Environmental Chemistry

Program: B.Sc. Engg: Chem. Engg.

Module: Environmental Engineering

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Recap:

- Curriculum/ class lectures for my module are available at:

  WWW.PU.EDU.PK/Faculties/Engg&Tech/ICET/Waheed
- Monthly summery of work May-June 2005
- Q & A

Environmental Chemistry

- Study of various **chemical phenomenon** in environment
- Environment: **physical and biotic** habitat which surrounds us (can be seen, touch, hear, smell)
- **Behavior** of chemical Species in various parts of environment (called Env. Segments), Path ways, Reactions, sources, fate, effects on 'environment' i-e physical and biotic monuments.
- **Dynamic Field** of Study and Research

Do You Know?

- **What is a System?** (Air, Water and Land)
- **What is Pollution?** (Undesirable change in Physical, chemical or biological characteristics of any of the segments of environment)

Environmental Segments

- **Lithosphere**
- **Biosphere.**
- **Atmosphere**
- **Hydrosphere**

Environmental Segments: Lithosphere

Lithosphere

- Soil (Complex Mixture of Organic Compounds & inorganic minerals
- Mental of rocks and Earth Crust
- Silicates of Na, K, Ca, Al, Fe, etc.
- Oxides of Fe, Mn, Ti,
- Carbonates of Ca, Mg,

Environmental Segments (Contd.) Lithosphere:

- Organic: Less than 5% (Productivity/ fertility of soil)
- Organics: Complex Colloidal Organics in Soil called Humus, Oregano Sulpher, phosphorous, polysacrides, etc.

Environmental Segments: Hydrosphere

Hydrosphere (Earth is called a Blue Planet)

- Surface & ground water resources
- Oceans, Rivers, Seas, Lacks, Streams, Reservoirs, Ice Capes of Glaciers, Polar Ice Capes.
- 80% of earth's surface is covered by water
- 97% of earth's water---in ocean and seas
- 2.4% is trapped in giant glacier & polar ice caps.
- Less than 1 % is available for domestic, agricultural and industrial use.

Do You Know?

Why BP of Water is 100 Degree Celsius?

- Compare it with Hydrides of Group VI Elements: Unusual
- Reason: Hydrogen Bounding; otherwise -100^{o} C
- Check your Information: properties of water; density, viscosity, Surface Tension, Dielectric constant, Sp. heat.

Environmental Segments: Biosphere

- Part of Environment Where life exists.
- 10,000 m below sea level to 6000 m above sea level
- It Covers whole realm of LIFE
- Interaction of life with other segments of environment
- All efforts to safe this part from all kind of detrimental effects of pollution.

Environmental Segments: Atmosphere

Atmosphere

- Comprises of a mixture of gases known as AIR
- Saves life cosmic radiations. (How? Next time)
- Extends up to about 500Kms above the earth's surface
- Exchange area for various matters among various segments of environment

Environmental Segments: Atmosphere (contd.)

- Relative Weights:
  Bio Sp. 1: Atm. 300: Hydro Sph. 70 000
- Weight of Atmosphere is about (4.5 to 5) X 10^{15} MT
- Temperature varies from -100 to +1200^{o} C
- Pressure varies from 1 atm. at sea level to 0.0000001atm at 100 Km above sea level.
- Density at sea level is 0.0013 g/ cu. m and decreases as we go up.
- Oxygen, Nitrogen and Carbon Dioxide are very important in atmosphere

Atmospheric Structure

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere

Atmospheric Structure:
Troposphere

Name of Region	Ht. above earth's surface	Temp. ^{o}C	Chem. Species
Tropo-sphere	0-11 km	15 to -56	O_2,N_2, CO_2, H_2O

Atmospheric Structure: Troposphere

- 70 % of Atmosphere mass
- Constant composition
- High lateral mixing and high turbulence
- Temperature decreases with height:
  Why?

Atmospheric Structure:
Stratosphere

Name of Region	Ht. above earth's surface	Temp. ^{o}C	Chem. Species
Strato-sphere	11-50 km	-56 to-2	O_3

Atmospheric Structure: Stratosphere

- Absorption of Ultra Violet Radiation due to Ozone
- Low moisture contents/ dry due to low turbulence.
- Temperature Rising Trend with height: Why? (Absorption of UV radiation in Ozone)
- Ozone 1 to 5 ppm
- Long Residence time of particulates: why?

