The Atmosphere & Air Pollution

Importance of The Atmosphere:

- ✓ The *atmosphere surrounds us* at every moment like an ocean of air, keeping us alive. It is responsible for our blue skies and for all of our weather
- ✓ The atmosphere is a protective blanket which nurtures life on the Earth and protects it from the hostile environment of outer space by absorbing most of the harmful cosmic rays from outer space and most of the electromagnetic radiation from the sun.
- ✓ The atmosphere is a source of carbon dioxide for plant photosynthesis and of oxygen for respiration.
- ✓ It provides nitrogen for nitrogen -fixing bacteria and ammonia-manufacturing plants to produce chemically bound nitrogen, which is an essential component of life molecules.
- ✓ Water vapor absorbs infrared radiation even more strongly than does carbon dioxide, thus water vapor in the atmosphere acts as a kind of "blanket" at night.
- ✓ ***Unfortunately, due to increase in industrial activity the atmosphere is used as dumping place for many pollutant materials, and pollution alters the characteristics of the atmosphere itself***.

Physical Characteristics of The Atmosphere:

There are the 5 most abundant gases in the earth's atmosphere.

Major Constituents:

Nitrogen, 78.08% (by volume)
Oxygen, 20.95%
Water vapor, 0 – 3 or 4%
Argon, 0.934%
carbondioxide, 0.035%

Major Regions Of The Atmosphere:

Major regions of atmosphere and their characteristics

Region	Altitude range Km	Temperature range ° C	Significant chemical species
Troposphere	0 – 11	15 to -56	N_2, O_2, CO_2, H_2O
Stratosphere	11 – 50	-56 to –2	O_3
Mesosphere	50 -85	-2 to –92	O_2^+, NO^+
Thermosphere	85 -500	-92 to 1200	O_2^+, O^+, NO^+

Troposphere: The lowest layer of earth from sea level to an altitude of 10 to 16 km is called the troposphere.

- In the troposphere, the temperature generally decreases with altitude. The reason is that the troposphere's gases absorb very little of the incoming solar radiation. Instead, the ground absorbs this radiation and then heats the tropospheric air by conduction and convection. *Temperature decreases with altitude (6 °C per kilometer).*

