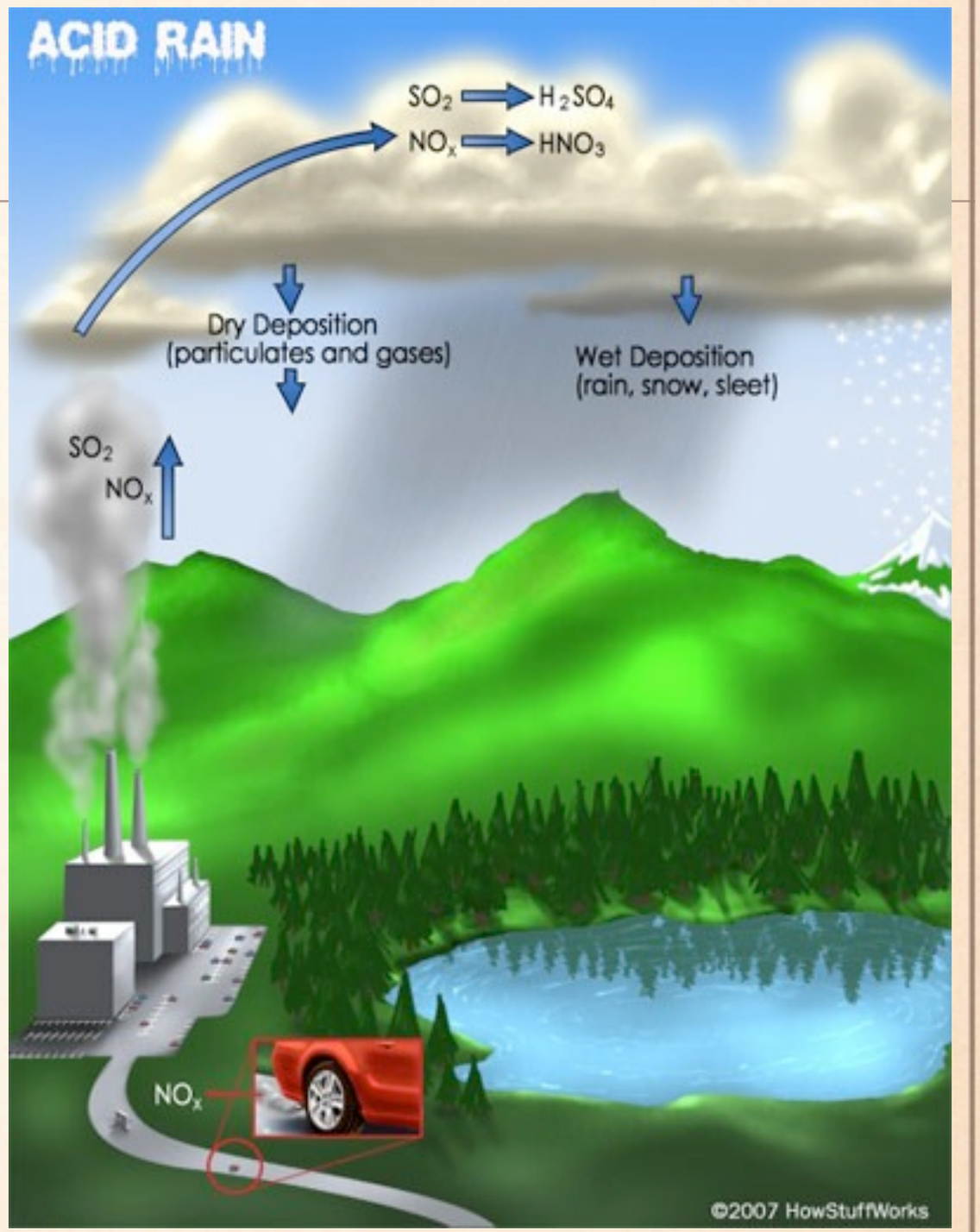
ATOC 3500

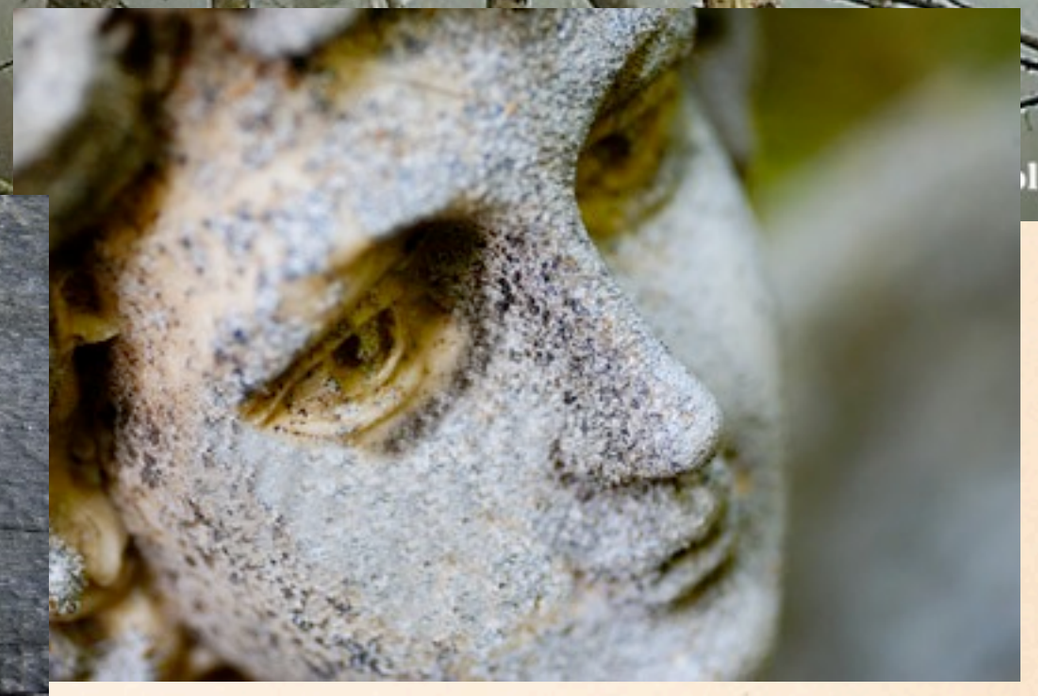
CAUSES

- Natural sources - volcanoes - SO_2

- Emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NOx) react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds. This mixture forms a mild solution of sulfuric acid and nitric acid. Sunlight increases the rate of most of these reactions.

- Electric utility plants account for about 70 percent of annual SO_2 emissions and 30 percent of NOx emissions in the United States. Mobile sources (transportation) also contribute significantly to NOx emissions. Overall, over 20 million tons of SO_2 and NOx are emitted into the atmosphere each year.





EFFECTS

ON WILDLIFE

Acid rain causes acidification of lakes and streams and contributes to damage of trees at high elevations.

Acid rain primarily affects sensitive bodies of water, that is, those that rest atop soil with a limited ability to neutralize acidic compounds (called "buffering capacity").

Many soils contain calcium carbonate or other minerals that can neutralize acid rain before it seeps into lakes and streams

In some sensitive lakes and streams, acidification has completely eradicated fish species, such as the brook trout, leaving these bodies of water barren.

Acid rain leaches calcium from the needles of red spruce, making them more susceptible to cold. It also leaches calcium and magnesium from the soil, which can stress sugar maples.

In addition, acid rain allows aluminum to accumulate in the soil. When trees take up aluminum, their roots can become brittle.