Atmospheric Structure:
Mesosphere

Name of Region	Ht. above earth's surface	Temp. ^{o}C	Chem. Species
Mesosphere	50 to 85 km	-2to-92	O^{+2}, NO^{+}

Atmospheric Structure: Mesosphere

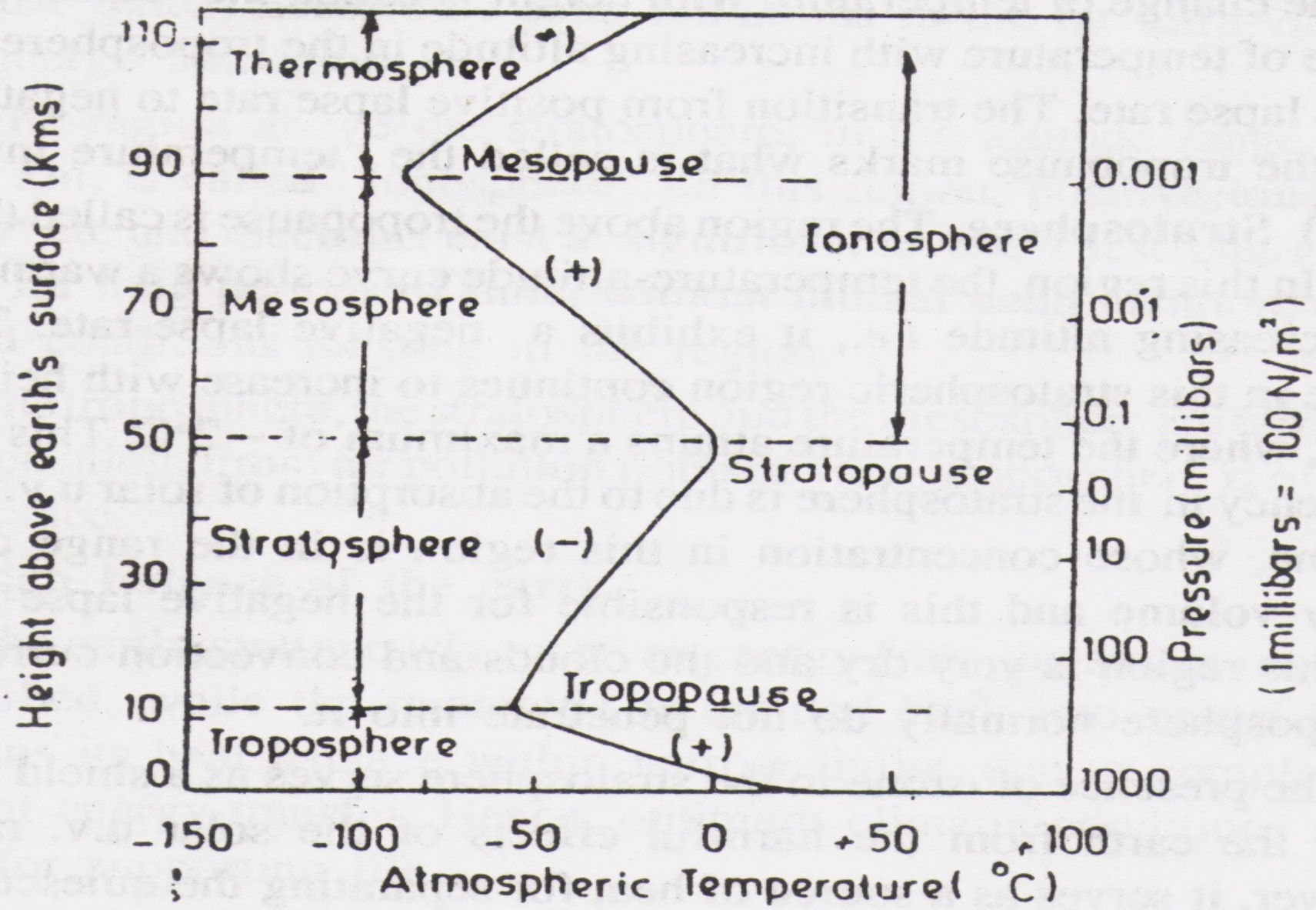
- Temprature decreases with height. Why?
- Less absorption of UV Rad. in this reign: less concentrations of gases
- Just Above region is “coldest region” called mesopause (-100 ^{o}C)

Atmospheric Structure:
Thermosphere

Name of Region	Ht. above earth's surface	Temp. ^{o}C	Chem. Species
Thermo sphere	85 to 500 km	-92 to 1200	O^{+2}, O^{+}, NO

Atmospheric Structure: Thermosphere

- Sharp rise in temperature starts with height
- “Hottest Region” 1200 ^{o}C
- Low pressure and low densities
- Oxygen and Nitric Oxide absorbs high energy rad. i-e UV and below
- Another classification: Ionosphere (50 to 100 km) as ions exits. without neutralization, rarefied/ complex conditions.



