Environmental Chemistry — Complete Exercise Solution

Multiple Choice Questions (MCQs)

i. The major component of troposphere is:

Answer: b) Nitrogen

Explanation: The troposphere (and atmosphere overall) is composed of approximately 78% Nitrogen (N_2), 21% Oxygen (O_2), and small amounts of Argon, CO_2, and other gases. Nitrogen is by far the most abundant component.

ii. The coldest region in atmosphere is:

Answer: c) Mesosphere

Explanation: The mesosphere extends from about 50 km to 80 km above Earth's surface. Temperature in this layer decreases with altitude, reaching as low as –90°C at its top. It is the coldest of all atmospheric layers.

iii. Ozone depletion causes:

Answer: b) Skin cancer

Explanation: The ozone layer absorbs harmful UV-B and UV-C radiation from the Sun. When ozone depletes, more UV radiation reaches Earth's surface. Prolonged exposure to UV radiation damages skin cells and causes skin cancer (melanoma). It also causes cataracts and immune system damage.

iv. The pH of acid rain is less than:

Answer: d) 5.6

Explanation: Normal rainwater has a slightly acidic pH of 5.6 due to dissolved CO_2 forming carbonic acid (H_2CO_3). When SO_2 and NO_2 (from pollution) dissolve in rainwater and form H_2SO_4 and HNO_3, the pH drops below 5.6 — this is acid rain.

v. Ozone is _____ gas:

Answer: c) Bluish

Explanation: Ozone (O_3) is a pale bluish gas with a pungent, distinctive smell. It is found naturally in the stratosphere and acts as a shield against harmful UV radiation.

Short Answer Questions

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i. What is Environmental Chemistry?

Environmental chemistry is the branch of chemistry that deals with the study of chemical and biochemical processes occurring in the natural environment (air, water, soil). It also studies the effects of human activities on the environment, including pollution, its causes, effects, and possible solutions. It helps us understand how pollutants are produced, how they spread, and how they can be controlled to protect living organisms and ecosystems.

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ii. Write a Short Note on Stratosphere.

The stratosphere is the second layer of the atmosphere, extending from about 12 km to 50 km above Earth's surface. Key features:

- Temperature increases with altitude (from –60°C to 0°C) because ozone absorbs UV radiation.
- Contains the ozone layer (O_3) at 20–35 km, which absorbs harmful UV-B and UV-C radiation from the Sun.
- Very little weather activity occurs here — it is calm and stable.
- Jet aircraft fly in the lower stratosphere due to its calm conditions.
- Depletion of the ozone layer in this region is a major environmental concern.

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iii. Effect of Acid Rain on Building Materials

Acid rain (pH < 5.6) has severe destructive effects on building materials:

- **Marble and Limestone:** These contain calcium carbonate ($CaCO_3$), which reacts with acid rain (H_2SO_4) to form calcium sulphate ($CaSO_4$), CO_2, and water. The stone crumbles and erodes:

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

- **Iron and Steel Structures:** Acid rain accelerates corrosion (rusting) of iron bridges, railings, and buildings.
- **Concrete:** The acid attacks and weakens concrete structures, reducing their strength and lifespan.
- Famous monuments like the Taj Mahal have been visibly damaged by acid rain.

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iv. What is the Importance of the Atmosphere?

The atmosphere is essential for life on Earth. Its key importances are:

- **Provides oxygen** (O_2) for breathing and respiration of living organisms.
- **Ozone layer** in the stratosphere absorbs harmful UV radiation, protecting life from skin cancer and other damage.
- **Regulates temperature** — acts like a blanket, keeping Earth warm through the greenhouse effect. Without it, Earth would be extremely cold.
- **Provides CO_2** for photosynthesis in plants, which produces food and oxygen.
- **Protects from meteorites** — most meteorites burn up due to friction before reaching Earth's surface.
- **Supports the water cycle** — water evaporates, forms clouds, and returns as rain.

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v. Physical Properties of Ozone

Property	Description
Formula	O_3
Colour	Pale bluish gas
Smell	Pungent, distinctive odour
State	Gas at room temperature
Density	Heavier than oxygen (O_2)
Solubility	Slightly soluble in water
Location	Found mainly in stratosphere (20–35 km altitude)
Stability	Unstable — easily decomposes to O_2
UV Absorption	Absorbs UV-B and UV-C radiation strongly

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vi. What are Primary and Secondary Air Pollutants?

Primary Air Pollutants: Pollutants that are directly emitted into the atmosphere from a source in harmful form are called primary pollutants.

