Department of Mathematics and Natural Science
CHE 101: Introduction to Chemistry

Environmental Chemistry

Environmental Chemistry

Content:

- Environments and its chemistry
- Environmental Pollution and Its sources
- Types of environmental pollution and their effects
- Atmospheric Chemistry, Aerosols
- Influence of CFC gases
- Creation of ozone hole
- Green house effects

Environment

The **surroundings** or **conditions** in which living organism is present is called environment.

Environmental Segments

Four segments-

- **Atmosphere**- above 500 – 1200 Km from surface
- **Hydrosphere**- water content above and below surface
- **Lithosphere**- minerals and soil
- **Biosphere**- covers all living organism

Anthrosphere

- consists of the things **humans construct, use, and do** in the environment
- Often not acknowledged as one of the environmental spheres
- But it is very important to consider it as fifth sphere.

Planet Earth:

- is composed of numerous minute substances and particles which are involved in reactions leading to the formation of new ones.

- Hence, the Earth is said to be a closed system and the energy comes and leaves the planet, of which most of the mass stays here.

- This means that all the elements on this planet are continuously recycled within the environment.

- For example, consider free oxygen molecules that were floating in the atmosphere yesterday and **it might be the part of someone's hamburger** the next day.

- It's all up to the chemists to study these cycles and watch their movements.

Environmental Chemistry: Definition

- is the scientific study of the biochemical and chemical phenomena that occur in natural places.

- Environmental chemistry is a study that is more than air, water, soil, and chemicals.

- This field **uses various techniques of biology, maths, genetics, engineering, hydrology, toxicology**, etc. that will help to fetch an answer to all the questions related to the environment.

- Environmental chemistry also contains aspects of analytical chemistry, physical chemistry, organic chemistry & inorganic chemistry

- as well as more diverse areas, such as epidemiology, public health, biochemistry, biology, & toxicology.

Environmental chemists are responsible for…

- finding how the unpolluted environment functions and

- finding ways of sustainable development which do not harm the environment

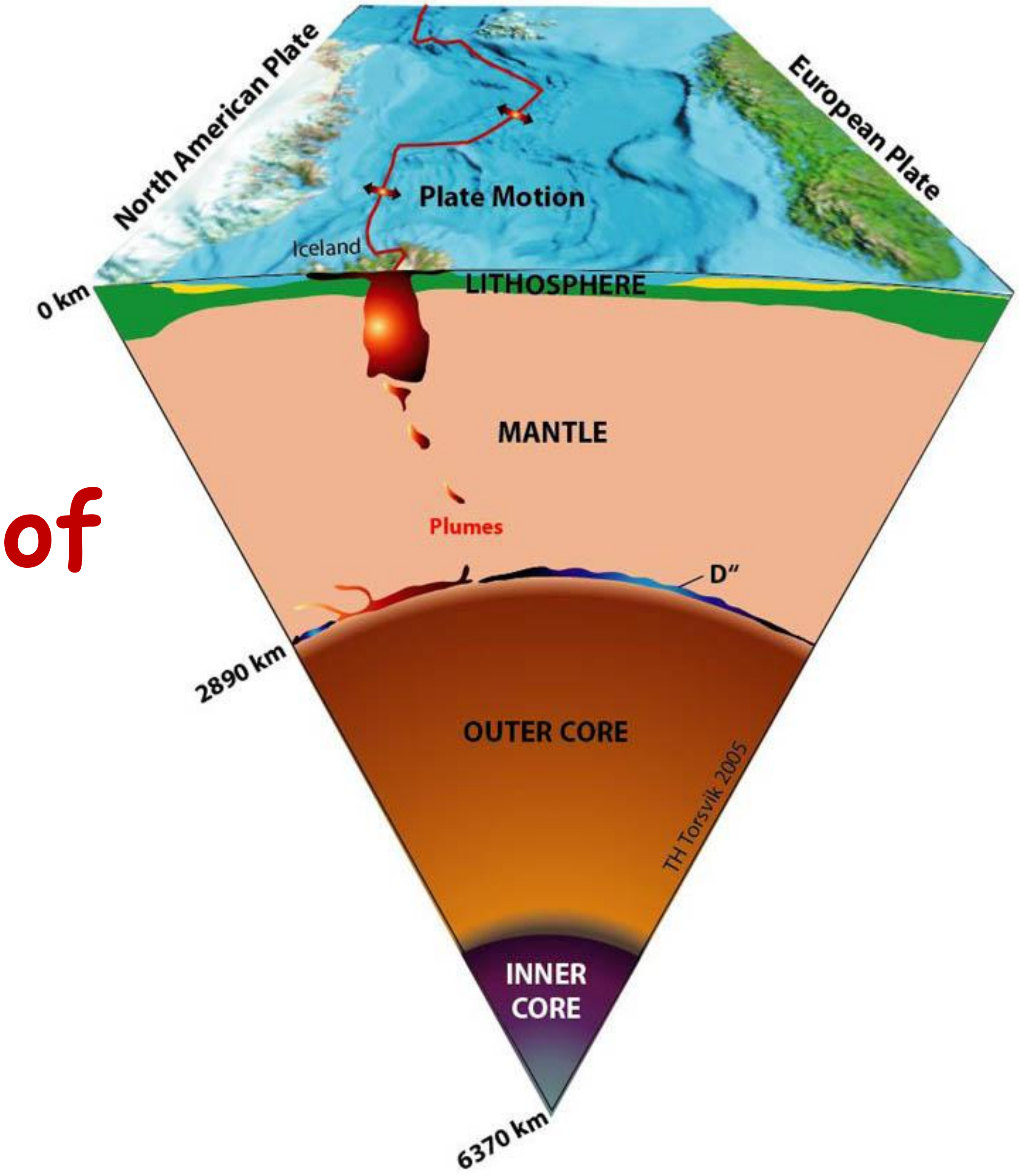
Applications of Environmental Chemistry

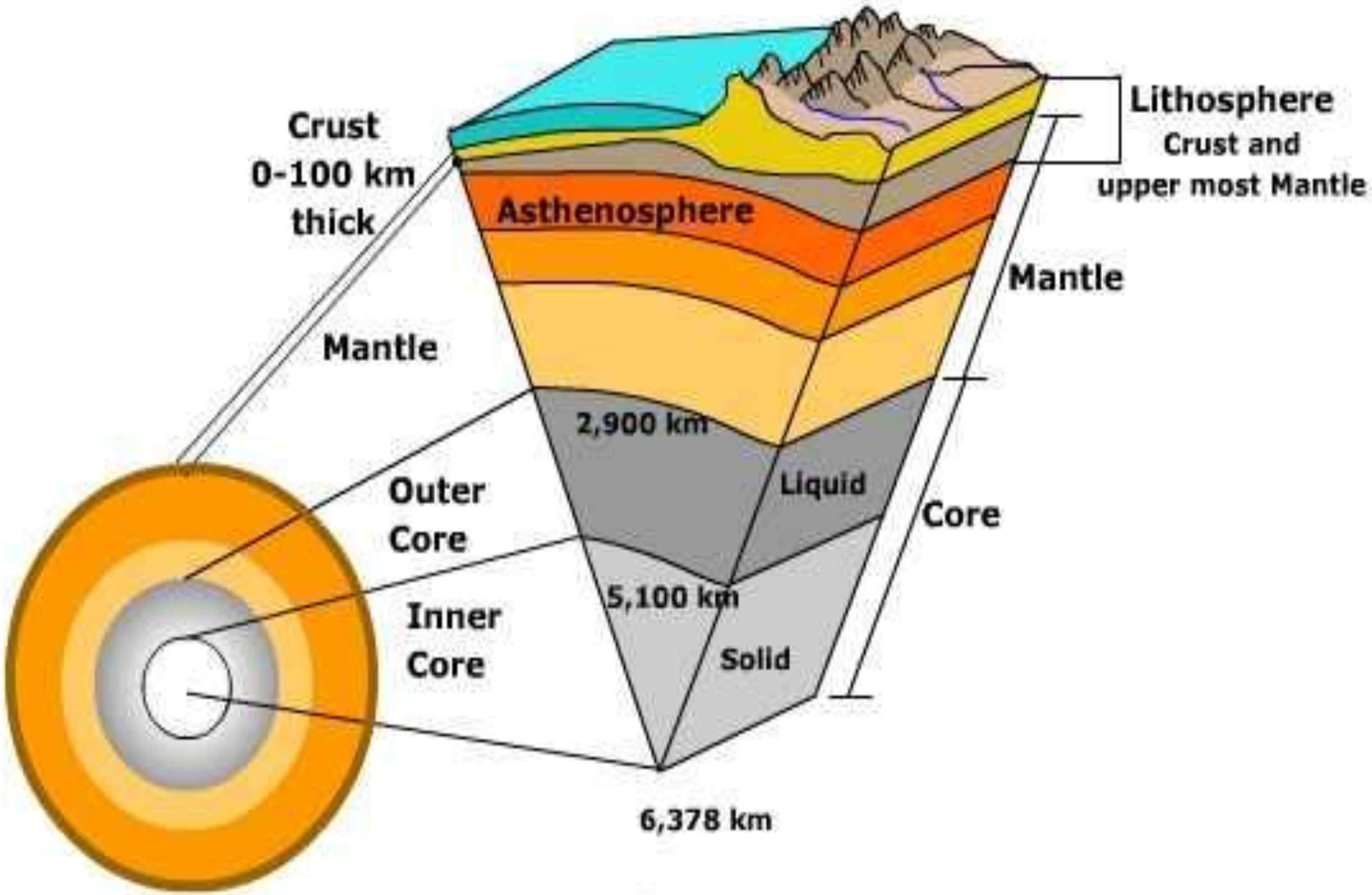
- studies the risk factors of all the chemicals in-depth to get a solution for the safety purpose of the environment.
- applied in the study of new products and their effects on the environment.
- used in the method of protecting groundwater which is polluted by soil, dust, and waste particles.
- useful for the protection of surface water from contaminants through the process of sedimentation, bacteriological, and radiation.