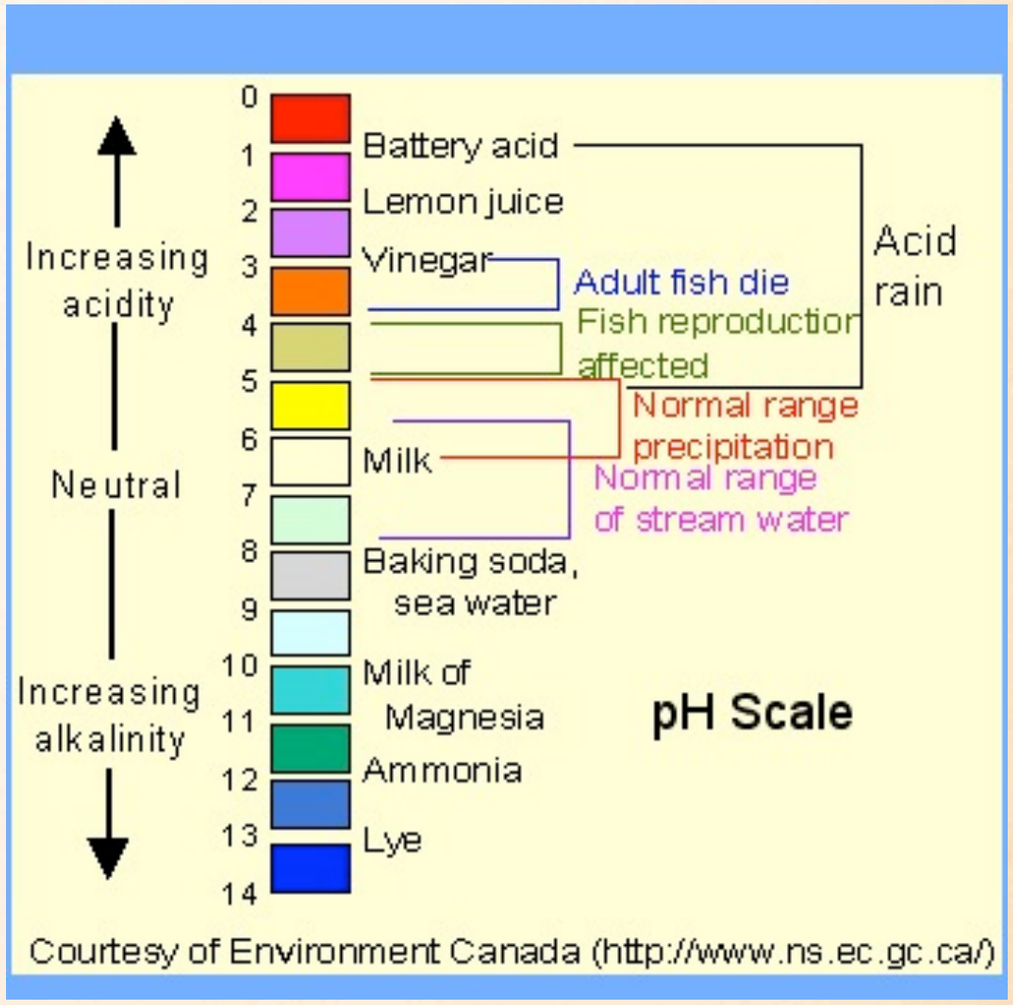
ON METALS AND HUMANS

- Corrosion of stone buildings and monuments

$$CaCO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Ca^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + H_2O + CO_2$$

- Prior to falling to the earth, SO2 and NOx gases and their particulate matter derivatives, sulfates and nitrates, contribute to visibility degradation and impact public health.

- Although Acid rain is not directly harmful to humans, inhaling SO2 and NOx are harmful to the lungs and can cause disease and premature death.



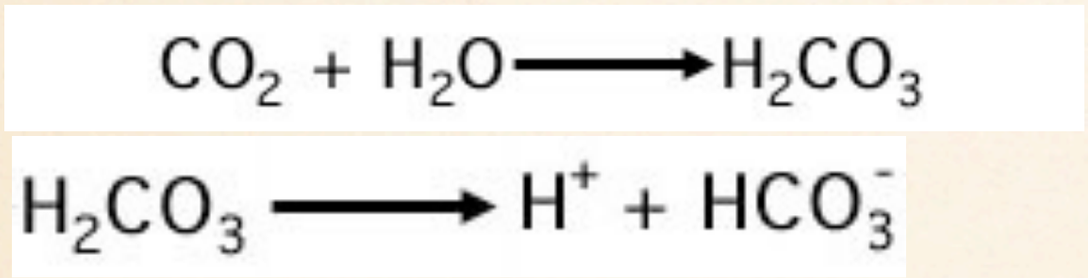
Gas	Natural Sources	Concentration
Carbon dioxide CO_2	Decomposition	355 ppm
Nitric oxide NO	Electric discharge	0.01 ppm
Sulfur dioxide SO_2	Volcanic gases	0-0.01 ppm