(+) Positive lapse rate

(−) Negative lapse rate

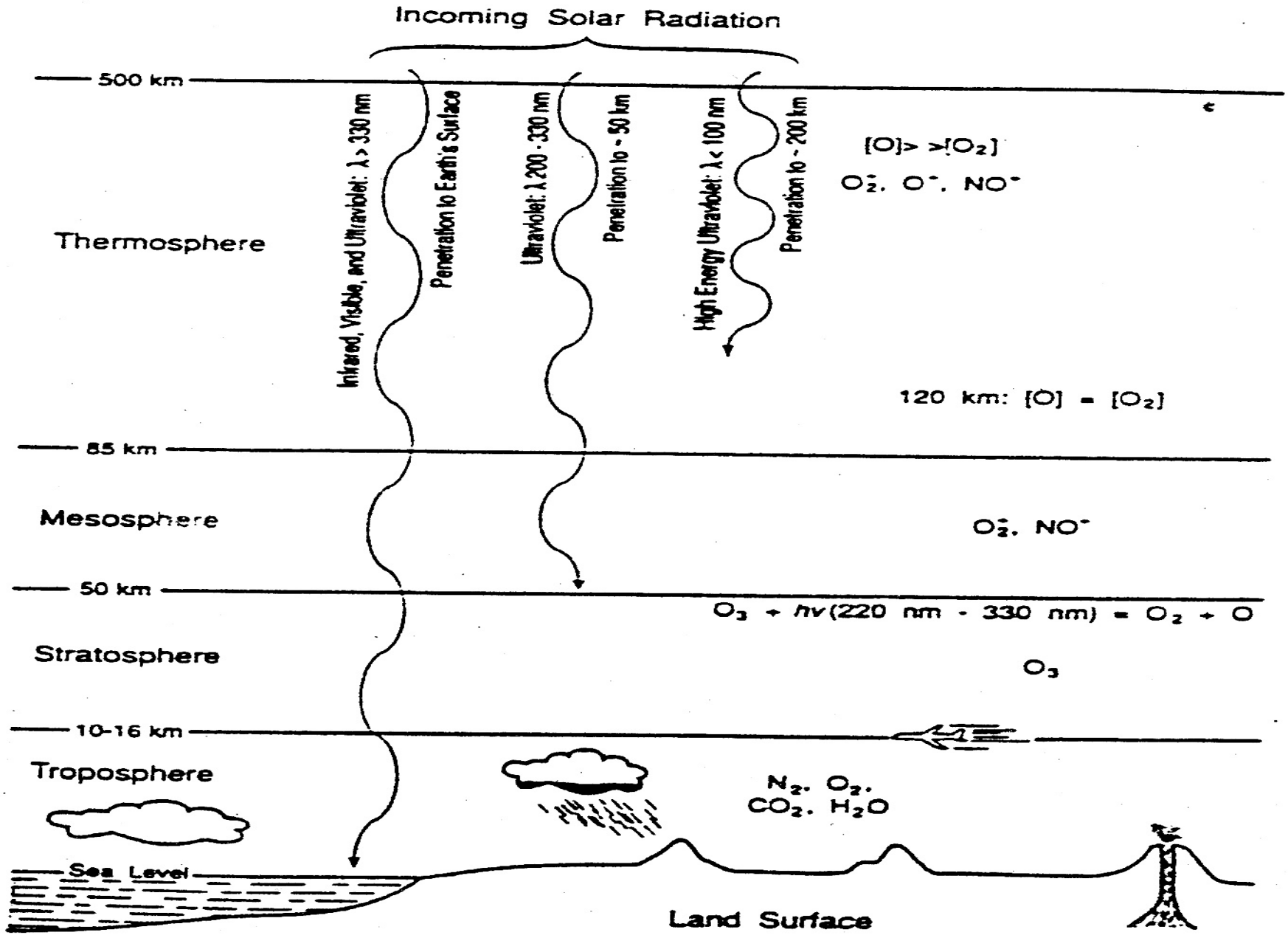


Figure 5.1: The structure of the atmosphere

Chemical Species & Particulates present in Atmosphere.

- Ions- discussed
- Radicals- discussed
- Particles-

  Role of particles (0.1u—100 u)
- Radiation balance
- Most important in troposphere
- Colloidal sized (< 0.1 micron) are called aerosole
- Mist, smokes, dust, ash, org. particle from vegetation, Bacteria, fog, pollen grains

Role of Particles

- Electrification phenomenon
- Nuclei for condensation
- Fog & cloud formation
- Absorb gases.
- Change the absorption spectrum of gases
- Reactions on their surfaces- neutralization, photo chemical oxidation, decomposition of O^3, Reactions of SO_2 $O_{3,}$, NO_2, etc.