Applications of Environmental Chemistry

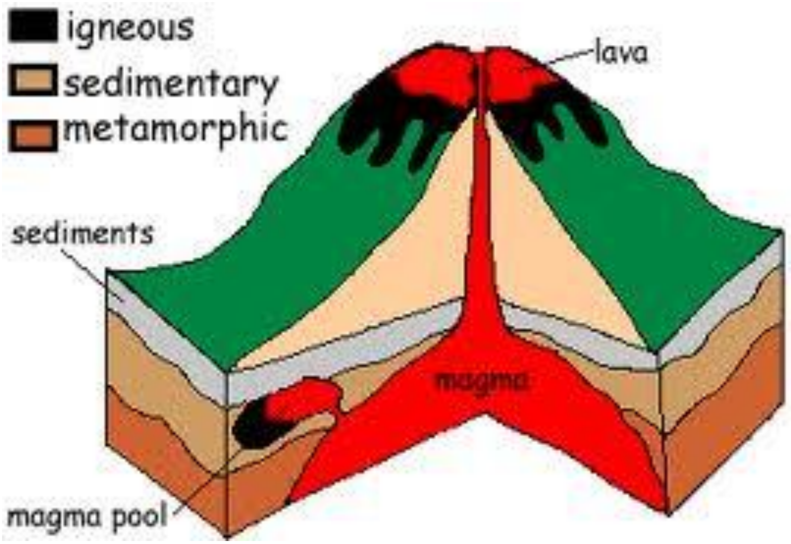
- The quality of the soil is protected by the methods of environmental chemicals such as by the use of indicators like ecotoxicological and chemical.
- Environmental chemistry is applied in Waste Management and Cleaner Production.

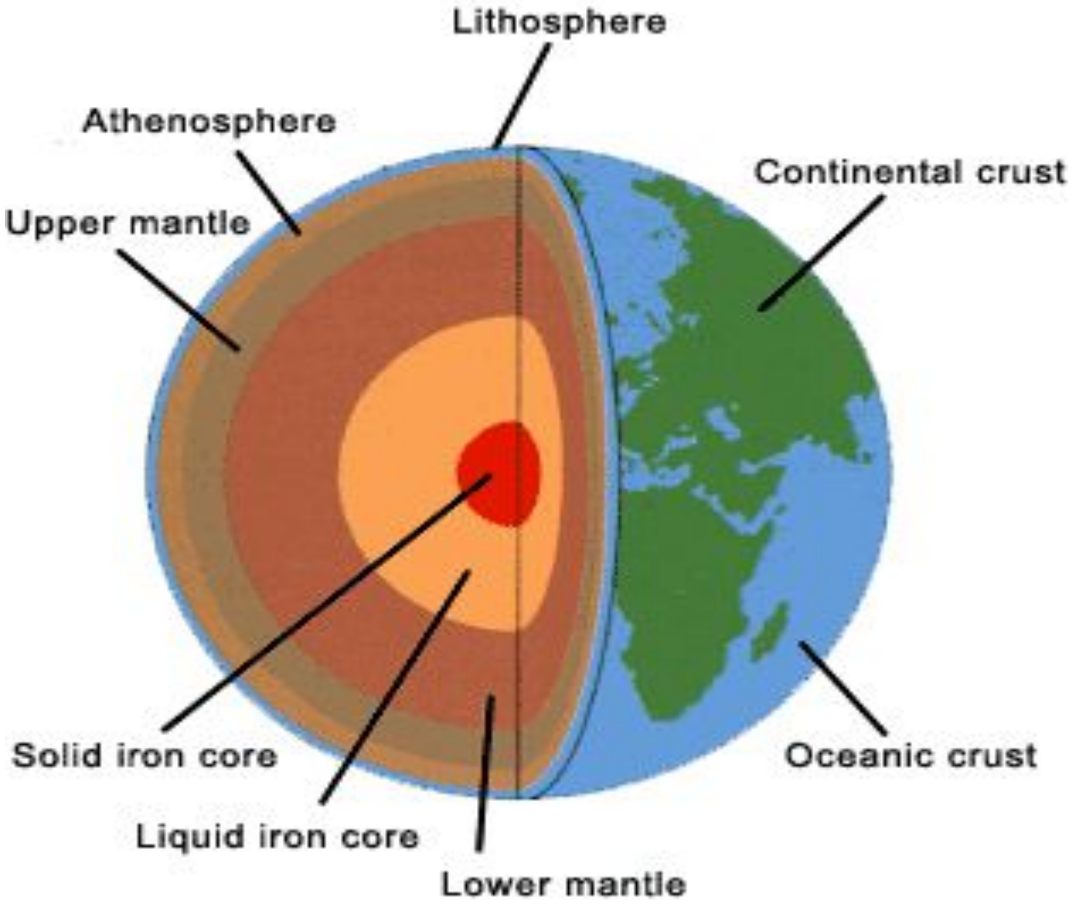
Structure of the Earth





Earth Structure
(Not to Scale)


igneous
sedimentary
metamorphic
lava
sediments
magma
magma pool


Lithosphere
Athenosphere
Upper mantle
Continental crust
Solid iron core
Liquid iron core
Lower mantle
Oceanic crust

Major elements (In Descending Order)

Atmosphere: N, O (79/78%, 21,20%)

Ocean: O, H (Cl, Na, Mg, S)

Sedimentary rocks: O, Si, Al, Fe, Ca, K, Mg, C, Na

Granitic igneous rock: O, Si, Al, K, Na, Ca, Fe, Mg

Baseltic igneous rock: O, Si, Al, Fe, Ca, Mg

Mantle: O, Si, Mg, Fe

Environmental Pollution

- Environmental pollution is defined as any undesirable change in physical, chemical of biological characteristics of our land, air or water
- that may harmfully affect human life or that of other desirable species, industrial process, living conditions and cultural asset or
- that may waste or deteriorate our natural resources.

Contaminants:

- A material does not exist in nature but introduced by human activity into environment.

- For example, Cl_2 gas escaped from a derailed railway tank in Florida 1978 and killed 8 people. This gas does not exist in the atmosphere.

Receptor:

- The medium which is affected by a pollutant. For example man is the receptor of photochemical smog causing irritation of the eyes and respiratory tract.

Sink:

- The medium which retains and interacts with a long-lived pollutant.

- For example- A marble wall act as a sink for atmospheric H_2SO_4 and ultimately get damaged.

$$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2O + CO_2$$

- The oceans are the sink for atmospheric CO_2

Types of Environmental Pollution:

1. Water pollution
2. Air pollution
3. Thermal pollution
4. Light pollution
5. Noise pollution
6. Land pollution

Pollutant:

- A substance present in nature and is greater than natural abundance due to anthropogenic activity and sometimes also natural, which **ultimately has a harmful effect on the environment, living organisms and mankind.**

- For example lead (Pb), SO_2, CO_2.

