## About the Book

Welcome to "Environmental Chemistry," a thorough examination of the intricate relationship between chemical processes and the environment. This book explores the fundamental principles, applications, and implications of environmental chemistry, offering insights into the dynamic interplay between human activities and the natural world.

In the opening chapter, "Fundamentals of Environmental Chemistry," readers establish a foundation for understanding environmental systems, including pollutant sources, reactions, and fates.

## About the Editors:

**Arun Sharma** is currently serving as Associate Professor in the department of chemistry at Career Point University, Kota (Rajasthan). His fields of research are electrochemistry, material science, immunosensors, quantum dots and warfare agents. He obtained his Ph.D. in Chemistry from Jiwaji University Gwalior (NAAC A++), in 2016.

**Dr. Erum Gull Naz** is a famous researcher in theoretical and computational chemistry, specializing in chemical reaction dynamics, rate constants, thermodynamics, and kinetics. She earned her Ph.D. at the prominent Indian Institute of Technology (IIT) in Jodhpur, Rajasthan. Her study also includes organo-physical chemistry and interstellar chemistry, which investigate basic processes that occur on Earth and beyond.

**Surabhi Singh,** a visionary leader having exemplary research, academic, & administrative experience in the field of Higher Education, obtained her Ph.D. in Environmental Chemistry from Career Point University, Kota (Rajasthan). Currently, she is serving as Associate Professor cum Head of Department of School of Basic and Applied Sciences at Career Point University, Kota (Rajasthan).

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**Ms. Insha Ara,** a researcher in theoretical and analytical chemistry, specializing in organic chemistry. She earned her Master of Science at the prominent Career point University in Kota , Raj where she studied many aspects of chemical processes, such as their Analytical and practical and get a Gold medalist in academics and got many certificates in academic

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# ENVIRONMENTAL CHEMISTRY

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CP PUBLICATION

# ENVIRONMENTAL CHEMISTRY

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# Preface

Welcome to "Environmental Chemistry," a thorough examination of the intricate relationship between chemical processes and the environment. This book explores the fundamental principles, applications, and implications of environmental chemistry, offering insights into the dynamic interplay between human activities and the natural world.

In the opening chapter, "Fundamentals of Environmental Chemistry," readers establish a foundation for understanding environmental systems, including pollutant sources, reactions, and fates.

Chapter 2, "The Impact of Various Environmental Pollutants on the Earth's Atmosphere," illuminates diverse pollutants affecting air quality and climate dynamics.

"Thermodynamic Principles and Applications in Engineering," Chapter 3, explores thermodynamics' role in environmental processes and engineering solutions, emphasizing energy considerations in sustainability efforts.

Chapter 4, "Biochemical Kinetics: Exploring Gibbs Free Energy and Enzyme Catalysis," focuses on biological transformations' mechanisms and relevance to environmental systems.

Chapters 5 through 8 delve into atmospheric chemistry, examining processes leading to inorganic and organic particulate matter formation, thermochemical and photochemical reactions, and their implications for atmospheric composition and climate change.

Chapter 9, "Green Chemistry for Water: Sustainable Solutions to Pollution," addresses the nexus between chemistry and water quality, proposing innovative approaches for mitigating pollution and promoting sustainable water management.

Lastly, Chapter 10, "Soil Chemistry," explores chemical dynamics within terrestrial ecosystems, including soil pollution, nutrient cycling, and human activities' impact on soil health.This multidisciplinary journey deepens our understanding of environmental chemistry's role in addressing contemporary challenges and fostering sustainable solutions for our planet's well-being.

We extend our heartfelt thanks to Pramod Maheshwari, Sir, Managing Director and Chairman of Career Point University, Kota, as well as the HOD and Dean for their inspiration and support during the book's development. Gratitude is also expressed to our families for their constant encouragement, and to students and the teaching community for their support. Suggestions to improve the book's quality are welcomed.

Dr. Arun Sharma

Dr. Erum Gull Naz

Dr. Surabhi Singh

Ms. Kriti Tripathi

Ms. Insha Ara

# Environmental Chemistry

# Syllabus

## Unit-I (Dr. Arun)

Stoichiometry, Gibb's energy, Chemical potential, Chemical equilibria, acid-base. reactions Solubility product, solubility of gases in water, the carbonate system, unsaturated and saturated hydrocarbons, Radio nuclides.