Examples:

- Carbon monoxide (CO) — from vehicles
- Sulphur dioxide (SO_2) — from burning of fossil fuels
- Nitrogen oxides (NO_x) — from vehicle exhaust
- Smoke and soot particles — from factories and burning

Secondary Air Pollutants: Pollutants that are NOT directly emitted but are formed in the atmosphere when primary pollutants react with each other or with sunlight.

Examples:

- Ozone (O_3) at ground level — formed when NO_x reacts with sunlight
- Sulphuric acid (H_2SO_4) — formed when SO_2 reacts with water vapour
- Smog — formed from reactions of primary pollutants in sunlight

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Long Answer Questions

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i. Composition and Layers of Atmosphere

What is the Atmosphere?

The atmosphere is a thick blanket of gases surrounding the Earth, held in place by gravity. It extends up to about 10,000 km above Earth's surface and is essential for life.

Composition of Atmosphere

Gas	Percentage
Nitrogen (N_2)	78%
Oxygen (O_2)	21%
Argon (Ar)	0.93%
Carbon dioxide (CO_2)	0.04%
Other gases (Ne, He, CH_4, O_3, H_2O vapour)	Trace amounts

Layers of Atmosphere

1. Troposphere

- Lowest layer; extends from 0 to 12 km
- Contains 75–80% of total atmospheric mass
- Temperature decreases with altitude (from +15°C to –60°C)
- All weather phenomena (rain, snow, storms, clouds) occur here
- Major components: N_2, O_2, CO_2, water vapour

2. Stratosphere

- Extends from 12 km to 50 km
- Temperature increases with altitude (due to ozone absorbing UV rays)
- Contains the ozone layer (O_3) at 20–35 km — shields Earth from UV radiation
- Calm and stable — jet aircraft fly here

3. Mesosphere

- Extends from 50 km to 80 km
- Coldest layer — temperature drops to –90°C at top
- Meteorites burn up in this layer due to friction
- Temperature decreases with altitude

4. Thermosphere (Ionosphere)

- Extends from 80 km to 700 km
- Temperature rises steeply — can reach 1500°C (due to absorption of X-rays and UV rays)
- Gas molecules are ionised here — enables radio wave transmission
- Aurora Borealis (Northern Lights) occurs in this layer

5. Exosphere

- Outermost layer; beyond 700 km
- Very thin — gases gradually merge into outer space
- Satellites orbit in this region

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ii. Air Pollution — Definition and Major Sources

What is Air Pollution?

Air pollution is the presence of harmful substances (gases, particles, biological molecules) in the atmosphere in concentrations that are harmful to living organisms, the environment, and property.

Major Sources of Air Pollution

A. Natural Sources

- **Volcanic eruptions** — release SO_2, CO_2, ash, and dust
- **Forest fires** — produce CO, CO_2, smoke, and soot
- **Dust storms** — add particulate matter to the atmosphere
- **Decomposition of organic matter** — releases CH_4 and H_2S

B. Industrial Sources

- Factories and power plants burn fossil fuels, releasing:
- SO_2 — from burning coal and petroleum
- CO_2 and CO — from incomplete combustion
- Nitrogen oxides (NO_x) — from high-temperature combustion
- Chemical industries release toxic gases like HCl, HF, NH_3

C. Transportation / Vehicle Exhaust

- Petrol and diesel engines release:
- Carbon monoxide (CO) — toxic gas
- Unburnt hydrocarbons
- Nitrogen oxides (NO_x)
- Lead compounds (from leaded petrol)

D. Domestic / Agricultural Sources

- Burning of wood, coal, and crop residue for cooking and heating
- Use of pesticides and fertilisers releases NH_3 and N_2O
- Smoke from open burning of garbage

E. Radioactive Pollutants

- Nuclear power plants and nuclear testing release radioactive substances into the atmosphere.

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iii. Ozone Depletion — Definition and Mechanism

What is Ozone Depletion?

Ozone depletion refers to the thinning and destruction of the ozone layer in the stratosphere, particularly over Antarctica (the "ozone hole"), due to chemical reactions involving man-made pollutants.

Causes of Ozone Depletion

The main cause is Chlorofluorocarbons (CFCs) — used in:

- Refrigerators and air conditioners
- Aerosol sprays
- Foam-blowing agents

Other causes: nitrogen oxides (NO_x), methane (CH_4), halons (in fire extinguishers)

Mechanism of Ozone Depletion

Step 1 — CFC Release into Atmosphere: CFCs (e.g., CCl_2F_2) are released from appliances and rise into the stratosphere.