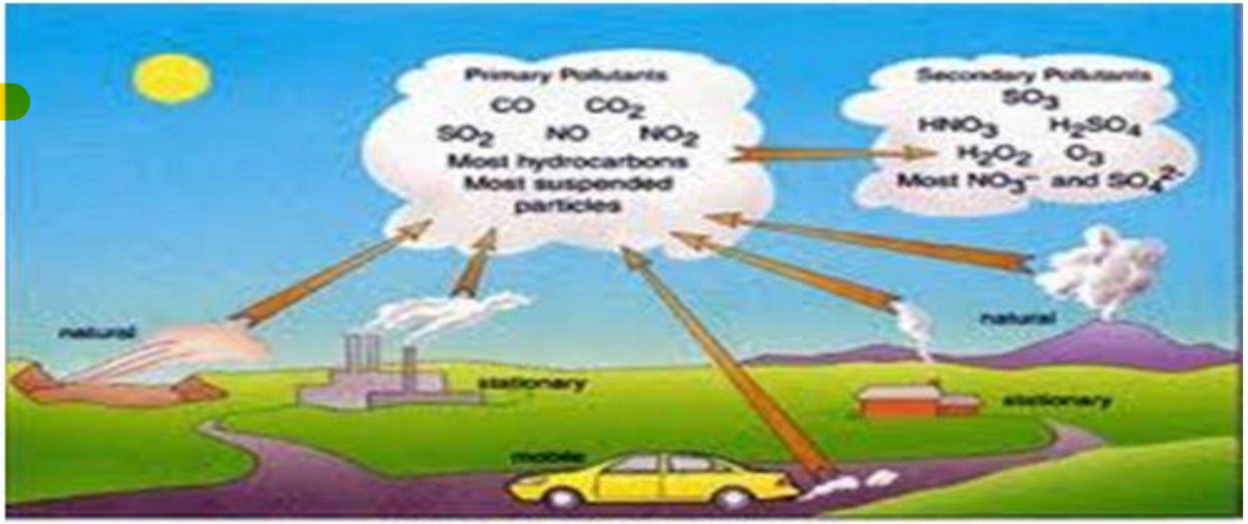
Pollutants may come from two source.

1. Anthropogenic activity (man made activity)

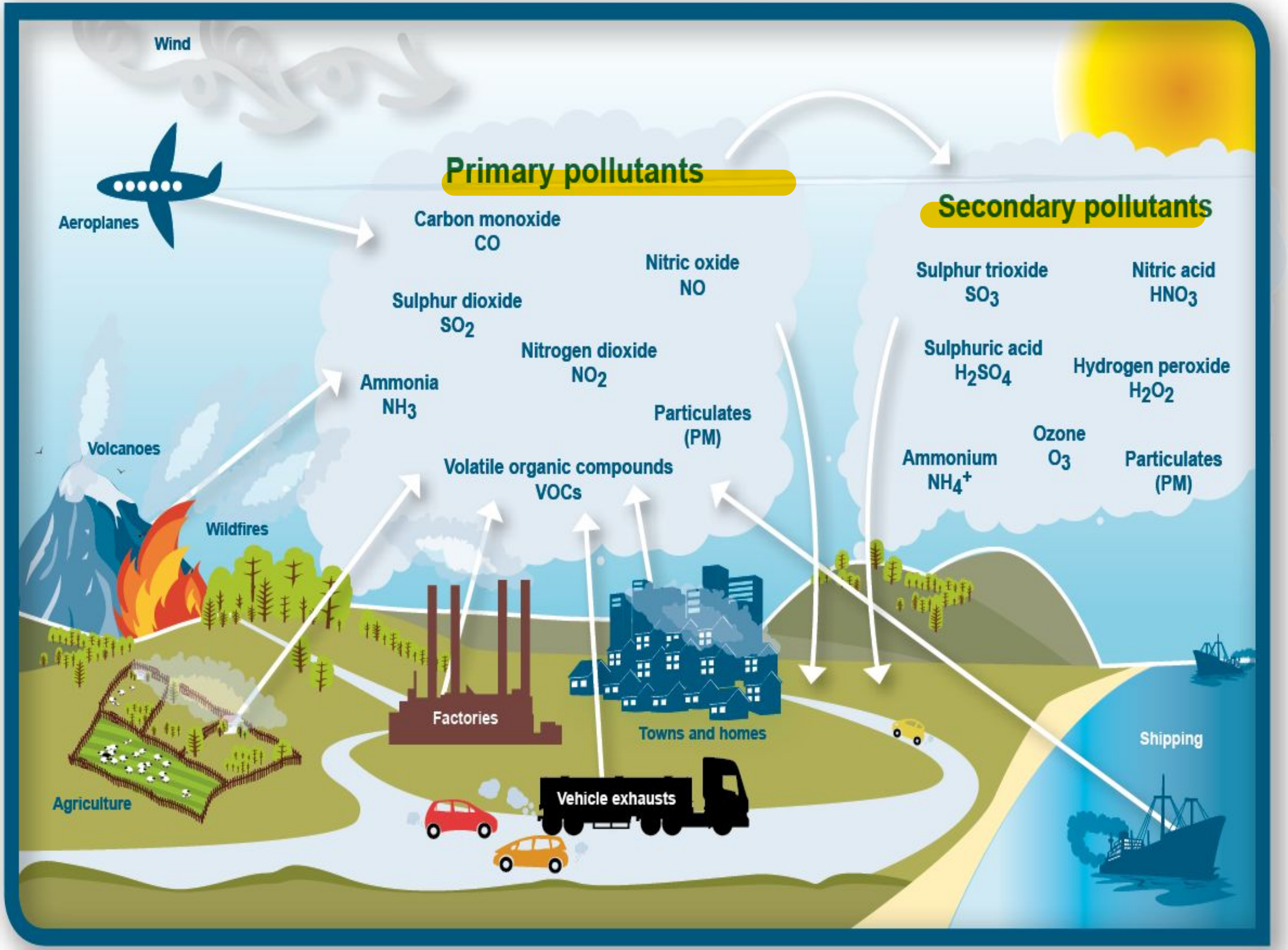
2. Natural activity

What is the difference between a primary and secondary pollutant?

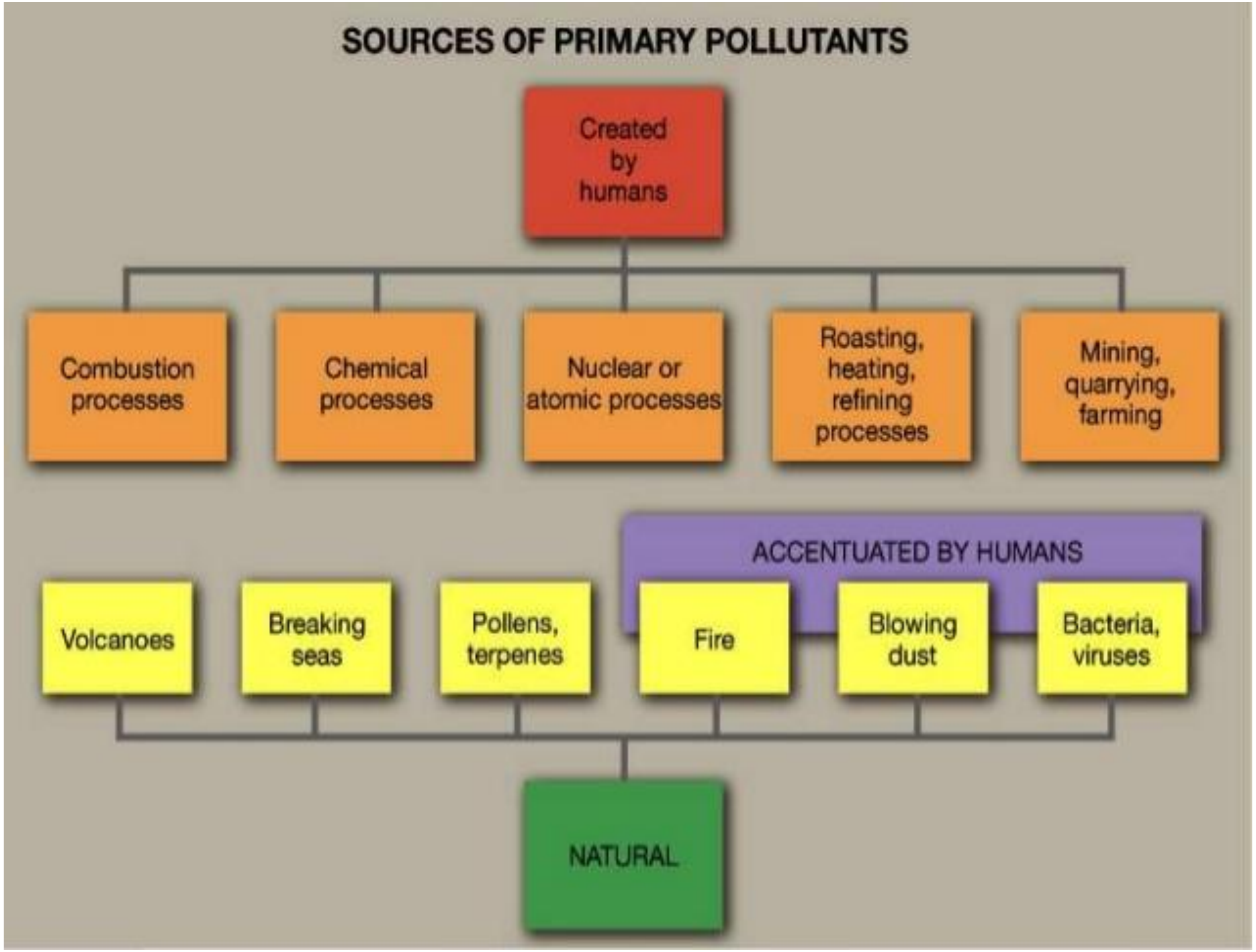
- Primary pollutant
  - Put directly into air by human activities
    - Ex: Sulfur dioxide released from burning fossil fuel.
- Secondary pollutant
  - Primary pollutants react with other primary pollutants or water vapor to make a new substance
    - Ex: Sulfur dioxide mixes with water in atmosphere and causes acid rain.