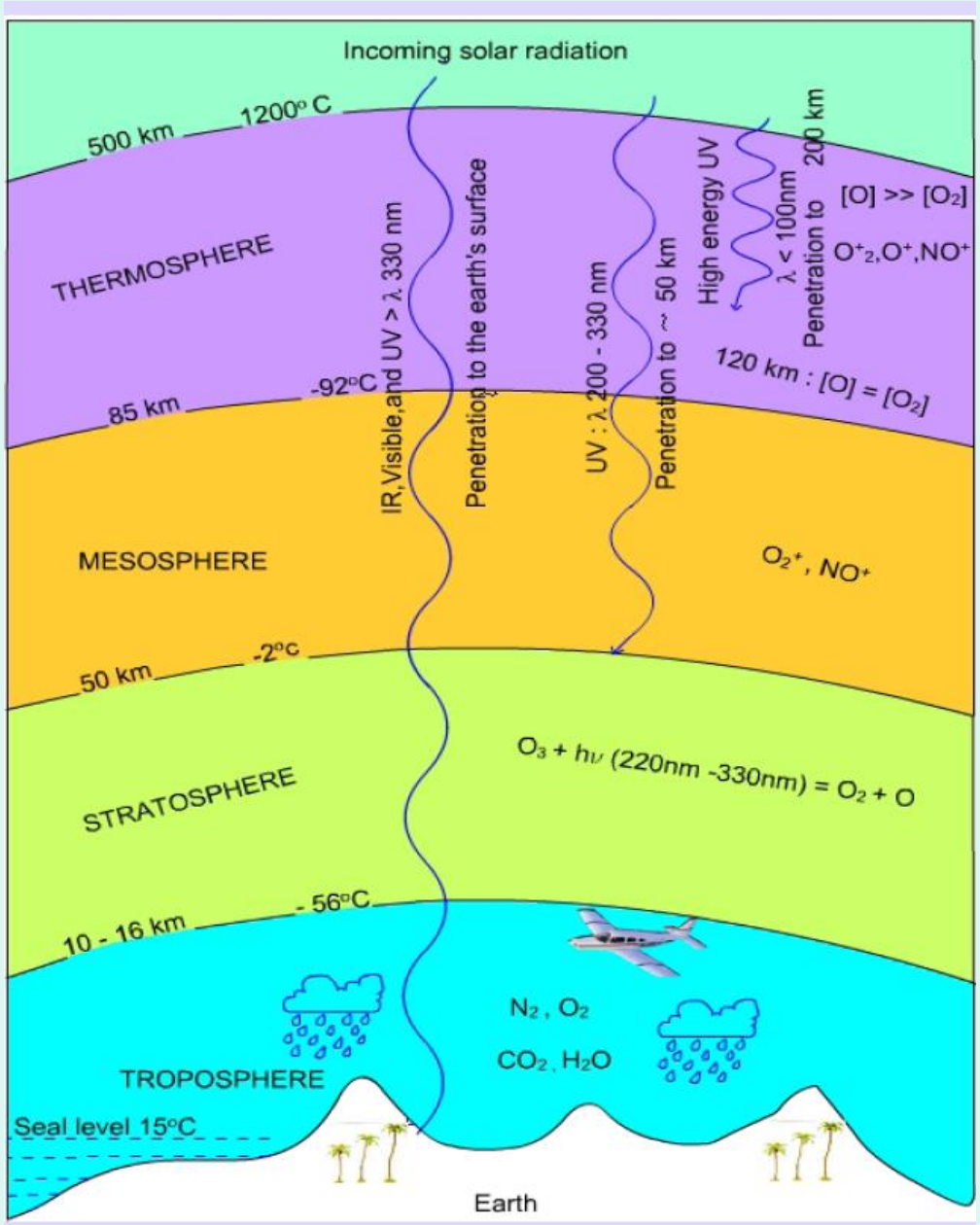


Fig 1 Major regions of the atmosphere

Troposphere

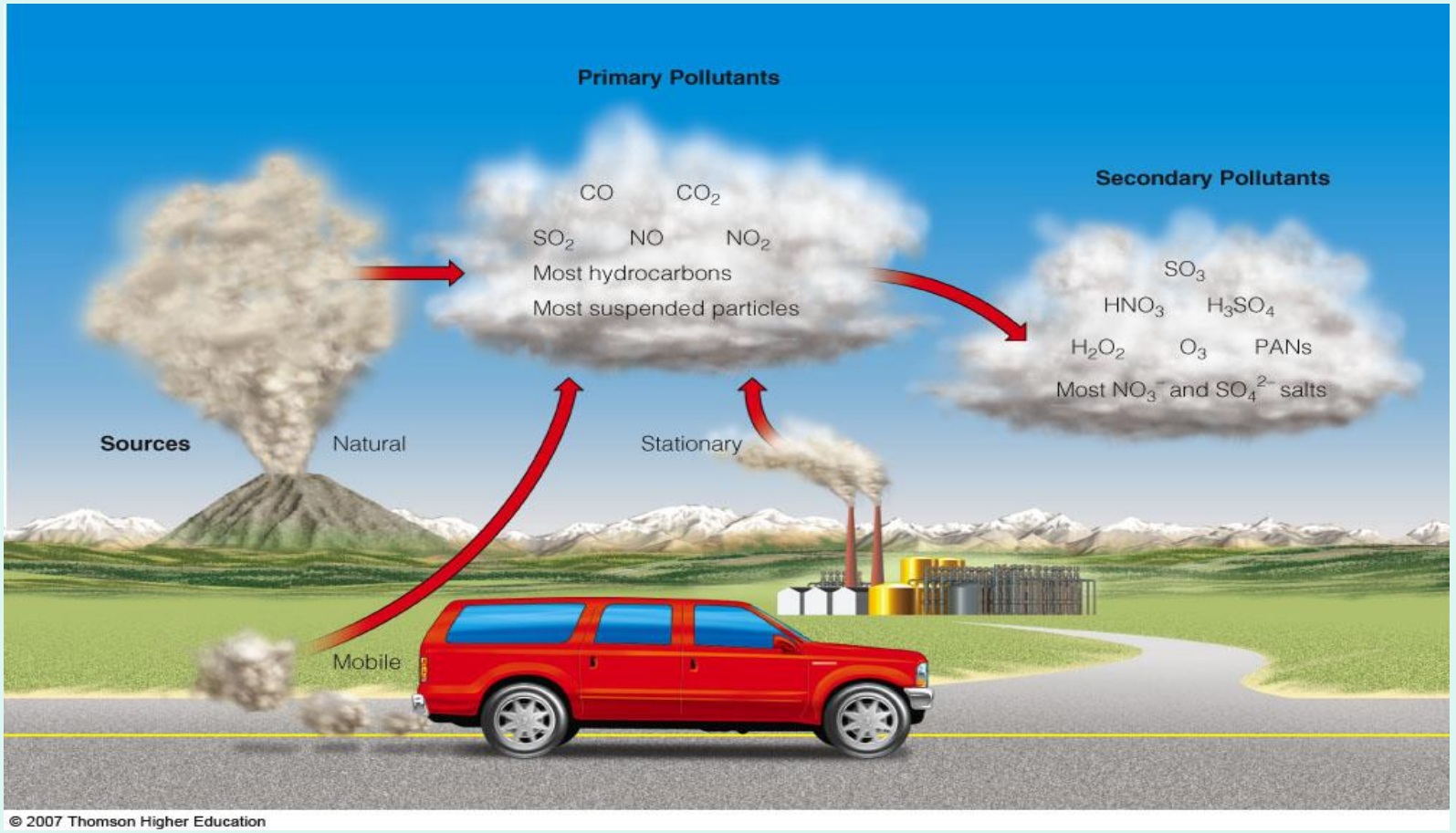
- The very cold layer at the top of troposphere is known as tropopause.
- Its low temperature and resulting condensation of water to ice particles prevents water from reaching altitudes at which it would photo dissociate through the action of intense UV light.
- If this happens, the hydrogen produced would escape the earth's atmosphere.