Table 1

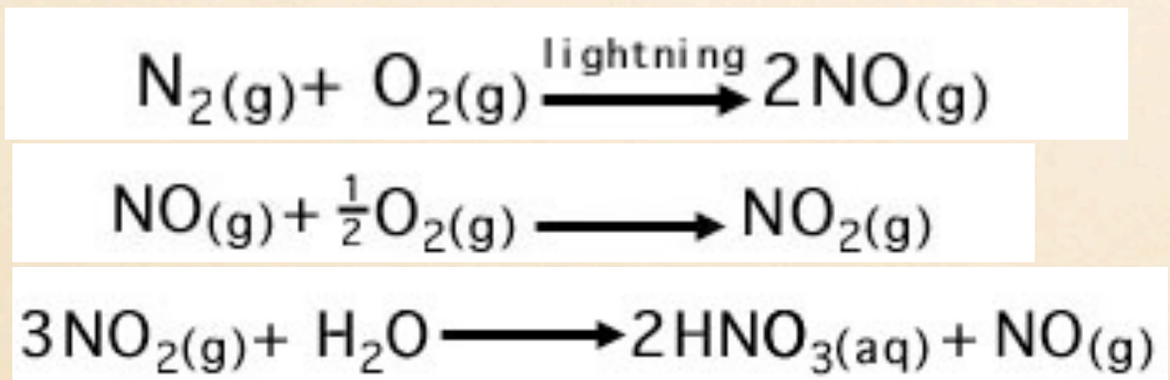
Carbon dioxide, produced in the decomposition of organic material, is the primary source of acidity in unpolluted rainwater.

NOTE: Parts per million (ppm) is a common concentration measure used in environmental chemistry. The formula for ppm is given by:

Natural Sources



Carbon Dioxide

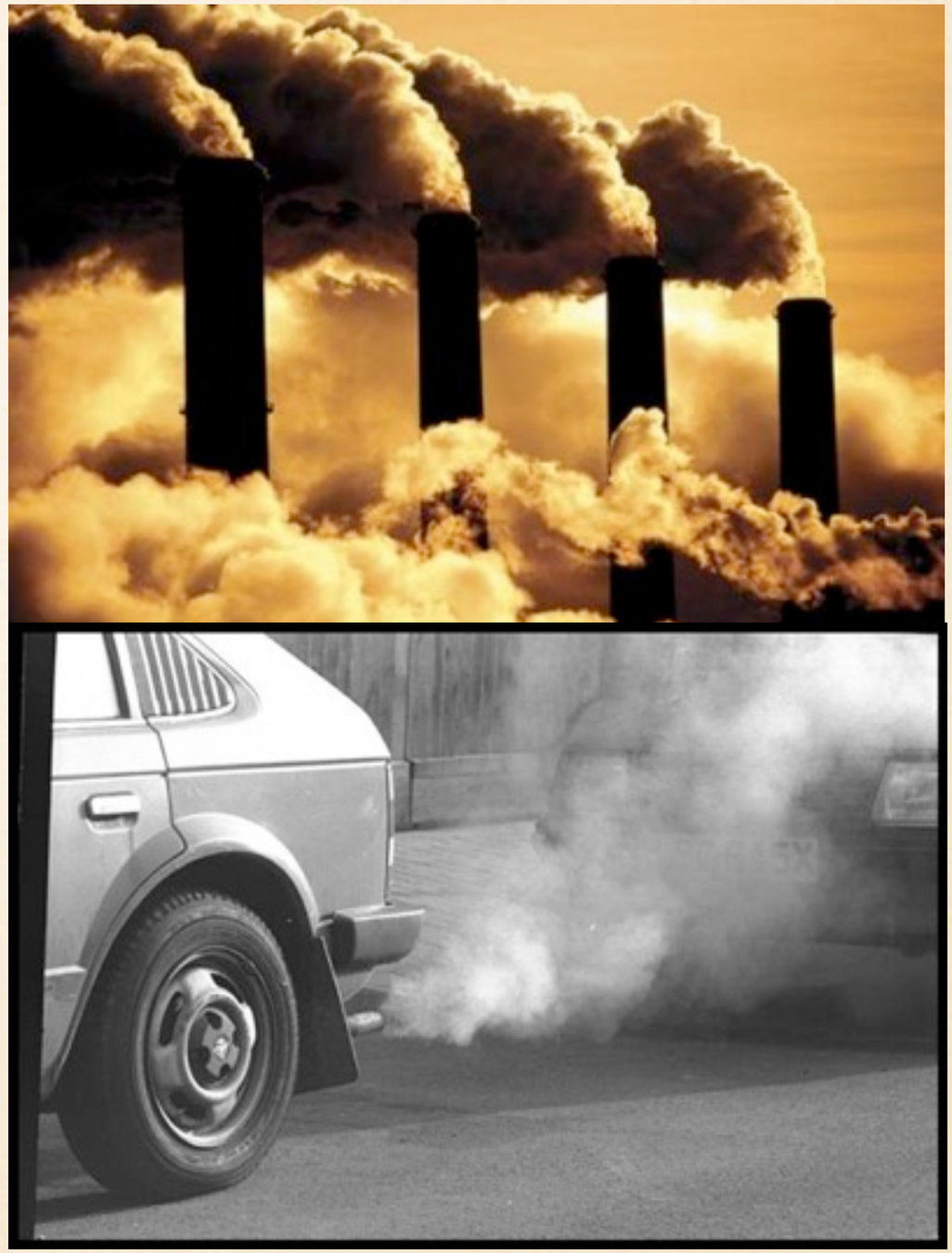


Nitric Oxide

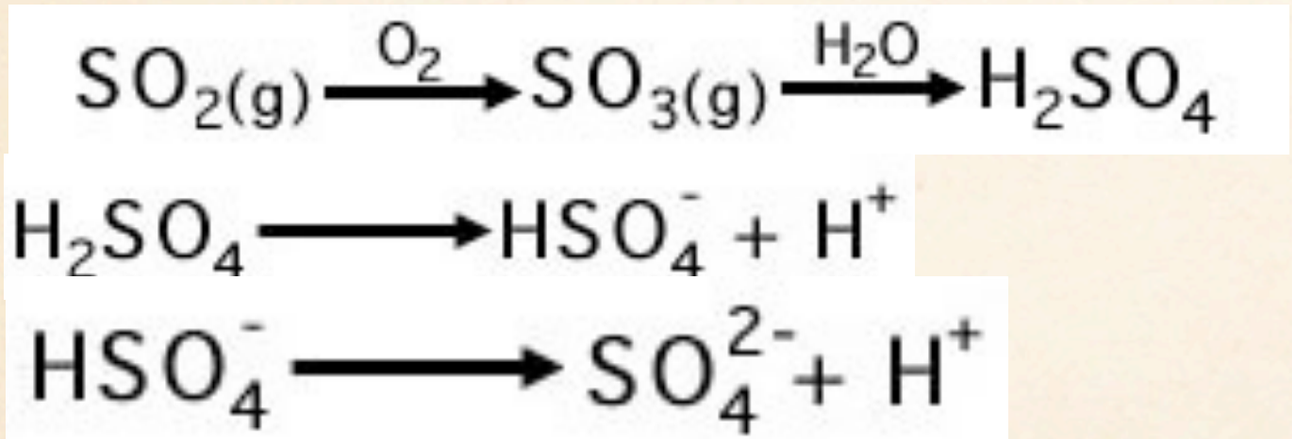
Gas	Non-Natural Sources	Concentration
Nitric oxide NO	Internal Combustion (cars)	0.2 ppm
Sulfur dioxide SO_2	Fossil-fuel Combustion	0.1 - 2.0 ppm

Table II

Humans cause many combustion processes that dramatically increase the concentrations of acid-producing oxides in the atmosphere. Although CO_2 is present in a much higher concentration than NO and SO_2, CO_2 does not form acid to the same extent as the other two gases. Thus, a large increase in the concentration of NO and SO_2 significantly affects the pH of rainwater, even though both gases are present at much lower concentration than CO_2.