Types and sources of air pollutants



Wind
Aeroplanes
Primary pollutants
Carbon monoxide
CO
Nitric oxide
NO
Sulphur dioxide
SO_2
Nitrogen dioxide
NO_2
Ammonia
NH_3
Particulates
(PM)
Volatile organic compounds
VOCs
Secondary pollutants
Sulphur trioxide
SO_3
Nitric acid
HNO_3
Sulphuric acid
H_2SO_4
Hydrogen peroxide
H_2O_2
Ozone
O_3
Ammonium
NH_4^+
Particulates
(PM)
Volcanoes
Wildfires
Factories
Towns and homes
Shipping
Agriculture
Vehicle exhausts



SOURCES OF PRIMARY POLLUTANTS
Created by humans
Combustion processes
Chemical processes
Nuclear or atomic processes
Roasting, heating, refining processes
Mining, quarrying, farming
ACCENTUATED BY HUMANS
Volcanoes
Breaking seas
Pollens, terpenes
Fire
Blowing dust
Bacteria, viruses
NATURAL

Water and it's pollution

The Natural Water Cycle

- There are some 1.5×10^9 km^3 of water on the surface of the Earth.
- Of this 98.3 per cent is in the oceans/seas and 1.6 per cent in the form of ice.
- The remaining 0.1 percent exists as groundwater and in lakes and rivers.
- All of this water, and the water used, has been a part of the natural water cycle, or global hydrological cycle, at some time
- This cycle is based on the continuous movement of water between the surface of the Earth and the atmosphere. The water cycle involves a dynamic balance between the two processes of **evaporation and precipitation**

The Natural Water Cycle

- This cycle is based on the continuous movement of water between the surface of the Earth and the atmosphere.
- The water cycle involves a dynamic balance between the two processes of evaporation and precipitation

The Natural Water Cycle :Evaporation

- Water is evaporated from the surfaces of both water bodies and land surfaces.
- also transpired from living plant cells.
- water vapour produced is circulated throughout the atmosphere, where it is eventually precipitated as snow and rain.

The Natural Water Cycle: Precipitation

- Snow and rain are thus the ultimate sources of all our drinkable (potable) water

- Depending upon the amount of rain, the water can follow two paths.

Path 1 (To lakes and oceans)

- If it is heavy rain, a very large amount of water will run off the land into streams and rivers, eventually finding its way into lakes and the oceans.

The Natural Water Cycle:precipitation

Path 2 (Groundwater):

- However, some water may manage to move downwards under the influence of gravity (termed infiltration), through porous rock strata, until it reaches an impenetrable layer.
- Here it collects and becomes the groundwater that is the source of wells and of the springs that feed streams, rivers and lakes.
- The surface of this groundwater is called the **water table**.
- Under natural conditions, a water table will fall or rise according to prevailing weather conditions, and whether or not it is being used as a water supply to a spring or as a reservoir for human use.
- Since groundwater spends a great deal of time in contact with subterranean rocks, what dissolved materials it contains will be a reflection of the geology of those rocks, as well as the surface material it has passed through

Water Cycle

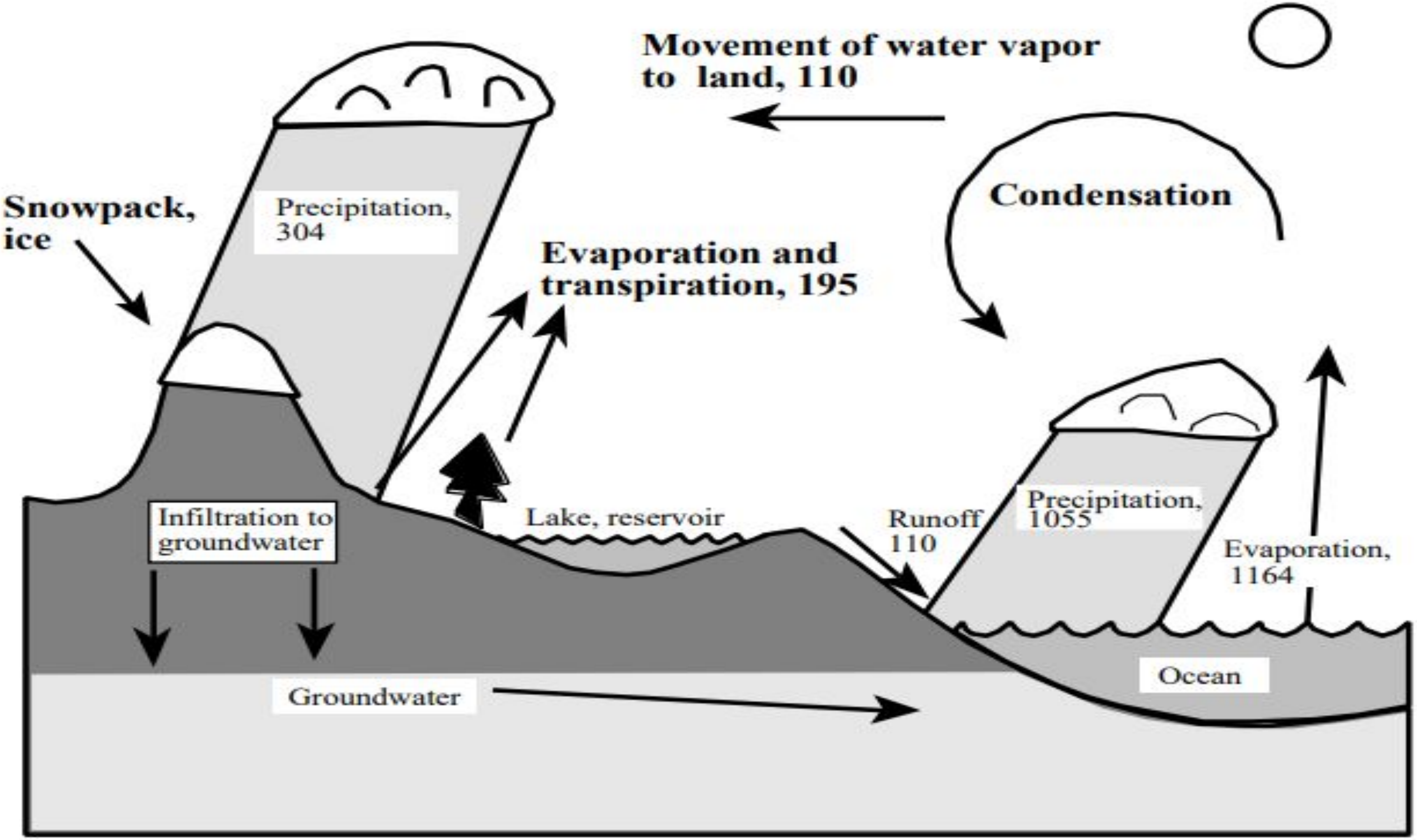


Figure 11.1 The hydrologic cycle, quantities of water in trillions of liters per day.

Some characteristics of pure water

Water is an angular, polar molecule and an excellent solvent for many ionic compounds:

- When, for example, sodium chloride dissolves in water, it is dissociated into its ions, which on thorough agitation are distributed evenly throughout the water.

- Thus, since water is a very mobile liquid, it makes salts more readily available and will deliver both unwanted and wanted materials to plants, animals, buildings, etc.

Some characteristics of pure water

Compared with other materials, water has a high specific heat capacity:

- 4.18 J C^{-1} g^{-1}.
- This means that it 'protects' living organisms, in that it requires a substantial amount of heat to raise its temperature to levels that might be dangerous.
- Water also acts as an excellent coolant in industry and elsewhere.

