



ENVIRONMENTAL CHEMISTRY-AIR

Student Learning Outcomes (SLOs)

After completing this lesson, the student will be able to:

- State that composition of clean, dry air is approximately 78% nitrogen, 21% oxygen, remainder as a mixture of noble gases and carbon dioxide.
- State the major sources of air pollutants: Some examples include (a) carbon dioxide from the complete combustion of carbon-containing fuels (b) carbon mono-oxide and particulates from the incomplete combustion of carbon-containing fuels. (c) methane from the decomposition of vegetation and waste gases from digestion in animals (d) oxides of nitrogen from car engines (f) ground level ozone from reactions of oxides of nitrogen, from car engines, and volatile organic compounds, in presence of light.
- State the adverse effects of air pollutants: Some examples include (a) carbon dioxide; higher levels of carbon dioxide leading to increased global warming, which leads to climate change. (b) carbon mono-oxide as toxic gas (c) particulates: increased risk of respiratory problems and cancer (d) methane: higher levels of methane leading to increased global warming, which leads to climate change. (e) oxides of nitrogen: acid rain, photochemical smog, and respiratory problems (f) sulphur dioxide: acid rain and haze.

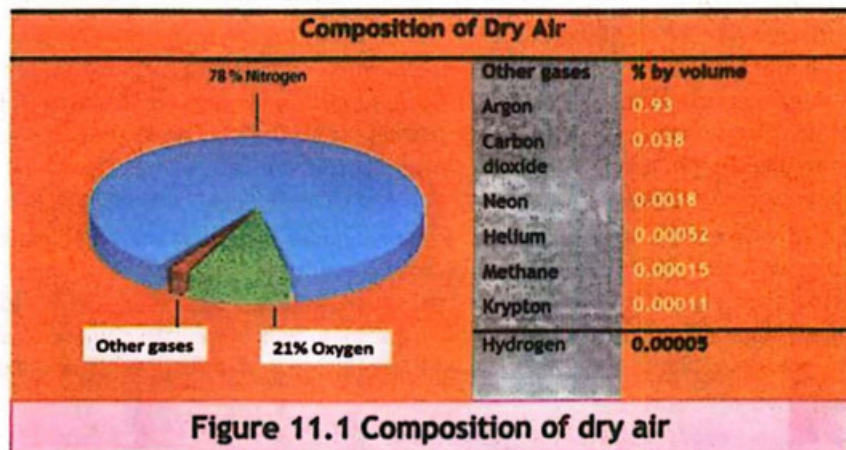
- Explain how the greenhouse gases carbon dioxide and methane cause global warming, some example include: (a) the absorption, reflection, and emission of thermal energy. (b) reducing thermal energy loss to space.
- Describe the role of sulphur in the formation of acid rain and its impact on the environment..
- Describe the strategies to reduce the effect of environmental issues. Some examples include (a) climate change: planting trees, reduction in livestock farming, decreasing use of fossil fuels, increasing use of hydrogen, and renewable energy, e.g., wind, solar (b) acid rain: use of catalytic converters in vehicles, reducing emissions of sulphur dioxide by using low sulphur fuels and flue gas desulphurization with calcium oxide.
- Describe the role of NO and NO₂ in the formation of acid rain, both directly and through their catalytic role in the oxidation of atmospheric sulphur dioxide.
- Explain how oxides of nitrogen form in car engines and describe their removal by catalytic converters, e.g. $\text{CO} + 2\text{NO} \longrightarrow 2\text{CO} + \text{N}_2$
- Define photosynthesis as the reaction between carbon dioxide and water to produce glucose and oxygen in the presences of chlorophyll and using energy from sun.
- Analyze how to use tools to reduce personal exposure to harmful pollutants (some examples include the usage of masks, air quality indices and CO detectors).
- Identify high risk situations in life including those where long-term exposure to these pollutants can lead to respiratory issues and reduction in quality and longevity of life.

INTRODUCTION

This chapter will help you understand what atmosphere means. How the atmosphere is polluted and what substances pollute it? It is also necessary to understand the sources of general air pollution and the harmful effects on living things and the environment. You start your day with a cup of tea, which is a mixture of water, milk, tea, fat, and sugar. The same applies to milk, which is a mixture of water, minerals, proteins, vitamins, and fats. If scum or impure ingredients are added, the tea or milk is contaminated and unhealthy to drink. Air is a mixture of various gases including. nitrogen, oxygen, hydrogen, carbon dioxide, noble gases, and water vapor. The summer season is getting longer and hotter all over the world compared to ten years ago, why? You also know why iron nails rust faster in rainwater than in tap water or mineral water.

11.1 COMPOSITION OF ATMOSPHERE

Air is a mixture of gases. Can you name the main gases that make up the air? The pie chart given below shows the composition of dry air by volume. (Figure 11.1)



Besides gases, there are varying amounts of water vapour in the air. There is little water in the air over the desert. Whereas in the tropical rainforest, the air may contain up to 4% water vapour. This means the amount of water vapour in the air varies from place to place and from time to time.

The envelope of gases and water vapour surrounding the planet Earth is called the atmosphere.