Step 2 — UV Radiation Breaks CFCs: UV radiation breaks the CFC molecule, releasing a **chlorine free radical (Cl•)**:

$CCl_2F_2 + UV \rightarrow CClF_2\bullet + Cl\bullet$

Step 3 — Chlorine Attacks Ozone: The highly reactive chlorine radical attacks ozone (O_3):

$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$

Step 4 — Chain Reaction Continues: The ClO• radical reacts with another oxygen atom to release Cl• again:

$ClO\bullet + O \rightarrow Cl\bullet + O_2$

The Cl The radical is regenerated and attacks more ozone molecules. This creates a chain reaction — one Cl atom can destroy up to 100,000 ozone molecules.

Net Reaction: $O_3 + O \rightarrow 2O_2$ (ozone is destroyed)

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iv. Acid Rain — Definition, Formation, and Effects on Environment

What is Acid Rain?

Normal rainwater has a pH of 5.6 (slightly acidic due to dissolved CO_2). When rainwater has a pH below 5.6 due to dissolved pollutants (H_2SO_4 and HNO_3), it is called acid rain.

Formation of Acid Rain

From Sulphur Dioxide (SO_2):

Burning of fossil fuels releases SO_2:

$S + O_2 \rightarrow SO_2$

SO_2 reacts with oxygen and water in the atmosphere:

$2SO_2 + O_2 \rightarrow 2SO_3$

$SO_3 + H_2O \rightarrow H_2SO_4$ (sulphuric acid)

From Nitrogen Oxides (NO_x):

Vehicle exhaust and industries release NO and NO_2:

$4NO + 3O_2 + 2H_2O \rightarrow 4HNO_3$ (nitric acid)

Both H_2SO_4 and HNO_3 dissolve in raindrops, making the rain acidic (pH < 5.6).

Effects of Acid Rain on the Environment

1. Effect on Aquatic Life:

- Acid rain lowers the pH of lakes and rivers.
- Fish and other aquatic organisms cannot survive at low pH — leads to death of aquatic life.
- At pH < 4, most aquatic life is destroyed.

2. Effect on Soil:

- Acid rain leaches important minerals (Ca^{2+}, Mg^{2+}, K^+) from the soil.
- Makes soil acidic and infertile, reducing crop yield.
- Kills beneficial soil bacteria and organisms.

3. Effect on Plants and Forests:

- Acid rain damages leaves — causes yellowing and falling of leaves.
- Slows photosynthesis and plant growth.
- Kills trees, especially in forests near industrial areas.

4. Effect on Building Materials:

- Marble, limestone, and concrete react with acids and erode:

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

- Accelerates corrosion of iron and steel structures.

5. Effect on Human Health:

- Acid rain water, if consumed, causes digestive problems.
- Leaches heavy metals from pipes into drinking water.

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v. How Does Ozone Depletion Adversely Affect Our Life?

The ozone layer absorbs 95–99% of harmful UV radiation from the Sun. When ozone depletes, more UV-B and UV-C reaches Earth's surface, causing serious adverse effects:

1. Skin Cancer:

- Increased UV-B radiation damages DNA in skin cells.
- Causes malignant melanoma (skin cancer) and other forms of skin cancer.
- A 1% decrease in ozone causes a ~2% increase in skin cancer cases.

2. Eye Damage — Cataracts:

- UV radiation damages the lens of the eye, causing cataracts (clouding of the eye lens).
- Can cause partial or complete blindness.

3. Weakening of Immune System:

- Excess UV radiation suppresses the human immune system.
- The body becomes less able to fight infections and diseases.

4. Damage to Marine Ecosystems:

- UV radiation penetrates the ocean surface and kills phytoplankton (microscopic plants).
- Phytoplankton form the base of the marine food chain — their destruction collapses the entire marine ecosystem.
- Kills fish eggs and juvenile fish near the water surface.

5. Damage to Plants and Agriculture:

- Excess UV radiation reduces photosynthesis in plants.
- Stunts plant growth, reduces crop yields, and damages forests.
- Reduces food production worldwide.

6. Increase in Global Warming:

- UV radiation breaking down ozone produces more O_2.
- Reduced ozone means more heat energy reaches Earth, contributing to global warming and climate change.

7. Effect on Rubber and Plastics:

- Increased UV radiation accelerates the degradation of rubber, plastics, and paints used in daily life.