The density of solid (ice) is less than that of water:

- Protects the aquatic organisms from dying and freezing

The Stratification Of A Water Body

- When a standing mass of water is heated by the Sun, temperature variations can be caused within that body.

- This variation is termed stratification .

- There can be three layers in a water body.

1. **Epilimnion:**

2. **Hypolimnion :**

3. **Thermocline:**

The Stratification Of A Water Body

Epilimnion:

- The surface of the water is warmed first, expands and therefore becomes less dense.
- This surface layer of warmer water is called the epilimnion.

Hypolimnion:

- The cooler, deeper layers are referred to as the hypolimnion.
- anaerobic organisms and methanogenic and sulphate-reducing bacteria tend to live at the bottom of a water body

Thermocline:

- Between these two 'extreme' layers is a narrow region called the thermocline, where rapid temperature change occurs.
- The degree of mixing between these layers of differing temperatures is very poor.

The Characteristics of Natural Waters

- Water has the ability to dissolve a wide range of materials, so that in its natural state (streams, rivers, lakes and underground sources/aquifers) it is never pure.

- It always contains a variety of soluble inorganic and organic compounds.

- In addition to these, water can carry large amounts of insoluble materials that are held in suspension. Both the amounts and types of impurities found in natural water vary from place to place and by time of year.

- These impurities determine the characteristics of a water body.

- Suspended solids in a moving body of water such as a river will settle out at various points or be carried longer distances, depending upon their size and the rate of flow of the water

- Suspended matter can affect the amount of light entering water and therefore restrict the amount of photosynthesis that can occur and therefore the growth of plants

The characteristics of natural waters

- How fast a water body moves affects the degree of mixing of water and how much dioxygen it will carry.

- Thus, fast-flowing highly agitated streams will not only be saturated with dioxygen but also carry well-mixed nutrients, which will ultimately be carried to a river.

- Small rapidly flowing streams are nearly always saturated with dissolved dioxygen.

- Sluggish rivers may well contain 'hot spots' of poorly mixed materials and have oxygen contents well below saturation levels.

- The temperature of a natural water body is crucial to the amount of dissolved dioxygen it can contain. The warmer the water, the less dioxygen it contains.

Water and living organisms

- Living organisms will exist in natural waters if dissolved or suspended organic matter is present.
- This organic matter can be utilised by the living organisms if it is biodegradable, i.e. can be decomposed by micro-organisms into simpler inorganic substances.
- Once photosynthesising plants and algae are established in a water body, these will initiate food chains and food webs.
- There should, in any given water body, be an equilibrium established between the amount of living matter produced and the amount of dead, decomposing organic matter produced. If this is not the case, then a water body can either **become choked with living organisms or devoid of them**

Water and living organisms

- Where the water body is situated and what the geological conditions are like will dictate the range and type of living organisms that can be present.
- The stability of an equilibrium depends upon the range of living organisms present and the ways in which the food chains and webs are interlinked.
- A cycle of nutrient movement through the water will be established, which exists in a quite delicate, easily disturbed, ecological balance.
- **As well as nutrients, a supply of dioxygen** is needed to maintain aquatic life.
- Dioxygen dissolved in natural waters takes part in the biodegradation of organic matter by aerobic bacteria and is also needed for aerobic respiration by all plants and animals.
- The dissolved dioxygen comes from two main sources – the atmosphere and photosynthesis

Using oxygen as a way of assessing water quality

- Assessing how much dissolved dioxygen is present in river water or some other water body is one way of evaluating the quality of that water.

- Removal of oxygen is caused mainly by the biodegradation of organic matter.

- It is possible to measure the ultimate oxygen demand by determining the difference between the amount of oxygen dissolved in a sample of water and the amount of oxygen left after the organic matter has used up as much as it can.

- The main problem with this is that it is very difficult to know how long to leave the sample to ensure that all of the oxygen has been used up.

- Hence, two main tests have been devised. The first one is the biological oxygen demand (BOD) test, which is standardised on a five-day period of biodegradation. A second test is based on the permanganate value (PV), which has been standardised at periods of three minutes and four hours

The BOD test

- measures the oxygen requirement of micro-organisms during the biodegradation of a water sample.

- The sample is incubated at 20 °C in a sealed bottle for five days. Both the initial and final oxygen content are determined.

Advantages:

- This test has been used for well over 70 years and is still the most important indicator of organic pollution.

- The test relies on biological action and is a simulation of actual processes which occur in polluted watercourses or an aerobic treatment plant.

- It has been internationally adopted as a trustworthy indicator of organic pollution

The BOD test

Pitfalls:

- However, the test is slow
- not suitable for rapid process control in a waste treatment plant.
- In addition, it is not a good indicator of industrial pollutants, since such wastes are toxic and often inhibit the microorganism activity on which the BOD test relies.
- It is more sensitive than the PV test for detecting and measuring biodegradable organic wastes

The PV Test

- The PV test uses a known concentration of acidified potassium manganate(VII) (permanganate) to oxidise both organic and inorganic materials.
- Here, the concentration of the manganate(VII) solution is measured at the start of the test and then again after three minutes and four hours at 27 °C.
- The difference reflects the uptake of oxygen and is expressed in g/m3 .
- It has been found that the ratio of the concentration of oxygen uptake after four hours to that used in three minutes gives an indication of the origin of polluting materials.
- It is an approximate measure of the ratio of organic to inorganic oxidisable materials.

The COD test

- In the chemical oxygen demand test (COD), the water sample is boiled for two hours in a mixture of potassium dichromate(VI) and concentrated sulphuric acid in the presence of silver(I) nitrate as a catalyst.

- This ensures the complete oxidation of most of the organic and inorganic materials present.

- It usually gives a higher value for the oxygen uptake than either the PV or BOD tests.

- In the UK, the costs of receiving and treating industrial wastes by water authorities are established on the basis of the COD values of the wastes after the settlement of suspended solids

Water pollution:

Any human activities that impairs the use of water as resources is called water pollution.

Water Pollutants

- Organic
- Inorganic
- Sediments
- Radioactive materials
- Thermal pollutants

Sources of Water Pollutants

- Industrial wastes
- Sewage and other oxygen-demanding wastes
- Infectious or disease causing agents
- Plant nutrients
- Synthetic organic chemicals
- Inorganic minerals and chemical compounds
- Suspended solids or sediments
- Radioactive substances like I-131, Sr-90, Ra-226
- Thermal discharges
- Oil
- Detergents, etc

Effects of Water Pollution

- Sewage and domestic wastes effect human health resulting diseases such as cholera, typhoid, dysentery
- Industrial discharges contain Lead, arsenic, Mercury, Cadmium etc., which pose deleterious impacts in life systems

  Lead – damages liver and kidney

  Arsenic – lung cancer, ulcers in gastro intestinal tract

  Cadmium – diarrhea, kidney cysts, bone deformation etc

  Mercury – Neurological disorders
- Agricultural discharges include fertilizers, pesticides which are toxic to both aquatic and human life.

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Thank you

Atmospheric Chemistry

WHAT IS THE ATMOSPHERE?

The atmosphere seen from space

- Gaesous envelope surrounding the Earth

- Mixture of gases, also contains suspended solid and liquid particles (*aerosols*)

Aerosol = dispersed condensed phase suspended in a gas

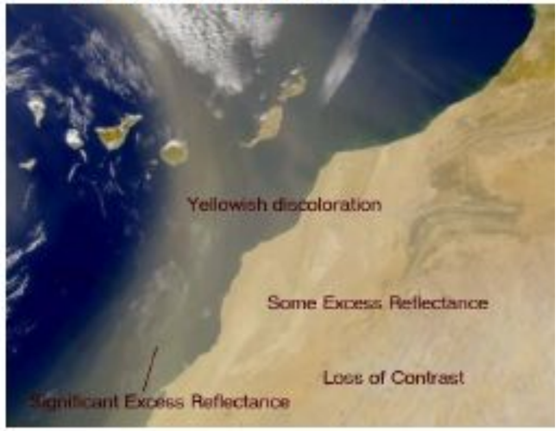
Or, some solid particle or liquid droplets which are suspended in atmosphere are collectively called aerosol

Aerosols are the "visible" components of the atmosphere

California fire plumes

Pollution off U.S. east coast

Dust off West Africa



Air Pollution

Air pollution is the introduction of particulates, biological molecules, or other harmful substances into Earth's atmosphere, causing diseases, allergies, death to humans, damage to other living organisms such as animals and food crops, or the natural or built environment.