CONCEPT ASSESSMENT EXERCISE 11.1

What two gases make up most of the air?

10.2 AIR POLLUTANTS

Think of a situation when you are in a park or a vegetable farm and in second case you are near a kiln or a garbage dump. Where would you feel fresh?

Pollutants are things like industrial wastes, herbicides, pesticides, insecticides, particles of dust and smoke, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone and lead containing paints. These things have a negative impact on the environment. Such substances effect environment as a result of human activity.

Anything that is in the air, water or soil which has a harmful effect on some part of the environment is called pollutant.

Pollutants damage the environment, health and quality of life. Important air pollutants are as follows:

11.2.1 Sulphur Oxides (SO_x)

You might have noticed that the colour of silk clothes fades away, if left in open air for a week or so. What due to it is?

Sulphur is found naturally in fossil fuels. The burning of fossil fuels in power plants, vehicles, industrial units, power generators and residential heating systems, therefore releases significant amounts of sulphur dioxide.

Sulphur dioxide is readily absorbed in the respiratory system. Being powerful irritant, it aggravates the symptoms of people who suffer from asthma, bronchitis, emphysema, and other lung diseases. Sulphur dioxide also responsible for acid rain and haze.

CONCEPT ASSESSMENT EXERCISE 11.2

1. What are pollutants?
2. List some effects of sulphur dioxide on human beings.
3. List some of the air pollutants.

The important oxides of nitrogen that cause air pollution are nitric oxide (NO) and nitrogen dioxide (NO_2). Collectively they are represented as NO_x .

The biggest source of nitrogen oxides is the burning of fossil fuels in vehicles, power plants, industrial units, and generators used to produce electricity. Car engines produce a lot of nitrogen

oxides. Oxides of nitrogen highly toxic and are responsible for acid rain, photochemical smog, headache, and respiratory problems.

11.2.3 Carbon dioxide

Carbon dioxide (CO_2) is a major air pollutant that has received increasing attention due to its association with climate change and global warming. Although it occurs naturally in the Earth's atmosphere, human activities such as burning fossil fuels, deforestation, and industrial processes have dramatically increased its levels.

11.2.4 Carbon monoxide

Incomplete combustion, occurs when there is not enough oxygen in the combustion process. It is a major source of carbon monoxide and particulate matter. It is mainly emitted by vehicles, industrial processes and residential heating systems that use fossil fuels and wood. Particulate matter refers to a mixture of fine particles suspended in the air, including soot, smoke, dust and other solid or liquid substances. These particles can have harmful effects on human health, especially if they penetrate deep into the lungs, causing respiratory problems and lung cancer. Carbon monoxide is a toxic gas. When inhaled, it combines with hemoglobin to form carboxy hemoglobin, which is unable to carry oxygen causing you to lose consciousness and suffocate. It does not allow blood cells to absorb oxygen, and can cause death. Carbon monoxide is a colourless and odourless gas, so its presence cannot be felt.

11.2.5 Methane

Methane enters the atmosphere from a variety of sources, including the decomposition of vegetation and waste. Wetlands, rice fields, landfills, and livestock are important sources of methane emissions. Methane is also produced during the digestive process in animals such as cows, goats, and sheep. These animals have a unique digestive system that produces large amounts of methane during digestion, which is released through belching and flatulence. Higher levels of methane contribute to the global warming, which is responsible for climate change.

11.2.6 Ground Level Ozone

Ground-level ozone is often called smog. It is a secondary pollutant produced by complex reactions between nitrogen oxides and volatile organic compounds (VOC) under the influence of sunlight. These reactions occur mainly in industrial and urban areas where emissions from

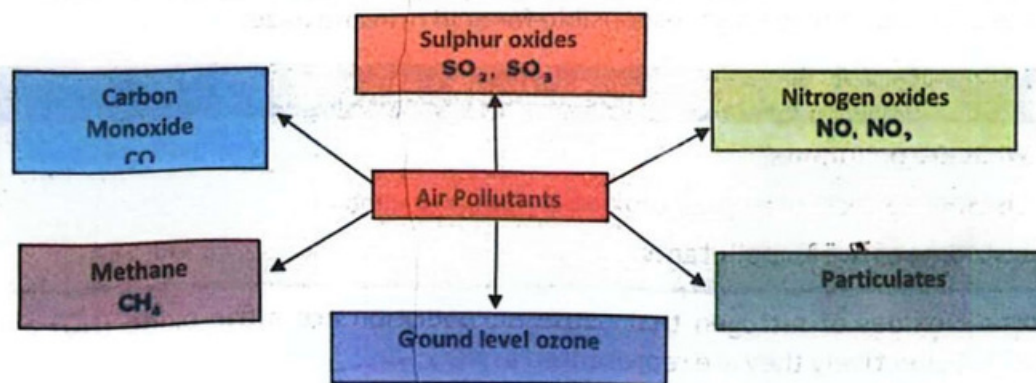


Figure 11.2: Air pollutants

industrial units and car engines are common. In sunlight, a series of chemical reactions occur between volatile organic compounds and nitrogen oxides. These reactions are called photochemical reactions. Sunlight breaks nitrogen dioxide into nitrogen monoxide and atomic oxygen. Atomic oxygen (O) then reacts with oxygen molecules (O₂) to form ozone (O₃). This ozone can irritate the respiratory organs and cause asthma and other respiratory problems. It can also damage vegetation, reduce yield and damage forests.