Stratosphere:

- The atmospheric layer directly above the troposphere is called the stratosphere.
- In this layer the temperature increases with increase in altitude, with a maximum of -2^{o}C at the upper limit of stratosphere.
- The heating effect is caused by the absorption of ultraviolet radiation energy by ozone. Ozone absorbs ultraviolet radiation with wavelengths as long as 290 nm. This radiation causes the ozone to decompose into O_2 molecules and oxygen atoms.

- The ozone layer in the stratosphere thus acts as a protective shield for life on earth from the injurious effects of sun's ultraviolet rays
- The radiation is lethal to unicellular organisms to (algae, bacteria, protozoa) to the surface cell of higher plants and animals.

AIR POLLUTION



- Stationary vs. mobile sources
- Natural sources (volcanoes, dust, fires, pollen, salt, VOCs)
- Primary vs. secondary pollutants

Carbon Monoxide

- ***CO is formed by incomplete combustion of carbon-containing materials*** (fossil fuels)
- Odorless, colourless
- it affects humans – hampers transportation of O_2 in blood
- **Exposure** to significant amount of CO can lower O_2 levels to the point that loss of consciousness and death can result.

A person breathing air that is only 0.1% CO for just a few hours can reduce the blood's normal oxygen capacity to 60%.

- **SOURCES INCLUDE**:

MOTOR VEHICLE EXHAUST, BURNING OF FORESTS/GRASSLANDS, TOBACCO SMOKE, COOKING WITH OPEN FIRES, INEFFICIENT STOVES

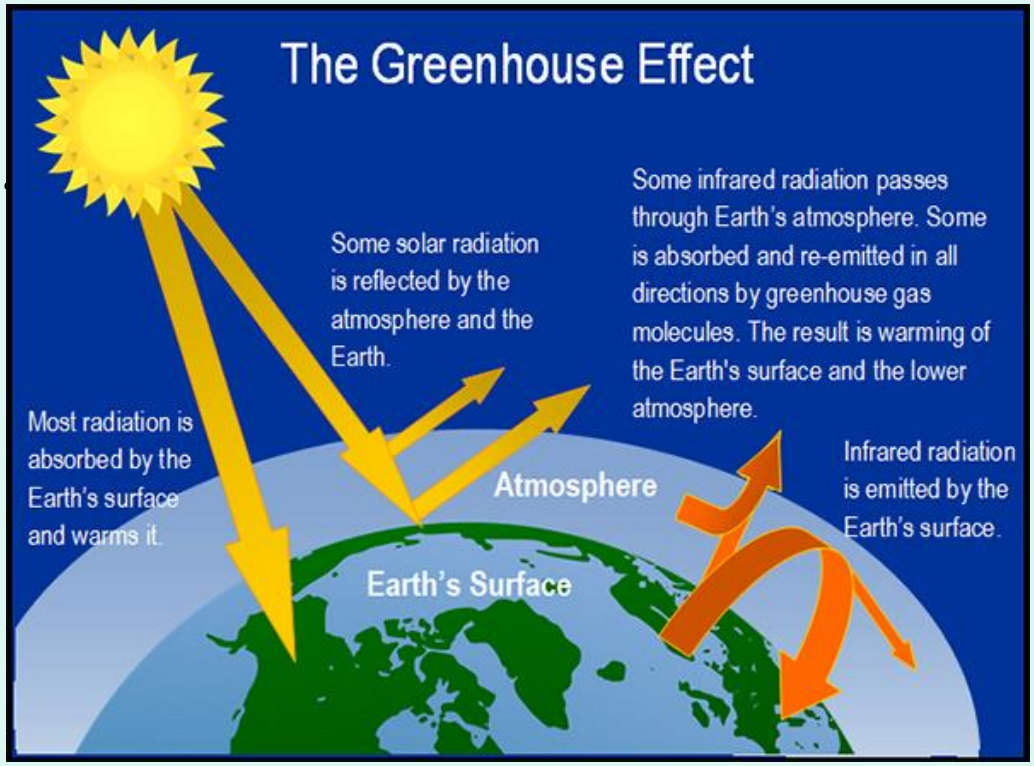
CARBON DIOXIDE

- ***CO2 is formed through complete combustion of carbon-containing materials*** (fossil fuels)
- S/B REGULATED BECAUSE CO2 IS BEING ADDED TO THE ATMOSPHERE FASTER THAN C CYCLE CAN REMOVE IT

Greenhouse gases and its effect

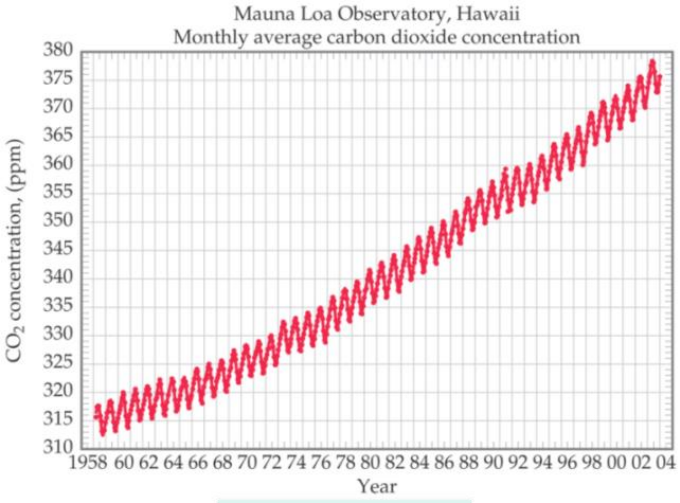
- The Greenhouse Effect is a naturally occurring phenomenon necessary to sustain life on earth.
- the greenhouse effect, is what makes the earth habitable for life
- It is because of this greenhouse-like function of the atmosphere that the average global temperature of the earth is 15°C (59 ° F).
- Without the atmosphere and these gases, the average global temperature would be a frigid -18 ° C (0 ° F), and life would not be possible on earth.
- The earth's atmosphere contains trace gases, some of which absorb heat. These gases (water vapor, carbon dioxide, methane, ozone, and nitrous oxide) are referred to as "greenhouse gases."