Nothing! He just flew through air of Dhaka City ☺️

Types of Air Pollution

Outdoor Air Pollution

- Smog
- Particulates
- Acid rain
- Greenhouse Gases

Indoor Air Pollution

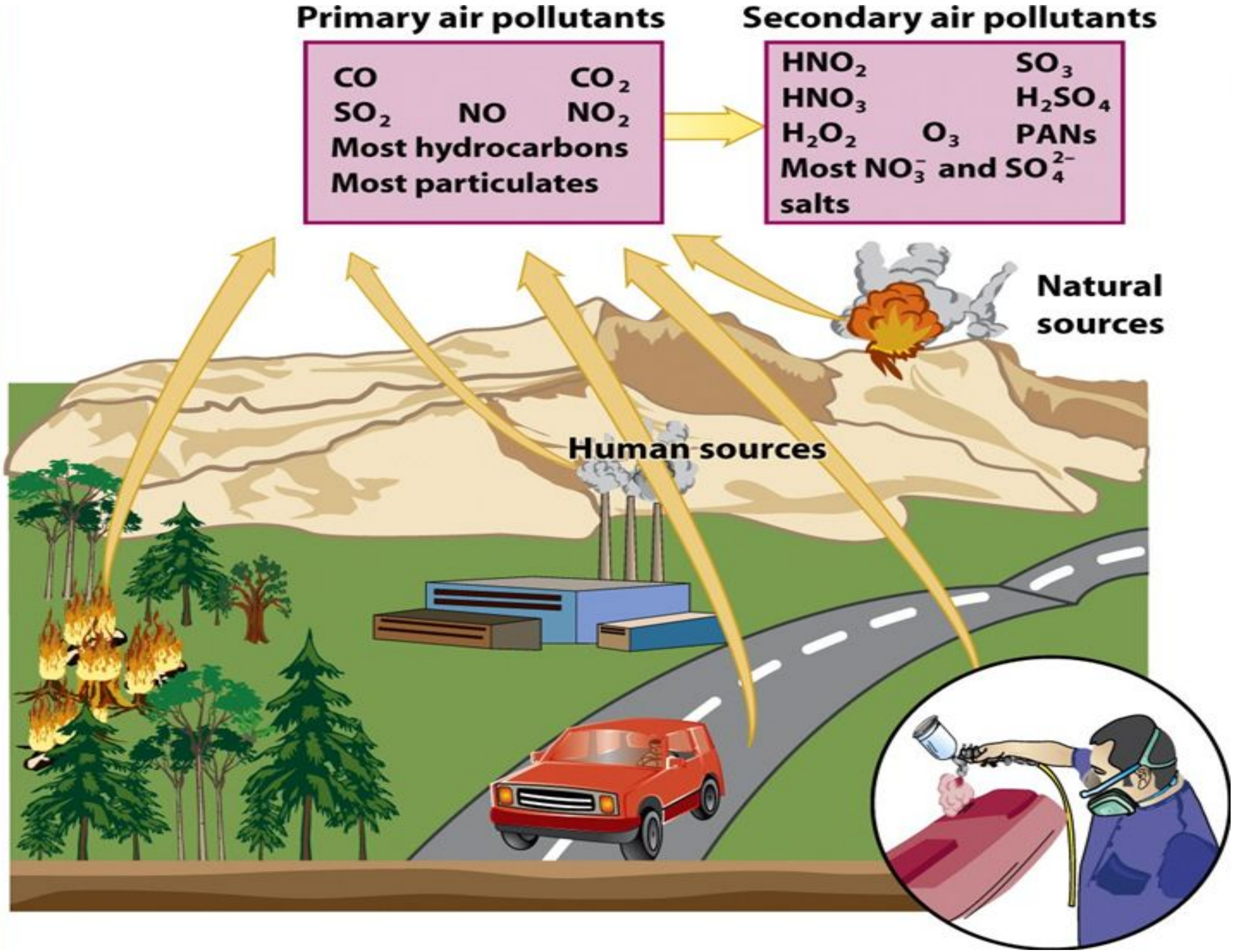
Causes

- Natural Sources
  - smoke that comes from wildfire, volcanoes, methane, dust

- Human dust
  - power plants and automobile fumes, burning wood, stoves, fireplaces and furnaces

Six major air pollutants

- Carbon monoxide (CO)
- Ozone (O_3)
- Nitrogen dioxide (NO_2)
- Sulfur oxides (SO_x)
- Carbon dioxide (CO_2)
- Lead (Pb)


Primary air pollutants
CO
CO_2
SO_2 NO NO_2
Most hydrocarbons
Most particulates
Secondary air pollutants
HNO_2 SO_3
HNO_3 H_2SO_4
H_2O_2 O_3 PANs
Most NO_3^- and SO_4^{2-} salts
Natural sources
Human sources

Effects

- Human Effects

  e.g. diseases

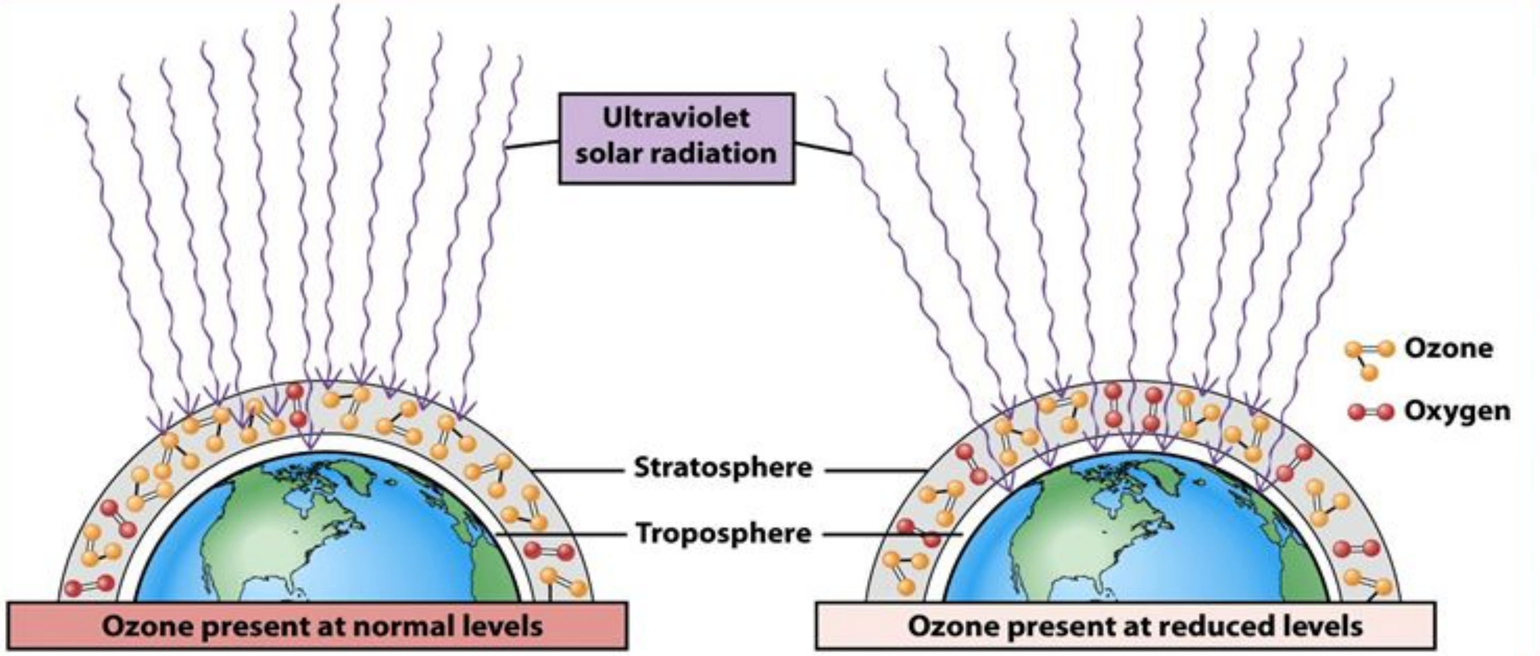
- Environmental Effects
  - Acid rain
  - Eutrophication
  - Haze
  - Wildlife
  - Ozone depletion
  - Crop and forest damage
  - Global Climate change

Health Effects of Air Pollution

- Sulfur Dioxide and Particulate material
  - Irritate respiratory tract and impair ability of lungs to exchange gases
- Nitrogen Dioxides
  - Causes airway restriction
- Carbon monoxide
  - Binds with iron in blood hemoglobin
  - Causes headache, fatigue, drowsiness, death
- Ozone
  - Causes burning eyes, coughing, and chest discomfort