Non-Natural Sources



Sulfuric Acid

Nitric Acid

In addition to the natural processes that form small amounts of nitric acid in rainwater, high-temperature air combustion, such as occurs in car engines and power plants, produces large amounts of NO gas.

Resolved?

Congress passed several amendments to the Clean Air Act in 1990 that cut emissions of sulfur dioxide through a cap-and-trade scheme. The goal was a 50 percent reduction in sulfur dioxide emissions from 1980 levels. That goal was achieved in 2008, two years before the deadline, which was set for 2010. Sulfur dioxide emissions fell from 17.3 million tons in 1980 to 7.6 million tons in 2008, less than the 8.95 million tons required by 2010.

Researchers are trying to add calcium back to the forests, but it is proving difficult as it takes a long time for the calcium to get back into the soil.

Limestone or lime (a naturally occurring basic compound) can be added to acidic lakes to "cancel out" the acidity. This process, called liming, has been used extensively in Norway and Sweden, and is considered a short-term remedy in only specific areas, rather than an effort to reduce or prevent pollution.

Power plant and factory chimneys can be fitted with scrubbers that release 90-95% sulfur free smoke and also produces sludge from which gypsum, a building material, can be produced.

Similar to scrubbers on power plants, catalytic converters reduce NOx emissions from cars.

Current Issues

HCFCs

-hydrochlorofluorocarbons (HCFCs) emerged as CFC replacements because they do not damage the ozone layer.

- however they create acid rain through the formation of oxalic acid.
  - $C_2O_4H_2$, $C_2O_2(OH)_2$, or HOOCCOOH

- HCFCs act like super greenhouse gases, 4,500 times more potent than carbon dioxide.