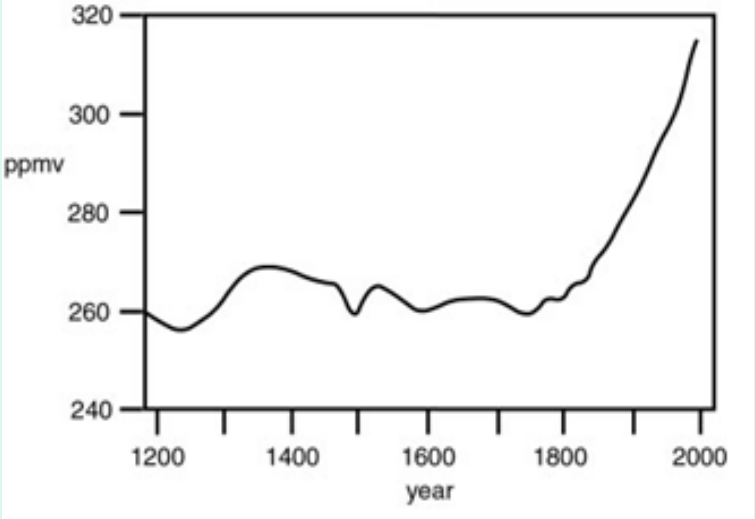
- Short-wave radiation from the sun passes through the earth's atmosphere and hits the ground.
- Most of this radiation is absorbed by land, oceans, and vegetation at the surface, the visible light is transformed into heat and radiates in the form of invisible infrared radiation (which heats the atmosphere by conduction and convection.)



- Some of the outgoing long-wave radiation is absorbed by the green house gases in the atmosphere and trap it;
- Other portion is reflected back into space.
- Green house gases are able to hold it in and re-radiate back the absorbed heat to the surface and we feel the heat.
- This blanketing effect is the **"greenhouse effect."**

Green house Effect of Carbon Dioxide





Is the greenhouse effect real?

_ Polar ice is disappearing, and polar bears are having trouble finding food.

_ many low lying countries (Bangladesh) will submerge If sea level rises by 5-12 ft.

_ Since CO2 dissolved in water, The oceans are the largest carbon sink in the world. Extra carbon has already lowered the pH of ocean water

_ doubling of the atmospheric CO_2 concentration is likely to lead to a 3.0 $\pm$ 1.5°C increase in the atmospheric temperature;

Given that the flow of oxygen into and out of the Earth's atmosphere is 3×10^{14} kg/year, what is the residence time of oxygen in the Earth's atmosphere?

Photosynthesis (the INPUT of O_2 to the atmosphere) + Outputs (respiration)

- ***At 15 ℃ and 1 atmospheric*** pressure, ***volume of the atmosphere is 4.3 x 10^{21} L***
- **At NTP** (at ***0 ℃ and 1 atmospheric*** pressure), **1 mol of a gas occupy 22.4 lit**.

Ans : $t = \dfrac{M}{F}$

F = flow rate = input or output rate = total mass of the element per unit time , ie., oxygen enters and leaves atmosphere at a rate of 3×10^{14} Kg/year

Since unit of ***F is in 3 x 10^{14} is in Kg, therefore we will need to convert M in Kg/year.***

∴ Mass of oxygen in Kg ⇒

$$(4.3 \times 10^{21}\ \text{L})(0.21)\left(\frac{\text{mol}}{22.4\text{L}}\right)\left(\frac{273}{288}\right)\left(\frac{32\text{g}}{\text{mol}}\right)\left(\frac{\text{kg}}{10^3\text{g}}\right)$$

L to Kg conversion

$= 1.2 \times 10^{18}$ Kg

∴ Residence time = (1.2 x 10^{18} Kg years) ÷ (3 x 10^{14} Kg)

= 0.40 x 10^4 years = 4000 years

Major Air Pollutants

- ***Ozone (O_3)***:

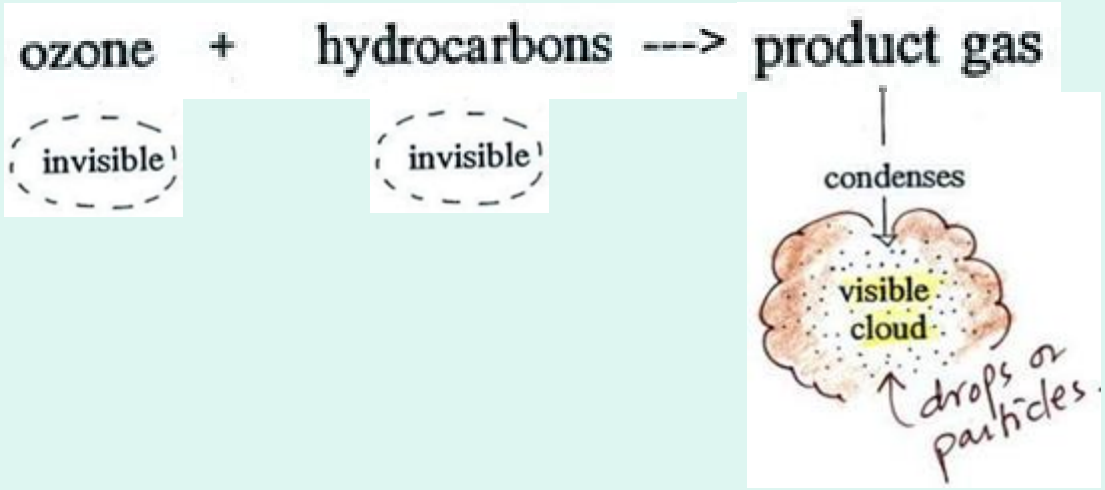
Reactions forming ozone & Photochemical Smog

$N_2 + O_2$ + high temp → 2NO (reaction in engines)

$2NO + O_2 \rightarrow 2NO_2$

$NO_2 + h\nu \rightarrow NO + O$ (photodissociation by sunlight of wavelength 393 nm)

$O + O_2 \rightarrow O_3$



- It is visible as a brown haze, and
- Cities that experience this smog daily include Los Angeles, Sydney, Mexico City, Beijing, and many more.

Photochemical Smog appears as brown haze

Health Effect of Ozone

- Ozone acts as a powerful respiratory irritant
- Long-term, repeated exposure to high levels of ozone may lead to large reductions in lung function, inflammation of the lung lining, and increased respiratory discomfort.

- **No need to memorize, ONLY for your information**

Major Air Pollutants

- ***Nitrogen oxides and nitric acid***:
  - Nitrogen oxide (NO) - forms when nitrogen and oxygen gas in air react at high-combustion temperatures in automobile engines and coal-burning plants. NO can also form from lightning and certain soil bacteria
  - NO reacts with air to form NO_2
  - ***NO_2 reacts with water vapor in the air to form nitric acid (HNO_3)*** and nitrate salts (NO_3^-) which are components of acid deposition.

Health Effect of Nitrogen Oxides

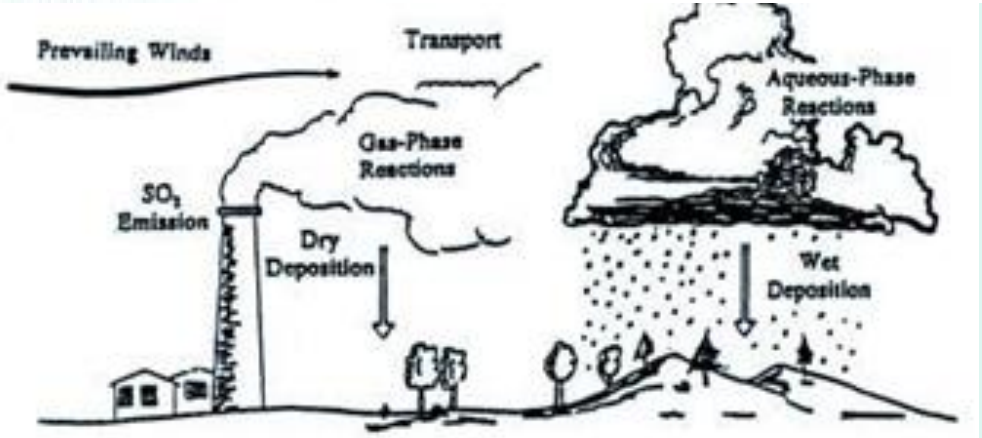
- Short term exposure to >3ppm - decrease lung function
- Prolonged exposure destroy lung
  - **No need to memorize the "health effect", ONLY for your information**