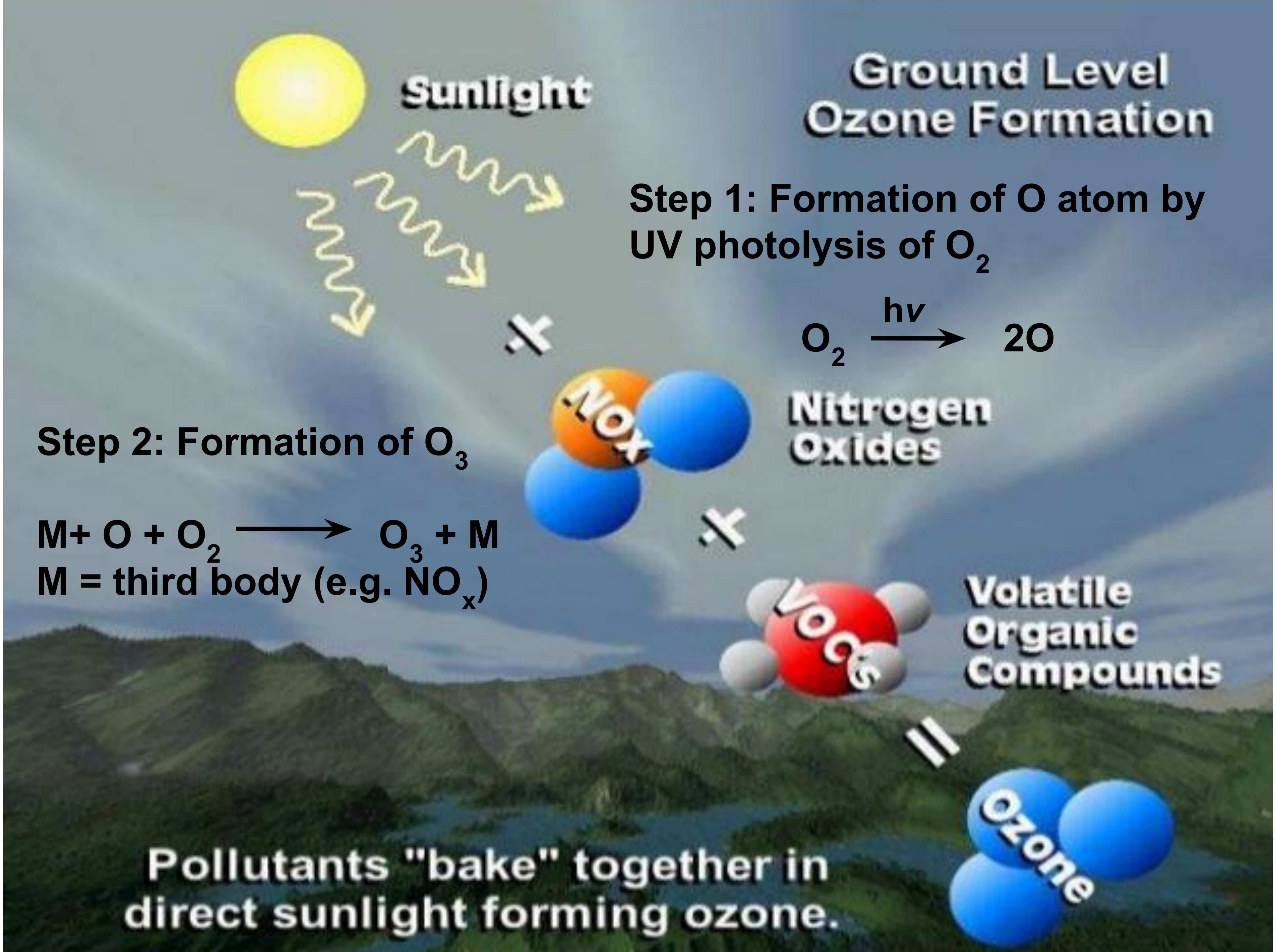
Ozone Depletion in Stratosphere

- Ozone Protects earth from UV radiation
  - Part of the electromagnetic spectrum with wavelengths just shorter than visible light



(a) Stratospheric ozone absorbs about 99% of incoming solar ultraviolet (UV) radiation, effectively shielding the surface.

(b) When stratospheric ozone is present at reduced levels, more high-energy UV radiation penetrates the atmosphere to the surface, where its presence harms organisms.



Step 1: Formation of O atom by UV photolysis of O_2

$$O_2 \xrightarrow{h\nu} 2O$$

Step 2: Formation of O_3

$$M + O + O_2 \longrightarrow O_3 + M$$

M = third body (e.g. NO_x)

Ozone depletion

Due to anthropogenic activity human produce some gas which react with ozone in stratosphere and thereby the concentration of ozone in the stratosphere decreases, which is known as ozone depletion.

Tropospheric Ozone Depletion

$$\left.\begin{array}{l} HO + O_3 \rightarrow HO_2 + O_2 \\ HO_2 + O \rightarrow HO + O_2 \end{array}\right\} HO_x \text{ chain reactions}$$

$$\left.\begin{array}{l} NO + O_3 \rightarrow NO_2 + O_2 \\ NO_2 + O \rightarrow NO + O_2 \end{array}\right\} NO_x \text{ chain reactions}$$

$$\left.\begin{array}{l} Cl + O_3 \rightarrow ClO + O_2 \\ ClO + O \rightarrow Cl + O_2 \end{array}\right\} Cl \text{ chain reactions}$$

Stratospheric Ozone Depletion

Chapman cycle

1) $O_2 + h\nu \rightarrow 2O^{\bullet}$

2) $O^{\bullet} + O_2 + M \rightarrow O_3 + M$

3) $O_3 + h\nu \rightarrow O_2 + O^{\bullet}$

Net: $O_2 + 2h\nu \rightarrow 2O^{\bullet}$

CFCs Catalytic Cycle I

$CCl_2F_2 + h\nu \rightarrow CClF_2 + Cl^{\bullet}$

4) $Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$

5) $ClO^{\bullet} + O^{\bullet} \rightarrow Cl^{\bullet} + O_2$

Cl. - Catalytic Cycle II

6) $ClO^{\bullet} + ClO^{\bullet} + M \rightarrow (ClO)_2 + M$

7) $(ClO)_2 + h\nu \rightarrow Cl^{\bullet} + ClOO$

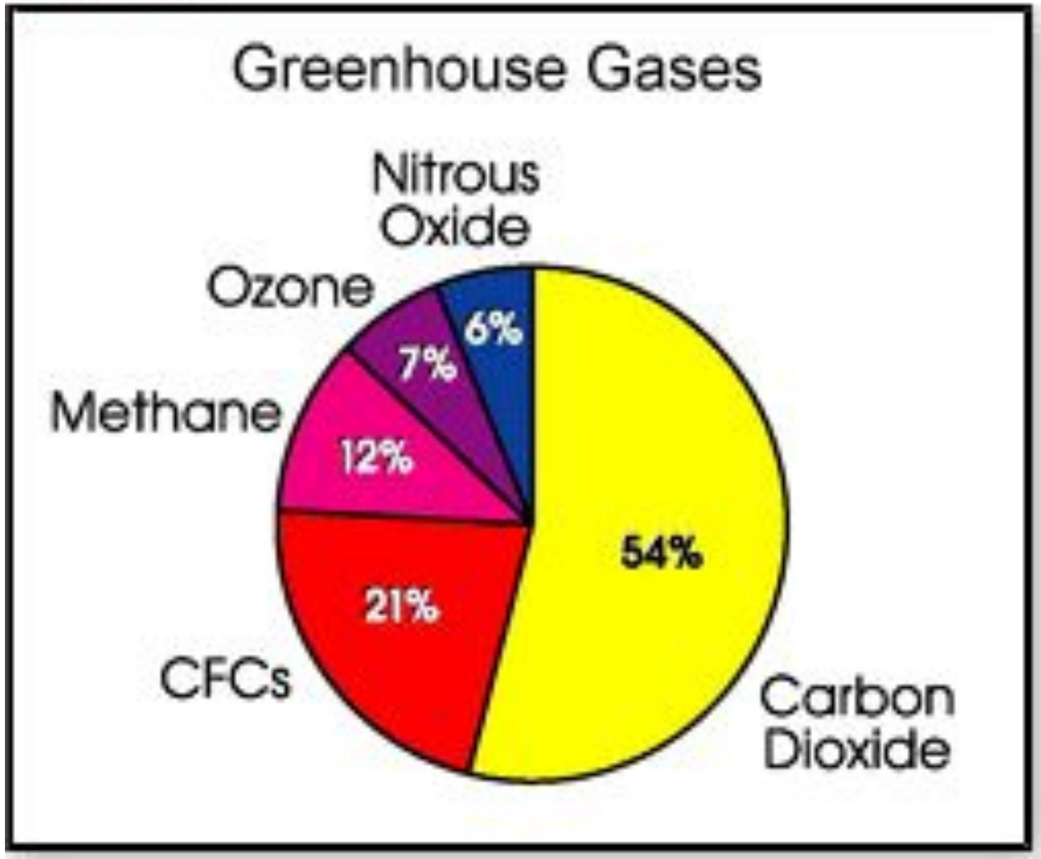
8) $ClOO + M \rightarrow Cl^{\bullet} + O_2 + M$