## Unit -II (Dr. Surabhi)

Classification of elements, chemical speciation, Particles, ions and radicals in the atmosphere. Chemical processes for formation of inorganic and organic particulate matter. Thermochemical and photochemical reactions in the atmosphere

## Unit - III (Dr. Erum)

First law of thermodynamics, enthalpy, adiabatic transformations, second law of thermodynamics, Carnot's cycle, entropy.

## Unit - IV (Dr. Erum)

Gibbs free energy, chemical potential, phase equilibria, Gibbs Donnan equilibrium, third law of thermodynamics, enzymes catalysis, Michaelis/Menten equation.

## Unit - V (Ms. Kriti Tripathi)

Oxygen and ozone chemistry, Chemistry of air pollutants, Photochemical Smog, Chemistry of water, concept of D.O., B.O.D., and C.O.D, water treatment : Sedimentation, Coagulation, Filtration, tertiary and advanced treatment, redox potential. Inorganic and organic components of soil, nitrogen pathways and NPK in soils.

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**Dr. Surabhi Singh and Ms. Kriti Tripathi**

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**About the Author's:**

**Arun Sharma** is currently serving as Associate Professor in the department of chemistry at Career Point University, Kota (Rajasthan). His fields of research are electrochemistry, material science, immunosensors, quantum dots and warfare agents. He obtained his Ph.D. in Chemistry from Jiwaji University Gwalior (NAAC A++), in 2016.

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CHAPTER 5

# Environmental in Atmosphere

Dr. Surabhi Singh and Insha Ara

**ABSTRACT**

The classification of elements, chemical speciation, and the presence of particles, ions, and radicals in the Earth's atmosphere are critical components in understanding atmospheric composition and its impact on environmental and human health. This abstract explores the intricate relationships between these elements.

Elements in the atmosphere exhibit diverse behaviors based on their chemical properties, leading to the classification of atmospheric constituents into distinct categories. Understanding chemical speciation is crucial, as it involves identifying and quantifying different chemical forms of elements, providing insights into their reactivity and potential effects. This knowledge is essential for assessing air quality and predicting environmental changes.

Particulate matter, ions, and radicals play pivotal roles in atmospheric processes. Particles, ranging from tiny aerosols to larger pollutants, influence climate, visibility, and respiratory health. Ions, both natural and anthropogenic, contribute to atmospheric conductivity and play a role in various chemical reactions. Radicals, highly reactive species, drive key atmospheric reactions, influencing pollutant transformation and the formation of secondary pollutants.

This abstract emphasizes the interdisciplinary nature of atmospheric science, where understanding the classification of elements and chemical speciation is fundamental for comprehending the behavior and impact of particles, ions, and radicals in the intricate tapestry of the Earth's atmosphere.

## Content-

1. Introduction

2. Chemical Speciation Of Elements In The Atmosphere

3. Particles, Ions And Radicals Present In The Atmosphere

4. Conclusion

## 1. Introduction

The environment in the Earth's atmosphere is a dynamic system involving complex interactions between various components, including gases, particles, and radiation. Understanding the environmental factors within the atmosphere is crucial for comprehending climate, air quality, and the overall well-being of our plane (World Health Organization (WHO), 2021). Here's an overview of key environmental aspects in the atmosphere:

**a) Greenhouse Gases:**

Greenhouse gases, such as carbon dioxide ($CO_2$), methane ($CH_4$), and water vapor ($H_2O$), play a vital role in regulating Earth's temperature by trapping heat in the atmosphere. However, anthropogenic activities have led to an increase in greenhouse gas concentrations, contributing to global warming (Intergovernmental Panel on Climate Change (IPCC), 2014).

**b) Ozone Layer:**

The ozone layer in the stratosphere protects life on Earth by absorbing harmful ultraviolet (UV) radiation. Human-made substances, such as chlorofluorocarbons (CFCs), have led to ozone depletion, particularly in polar regions (World Meteorological Organization (WMO), 2018).