Major Air Pollutants : *Sulfur dioxide (SO_2)*

- come from human sources, from sulfur-containing coal and from oil refining and smelting of sulfide ores.
- SO_2 in the atmosphere can be converted to sulfuric acid (H_2SO_4) and sulfate salts (SO_4^{2-}) that return to earth as a component of acid deposition.
- Causes classical smog

Sulfur and Acid Rain

Acid rain was first observed in Scandinavia in the 1950s; in the United States in the 1960s.



SO_2 is converted to sulfuric acid, H_2SO_4, in clouds and falls to the ground as acid rain.

Effects of Acid rain

(1) can upset the ecology in lakes and streams. Fish can't live in water with pH < 4.5.

(2) Attacks plant foliage and roots:

Removes the protective coating on leaves. Plant becomes susceptible to pests, disease, and other pollutants such as ozone.

Dissolves and carries away nutrients in the soil. Also dissolves toxic materials that enter roots and water supply

(3) Damages materials, especially stone monuments and buildings.

$$CaCO_3(s) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + H_2O + CO_2(g)$$

limestone, marble	sulfuric acid	gypsum slowly dissolved by rain water.

London smog (classical smog), 1952

The Great London smog is still one of the two or three deadliest air pollution events in history.

- London, England, 1952, from December 5 to 8.
- Killed at least 4000 Londoners
- 8000 additional people died in the following weeks and months
- 700 death: London 1962

Most of the deaths were caused by *hypoxia (deficiency in the amount of oxygen reaching the tissues) which led to respiratory tract infections*

The Role of SO_2 in London Smog

i) Early in the morning during winter after LONGER NIGHTS, before sun rises
ii) Winds are calm
iii) Clear sky
iv) Since there is no up and down motion of air. Hence, SO_2, get stuck in the in the layer near surface (as there is no air motion). SO_2 concentration build up.

Q. The New Jersey Power Company PSE&G has determined that for every 10,000 kW it generates, it must burn approximately 2000 g of coal. The coal used at this particular facility is a form of bituminous coal with the approximate chemical formula $C_{100}H_{85}S_{2.1}N_{1.5}O_{9.5}$. As an engineer, you have been asked to calculate the amount of CO_2 and SO_2 discharged into the atmosphere.

ANS: The molecular weight is determined from the molecular formula:
MW = (100) (12.00) + (85)(1.000) + (2.1)(32.06) + (1.5)(14.00) + (9.5)(16.00) = 1525 g/mol

Assuming complete combustion, the stoichiometric equation for the combustion of the coal can now be written:

$$C_{100}H_{85}S_{2.1}N_{1.5}O_{9.5} + 120.1O_2 \rightarrow 100CO_2 + 42.5H_2O + 2.1SO_2 + 1.5NO_2$$

1525 g of coal produces $\rightarrow$ 100 × 44 g of CO_2

1 g of coal produces $\rightarrow$ (100 × 44) ÷ 1525 g of CO_2

2000 g of coal produces $\rightarrow$ (100 × 44 × 2000) ÷ 1525 g of CO_2

= 5770 g of CO_2

Major Air Pollutants

Suspended particulate matter (SPM):

- small and light enough to remain suspended in the air

Examples include

small particles (liquid or solid)
- smoke or soot
- chemicals
- metals
- soil, dust, pollen

- ***The most harmful forms of SPM are fine particles (PM-10, with an average diameter < 10 micrometers) and ultrafine particles (PM-2.5)***
- ***Causes bronchitis, mutations, reproductive problems***

The following numerical problem has been EXCLUDED from syllabus

Q. A power plant generates 2.76 x 10^5 megawatt hours (MWh) of electricity per year by burning 1.66 x 10^5 tons of a low-grade coal containing 3.2% sulfur and 15.4% ash. The ratio of fly ash to bottom ash is 0.65 and the plant's efficiency is 85%. Determine the amount of each particulates emitted per year.