Works Cited

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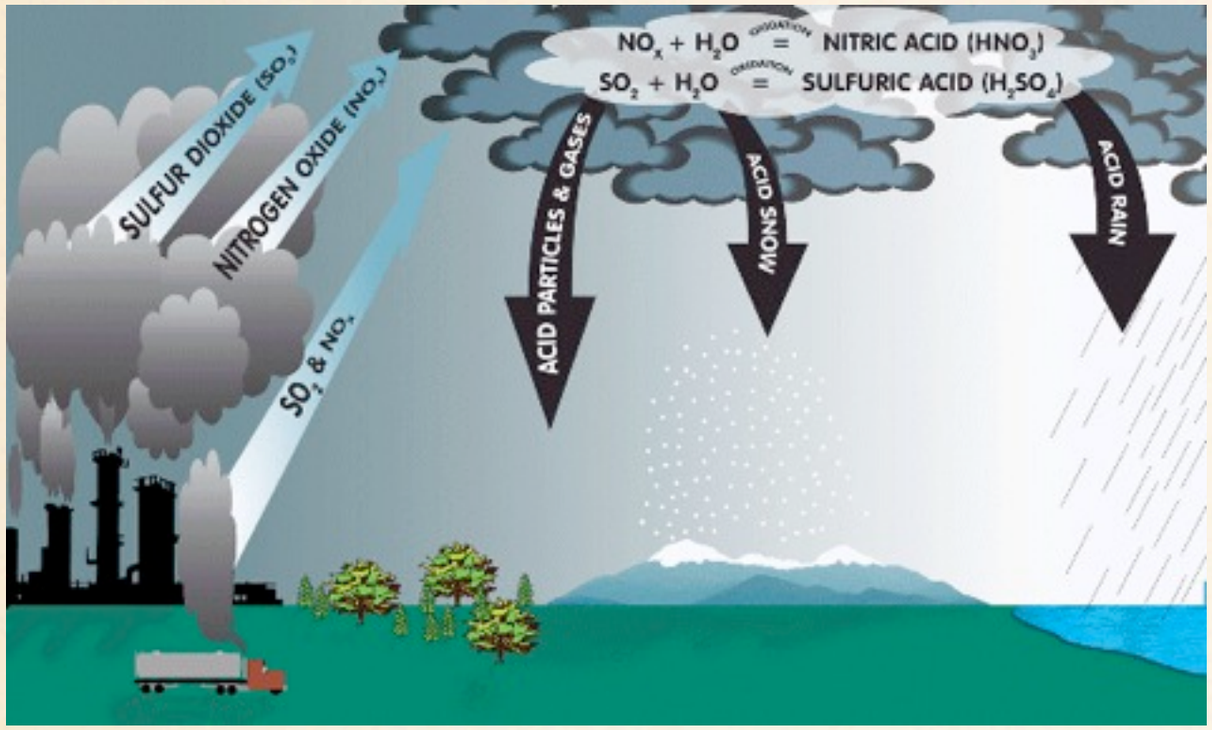
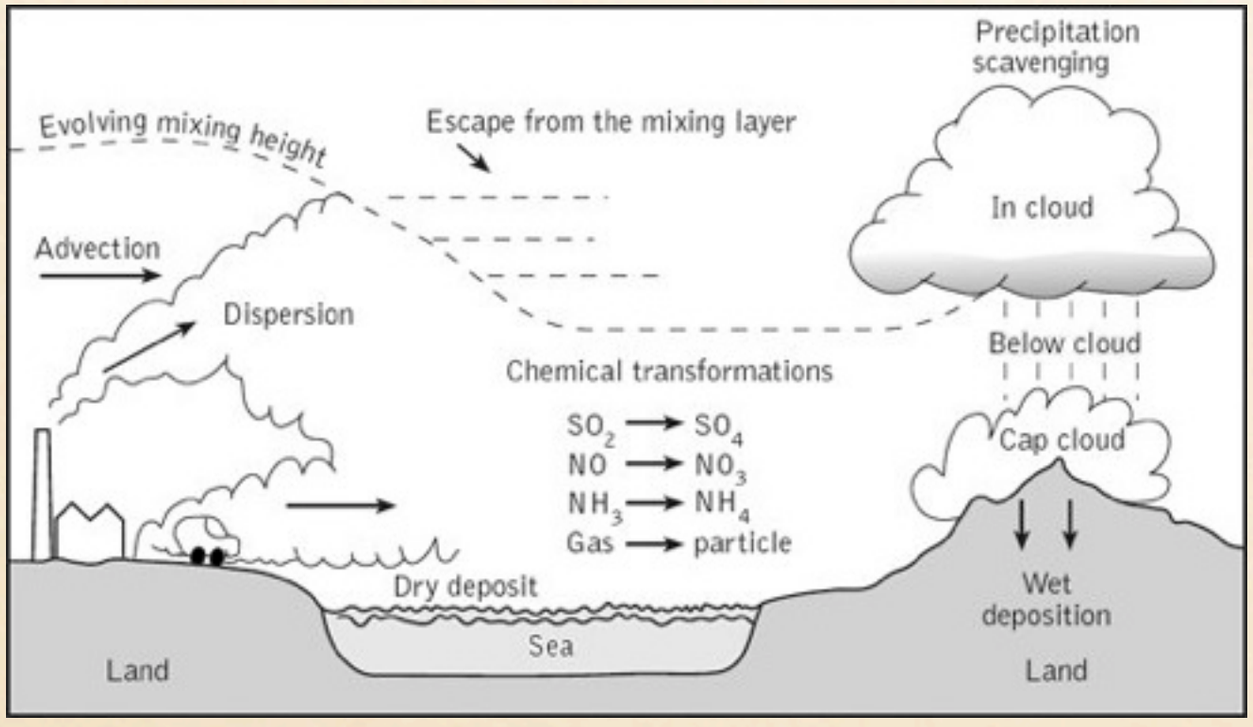
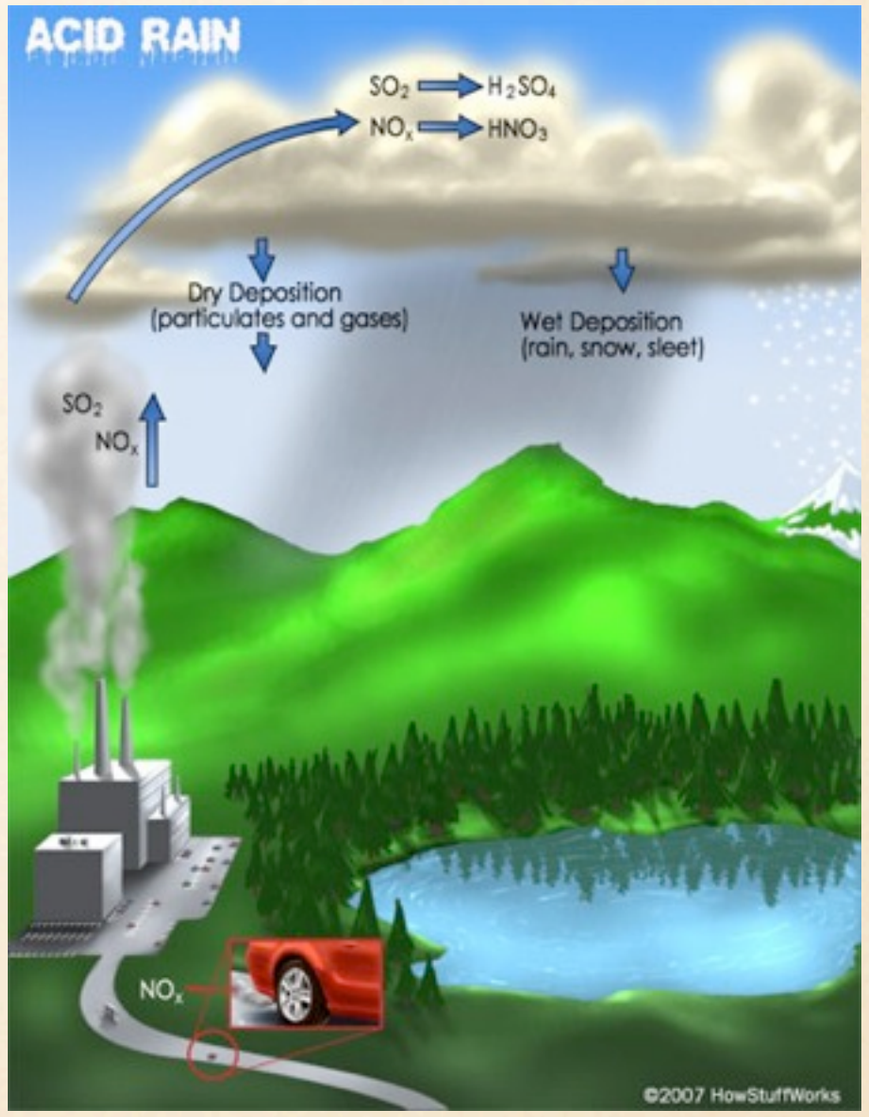

$NO_x + H_2O \xrightarrow{\text{OXIDATION}} NITRIC\ ACID\ (HNO_3)$
$SO_2 + H_2O \xrightarrow{\text{OXIDATION}} SULFURIC\ ACID\ (H_2SO_4)$
SULFUR DIOXIDE (SO_2)
NITROGEN OXIDE (NO_x)
SO_2 & NO_x
ACID PARTICLES & GASES
ACID SNOW
ACID RAIN

Questions?


Precipitation scavenging
Evolving mixing height
Escape from the mixing layer
In cloud
Advection
Dispersion
Below cloud
Chemical transformations
$SO_2 \rightarrow SO_4$
$NO \rightarrow NO_3$
$NH_3 \rightarrow NH_4$
Gas → particle
Cap cloud
Dry deposit
Wet deposition
Sea
Land
Land


ACID RAIN
$SO_2 \rightarrow H_2SO_4$
$NO_x \rightarrow HNO_3$
Dry Deposition (particulates and gases)
Wet Deposition (rain, snow, sleet)
SO_2
NO_x
NO_x
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