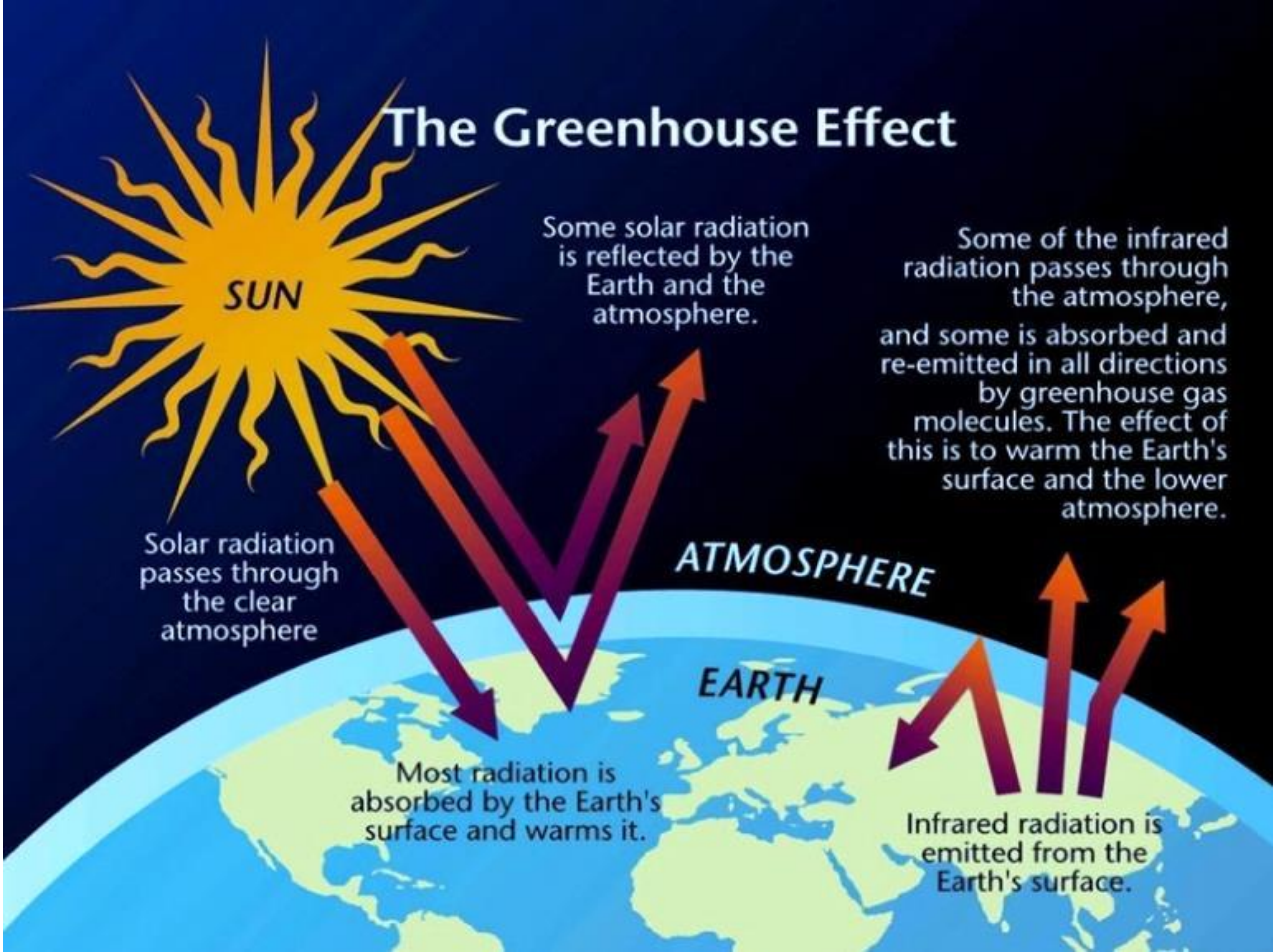
Effects of Ozone Depletion

- Higher levels of UV-radiation hitting the earth
  - Eye cataracts
  - Skin cancer (right)
  - Weakened immunity
- May disrupt ecosystems
- May damage crops and forests

Greenhouse Effect

The *greenhouse effect* is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere.




The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

- Carbon dioxide (CO_2) and other *greenhouse gases* act like a blanket, absorbing IR radiation and preventing it from escaping into outer space. The net *effect* is the gradual heating of Earth's atmosphere and surface, a process known as global warming.

Air composition-based calculation

- Air composition (apprx) = 80% N_2 and 20% O_2 (mol basis only)
- Average molecular weight of Air = $(0.8 \times 28 + 0.2 \times 32)$ = 29 g/mol (apprx)

Math Sample:

- 2kg pure charcoal (^{12}C) is to be burnt completely with air. **Find the air, CO_2 and N_2 amount in kg's.**

Air composition-based calculation

Solution:

- $C + O_2 = CO_2$ (you must use a balanced equation) .Therefore from the mole ratio of the reaction we write,
- $C : O_2 : CO_2 = 1:1:1$ and from air composition we got $O_2 : N_2 : Air = 1:4:5$
- Given, **2 kg C = 2000 g/ (12 g/mol) = 166.67 mole C**

- Therefore, similar mole of O2 required. So equivalent Air supposed to be 5 times than the mole amount of O2 and released N2 will be 4 times than the required O2.

- Therefore, Air amount = 5 x 166.67 moles

= 833.34 moles

= (833.33x29/1000) kg

= 24.17 kg air

Air composition-based calculation

Now find out the amount of N2 and CO2 yourself.

Do yourself

1. If 18.67 kg N_2 is entirely used to produce ammonia gas, then how many kg's of H_2 we require and how many Kg's of ammonia gas will be produced?

2. If we need to produce calcium carbonate from 7.34 kg carbon dioxide gas, how many kg's of calcium oxide we need to purchase from market?

3. If we want to produce urea from the above-mentioned system, how much Urea we can theoretically produce?

$$2NH_3(g) + CO_2(g) \longrightarrow \underbrace{H_2N{-}CO_2^{-}\ NH_4^{+}(s)}_{\textit{ammonium carbamate}}$$

$$\downarrow$$

$$\underbrace{H_2N{-}CO{-}NH_2}_{\textbf{\textit{urea}}} + H_2O(g)$$

Sample maths part-2

Mole Fraction = mole of particular species / Σtotal moles of the mixture.

1. A gas mixture contains 20% O_2, 30% CO_2, 25% H_2 and Rest N_2 (mole basis). Find the average molecular weight of this gas mixture.

Ans:

Avg molecular weight = Σ(mole fraction x gas molecular weight)

$$= 0.2 \times 32 + 0.3 \times 44 + 0.25 \times 2 + 0.25 \times 28$$

$$= 27.1 \text{ g/mol (ans).}$$

Sample maths part-2

- A certain mole of charcoal (^{12}C) has to be completely converted to CO_2 after reaction with the oxygen of air. If double amount of air (mole basis) was supplied in the reactor then **find the average molecular weight of the outlet gas mixture** stream. Note that, carbon has no reaction with nitrogen in this case.

- We did it in the class. Now try it in the next problem.

Sample maths part-2

- A certain mole of charcoal (^{12}C) has to be completely converted to CO_2 after reaction with the oxygen of air. If a triple amount of air (mole basis) was supplied in the reactor then find the amount (in gram) of charcoal used if 970 grams of N2 gas was found in the outlet gas stream. Note that, carbon has no reaction with nitrogen in this case.

2 kg charcoal (^{12}C) was allowed to burn in the presence of 16 kg air to produce CO_2. If we consider no CO was produced and carbon has no reaction with N2 then find the following-

- What is the limiting reactant here? (Ans: Oxygen)
- How much of the excess reactant will be left in the reactor? (C=675.9g)
- How much N_2 gas will be found in the outlet stream? (12.36 kg)
- How much O_2 will be found in the outlet stream?
- If the entire N_2 gas is separated from the outlet stream and allowed to react with supplied H_2 gas to produce ammonia gas by Haber-Bosch principle, then determine how much H_2 gas will be required and how much ammonia gas will be produced (kg).
  (Ans: H_2 = 2.65 kg and NH_3= 15.006 kg)

Thank You