**c) Air Quality:**

The atmosphere's composition significantly affects air quality. Particulate matter (PM), nitrogen oxides (NOx), sulfur dioxide ($SO_2$), and volatile organic compounds (VOCs) are among the pollutants that impact human health and the environmen (World Health Organization (WHO). (2021).

**d) Aerosols and Particles:**

Atmospheric aerosols and particles influence climate by scattering and absorbing sunlight. They also play a role in cloud formation and act as nuclei for water droplets (IPCC, 2013).

**e) Radiation Balance:**

The balance between incoming solar radiation and outgoing thermal radiation determines Earth's energy balance. Changes in this balance can impact climate and lead to phenomena like global warming (Hartmann, 2016).

**f) Atmospheric Circulation:**

The movement of air masses, driven by differences in temperature and pressure, influences weather patterns and climate. Atmospheric circulation plays a crucial role in distributing heat around the planet (Wallace & Hobbs, 2006).

Understanding the environment in the atmosphere requires a multidisciplinary approach, integrating knowledge from atmospheric science, climatology, and environmental science. Ongoing research and monitoring efforts contribute to our understanding of these complex interactions and inform policies aimed at addressing environmental challenges on a global scale.

**Classification of elements present in the atmosphere**

The Earth's atmosphere is composed of a mixture of gases that surround our planet, creating a dynamic and essential environment for life. These gases can be classified into two main categories: permanent gases and variable gases(Ciais, P., et al. 2013) .

**(i) Permanent Gases:**

**Nitrogen ($N_2$):** Nitrogen makes up approximately 78% of the Earth's atmosphere, making it the most abundant gas. Its presence is crucial for life, as nitrogen is an essential component of amino acids, proteins, and nucleic acids.

**Oxygen ($O_2$):** Oxygen constitutes about 21% of the atmosphere. This gas is vital for the respiration of most living organisms, serving as a key component in the process of cellular respiration.

**Argon (Ar):** Argon is a noble gas that makes up about 0.93% of the atmosphere. Although it is chemically inert, argon plays a role in various industrial applications, such as welding.

**(ii) Variable Gases:**

**Carbon Dioxide ($CO_2$):** Carbon dioxide is a minor component of the atmosphere, constituting about 0.04%. Despite its low concentration, $CO_2$ plays a critical role in the greenhouse effect, influencing Earth's climate (NOAA Earth System Research Laboratory. (2022).

**Water Vapor ($H_2O$):** Water vapor is a variable gas, with its concentration depending on factors like temperature and location. It plays a crucial role in the Earth's climate system, contributing to the water cycle and cloud formation (NASA Earth Observatory, 2022).

**Methane ($CH_4$), Nitrous Oxide ($N_2O$), and Ozone ($O_3$):** These gases are present in trace amounts but have significant impacts on climate and atmospheric chemistry. Methane and nitrous oxide are potent greenhouse gases, while ozone in the stratosphere protects life on Earth by absorbing harmful ultraviolet (UV) radiation.

Knowing the composition of Earth's atmosphere is crucial for studying climate change, atmospheric chemistry, and the overall health of our planet. Ongoing research and monitoring contribute to our understanding of the complex interactions between these gases and their impact on the Earth system.

## 2. Chemical Speciation Of Elements In The Atmosphere

Chemical speciation refers to the identification and quantification of different chemical forms or species of elements in a given environment. In the atmosphere, elements exist in various chemical forms due to reactions and interactions with other substances. Understanding chemical speciation is crucial for assessing the environmental impact, reactivity, and behavior of different elements. Here's an overview of the chemical speciation of some key elements in the atmosphere:

**a) Sulfur (S):**

Sulfur exists in the atmosphere in different oxidation states, including sulfur dioxide ($SO_2$) and sulfate aerosols ($SO_4^{2-}$). These compounds play a significant role in atmospheric chemistry, contributing to acid rain formation and affecting air quality (Finlayson-Pitts & Pitts 2000).