Role of Particles contd.
Radiation Balance of Earth

- Recall e.m. waves and Radiant Heat Transfer.
- Sun is like black body at 6000^{o}K
- 92 % rad. in range 315 to 1400 nm.
- 40 % of above on in VISIBLE REGION
- Earth absorbs rad in VR and emits in INFRA RED REGION

Role of Particles contd.
Radiation Balance of Earth

- Heat input to our planet is 2.68x 10 ^{24} joul/ year
- Earth is like a black body at 288 K emission of rad. 4 000 to 50 000 nm
- 30% reflected back, 17% absorbed, 53% transmitted to earth crust.

Reactions in the Atmosphere

- Reactions involving oxides of nitrogen/ NOx, N2O/ N2O4

(Ozone depletion)

- $N_2O + UV = N_2 + O$ (most important)
- $N_2O + O = NO + NO$
- $NO + \mathbf{O_3} = NO_2 + O_2$
- $NO_2 + \mathbf{O_3} = NO_2 + O_2$

Reactions in the Atmosphere contd.

Oxides of Sulphur dioxide.

SOx

- SO2 + hv = $SO_2^{(Activated)}$
- $SO_2^{(Activated)} + O_2 = SO_4$
- $SO_4 + O_2 = SO_3 + O_3$ (dangerous at ground level/ in troposphere)

Acid In Atmosphere

- $4NO_2 + O_2 + 2H_2O = 4\ \mathbf{HNO_3}$
- $2NO_2 + \mathbf{O_3} + H2O = 2\ \mathbf{HNO_3} + O_2$
- $SO_3 + H_2O = \mathbf{H_2SO_4}$
- $SO_2 + ½\ O_2 + H_2O = \mathbf{H_2SO_4}$

Oxidation of Organic Compounds

- Photochemical and chemical reactions of hydrocarbons like aldehydes, ketones, etc, and contribute to **smog** formation
- R-H + O2 + hv + M (other species) = various ions, activated atoms/ molecules, radicals involving organic radicals, C, O, etc.

Complex Reactions in Atmosphere

- HNO_2 & HNO_3 + hv = NO_2 + H ^{activated} / NO + HO ^{activated}/ NO_2 + HO ^{activated}
- SO2 + HO ^{activated} + O2 = HSO_3 ^{activated} + NO_2 ^{activated}
- All these activated ions/ radicals undergo various complex reaction.
- Difficult to understand the exact pathways and reaction mechanisms.
- Ultimate damages are: **Acid deposition, Build up of Green House Gases, Ozone depletion**

Smog

- Industrial Smog:
- huge gray smoke from stacks of factories.
- burning of coal for heat and energy
- the main pollutant of industrial smog is sulfur dioxide-a compound largely responsible for acid precipitation.

Smog contd.

- Photochemical Smog
- motor vehicles, use of fossil fuels for heating, industry, and transportation
- slashing-and-burning of trees
- volatile organic compounds (VOCs) and nitrogen oxides
- Interacting with sunlight
- pollutants-namely peroxyacetyl nitrates (PAN) and ground-level (tropospheric) ozone

Industrial Smog:

- Polluted air associated with industrial activities is often called Industrial Smog.
- Produced by the burning of coal of high level sulfur.
- **In London on Thursday 4th December, 1952 at valley of Thames River**
- Saturday was a day of darkness.
- 20 miles around London no light came out through the weak-end.
- On Monday 8th December – 100 people died of heart attack.
- Before cleaned on Tuesday 9th December 4000 deaths were attributed to the smog.
- The total death count was 8000.

The Chemistry of Industrial Smog:

- Coal:
  - 3% Sulfur
  - 97% Carbon
  - Varying amount of mineral matter
  - $C + O_2 \rightarrow CO_2$
  - $2C + O_2 \rightarrow 2CO$
  - Unburned carbon ends-up as soot.

- Sulfur Oxides:
- $S + O_2 \rightarrow SO_2$
- S readily absorbed in respiratory system
- $2SO_2 + O_2 \rightarrow 2SO_3$
- $SO_3 + H_2O \rightarrow H_2SO_4$
- Particulate Matter:
- Solid & liquids particles of greater than molecular size e.g. soot and mineral matter in coal.
- A six city of Harvard Researchers in the 1990s 60,000 premature deaths per year in USA because of there tiny particles.

Health & Environmental Effects of Industrial Smog:

- Damage the Lungs.
- Dangerous for Plants.
- Leaves become Bleached.
- Yield and Quality of Farm Corps severely damaged.
- Cause Acid Rain.

How to Handle Industrial Smog:

- Electrostatic precipitation.
- Bag Filtration.
- Cyclone Separator.
- Wet Scrubber.

Photochemical Smog:

- Occurs in dry sunny weather.
- Main Causes:
  - Unburned hydrocarbons.
  - Nitrogen oxides from automobiles.