**b) Nitrogen (N):**

Nitrogen undergoes various transformations in the atmosphere, leading to the formation of nitrogen oxides (NOx), such as nitrogen dioxide ($NO_2$) and nitric oxide (NO). These compounds contribute to air pollution and the formation of ground-level ozone (Seinfeld & Pandis, 2006).

**c) Mercury (Hg):**

Mercury in the atmosphere exists in different forms, including elemental mercury ($Hg^0$) and reactive mercury species like divalent mercury ($Hg^{2+}$). Understanding the speciation of mercury is crucial due to its toxicity and potential for long-range transport (Selin, 2009).

**d) Carbon (C):**

Carbon exists in various forms in the atmosphere, such as carbon dioxide ($CO_2$), methane ($CH_4$), and volatile organic compounds (VOCs). The speciation of carbon compounds is essential for studying greenhouse gas concentrations and their impact on climate change (Jacob, 1999).

**e) Trace Metals:**

Trace metals, including lead (Pb), cadmium (Cd), and arsenic (As), undergo complex speciation in the atmosphere, often binding to particles or forming soluble complexes. Understanding their speciation is crucial for assessing their environmental impact and human health risks (Pirrone & Mason, 2009).

Research in the field of chemical speciation continues to evolve, driven by advancements in analytical techniques and increased awareness of the environmental impacts of different chemical forms of elements in the atmosphere. Ongoing studies contribute to our understanding of atmospheric chemistry and inform environmental policies aimed at mitigating air pollution and addressing global challenges.

## 3. Particles, Ions And Radicals Present In The Atmosphere

The Earth's atmosphere is a complex mixture of particles, ions, and radicals, each playing a crucial role in atmospheric chemistry, air quality, and climate. Understanding the composition and behavior of these atmospheric constituents is essential for comprehending various environmental processes. Here's an overview of particles, ions, and radicals present in the atmosphere:

**a) Atmospheric Particles:**

**Aerosols:** Aerosols are tiny solid or liquid particles suspended in the air. They include dust, soot, sea salt, and various organic compounds. Aerosols influence climate by scattering and absorbing sunlight and by serving as cloud condensation nuclei.

**Fine Particulate Matter (PM2.5) and Coarse Particulate Matter (PM10):** PM2.5 and PM10 refer to particles with diameters less than 2.5 micrometers and 10 micrometers, respectively. They have implications for respiratory health and contribute to air pollution (Seinfeld & Pandis, 2006)

**b) Atmospheric Ions:**

**Positive Ions (Cations) and Negative Ions (Anions):** Atmospheric ions are charged particles present in the air. They can be generated through processes like cosmic ray interactions, radioactivity, and ionization from lightning. These ions can affect air quality and play a role in atmospheric electricity (Rees, 2005).

**Ionospheric Ions:** In the upper atmosphere, ions play a crucial role in the ionosphere, influencing radio wave propagation. Ionospheric ions are essential for the functioning of communication and navigation systems (Rees, 2005).

**c) Atmospheric Radicals:**

**Hydroxyl Radicals (OH):** Hydroxyl radicals are highly reactive and play a key role in atmospheric oxidation processes. They contribute to the removal of pollutants and greenhouse gases from the atmosphere.

**Nitrogen Oxide Radicals (NOx):** NOx radicals, including nitric oxide (NO) and nitrogen dioxide ($NO_2$), are important in atmospheric chemistry, influencing air quality and the formation of ozone (Finlayson-Pitts & Pitts, 2000).

So the interactions between particles, ions, and radicals is crucial for modeling atmospheric processes, predicting air quality, and addressing global environmental challenges. Ongoing research in this field continues to advance our knowledge of atmospheric composition and its impact on climate, human health, and ecosystems.

## 4. Conclusion

In a nutshell, the intricate interplay between the classification of elements, chemical speciation, and the presence of particles, ions, and radicals underscores the complexity of the Earth's atmosphere. Advancements in atmospheric science are pivotal for addressing environmental challenges and mitigating the impacts of air pollution. A comprehensive understanding of these components facilitates accurate modeling, monitoring, and effective policy implementation. As we navigate a rapidly changing world, continued research in this field remains imperative for safeguarding both human health and the delicate balance of our planet's ecosystems.

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