CONCEPT ASSESSMENT EXERCISE 11.3

1. Write the names of main pollutants in the air.
2. Complete the following reactions.
 - a) $\text{SO}_{2(g)} + \text{O}_{2(g)} \longrightarrow$
 - b) $\text{C}_{(s)} + \text{O}_{2(g)} \longrightarrow$
 - c) $\text{CO}_{(g)} + \text{O}_{2(g)} \longrightarrow$

11.3 SOURCES OF AIR POLLUTION

Air that contains harmful particles and gases is said to be polluted. Some air pollution occurs naturally. But many types of air pollution are the result of human activities.

11.3.1 Natural Sources

Many natural processes such as, forest fires, dust storms release smoke, and dust particles into the air. Volcano's emit clouds of dust and poisonous gases along with ash. Which gas is emitted by volcanoes? Termites and cows also release large amount of methane in the air. Considerable electrical discharges in the atmosphere produce nitrogen oxides.

11.3.2 Human Activities

Most of the air pollution is the result of burning fossil fuels, such as coal, petroleum, and natural gas. Nearly half of the air pollution comes from cars and other motor vehicles. Factories and power plants that burn coal or oil release poisonous gases in the air. Burning fossil fuels and incineration release carbon monoxide (CO), nitrogen oxides (NO, NO₂), and sulphur oxides (SO₂, SO₃). Table 10.1 shows effect produced by air pollutants.

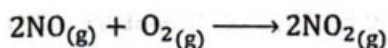
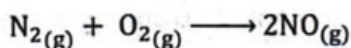
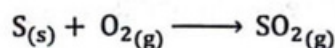
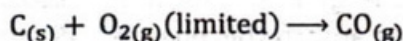


Table 11.1: Shows effect produced by air pollutants

Air pollutant	Physical properties	Sources	Harmful effects
Carbon monoxide	Colourless, odourless and poisonous gas	Incomplete burning of wood, fuels and vehicle exhaust.	Headache, brain damage, death.
Sulphur dioxide	Colourless gas with unpleasant and irritating odour	Power stations and industries using fossil fuels	Breathing difficulties, bronchitis, emphysema, lung cancer, acid rain and green house effect
Oxides of nitrogen	NO is colourless, odourless gas soluble in water. NO ₂ is reddish brown gas with pungent odour soluble in water. Both are highly toxic gases	Exhaust fumes of motor vehicles, power stations and industries using fossil fuels	Coughs, headaches lung diseases, acid rain and greenhouse effect (global warming)

CONCEPT ASSESSMENT EXERCISE 11.4

- Write three human activities that are responsible for air pollution.
- Write three natural processes that are contributing in air pollution.
- List main sources of the following air pollutants.
(a) SO₂ (b) CO (c) NO₂

11.4 GLOBAL WARMING

The increasing use of fossil fuels and the deforestation have led to an increase in the levels of CO₂ in the air. Gases like water vapour, methane, and carbon dioxide act in a similar way in the atmosphere. These gases are called greenhouse gases.

When sunlight reaches the Earth's surface, some of it is absorbed by the Earth's surface, including vegetation, oceans, and land. This absorption warms the earth. As the earth's surface heats up, it emits energy in the form of infrared radiation. Greenhouse gases absorb this energy. These gases re-radiate some of the infrared radiation (see Figure 11.3).

As a result greenhouse gases act like a blanket, trapping some of the heat energy in the lower atmosphere. This process is referred as greenhouse effect. This effect reduces thermal energy loss to space and helps to regulate the Earth's temperature. Without this effect, the Earth would be much colder making it difficult for life to exist. Human activities have been increasing the concentration of greenhouse gases in the atmosphere, by burning fossil fuels, deforestation, and industrial processes. This additional increase in greenhouse gases is enhancing the natural

DO YOU KNOW?

Green-houses are constructed from glass or transparent polymer films. Sun light can pass through these materials and is used by the plants for photosynthesis. The plants radiate some energy in the form of infrared or heat radiations which cannot pass through these materials and is reflected back. As a result the atmosphere inside the green-house becomes hot enough to promote plant growth. The temperature inside a greenhouse can be 10oC to 15oC higher than outside.

greenhouse effect. This is leading to a significant increase in the atmospheric temperature causing global warming and climate change. The higher the concentration of greenhouse gases in the air, the greater the greenhouse effect and the greater the increase in temperature. The greenhouse effect is a natural phenomenon of the earth's energy distribution mechanism. The warming of the atmosphere due to our influence on the greenhouse effect is called global warming. Global warming is caused by disturbing the natural balance of greenhouse gas concentrations in the atmosphere.

If global warming continues, then

- Temperature of the earth will gradually increase.
- The earth climate may change, affecting both the rate of rainfall and how much it rains. This could cause both increased risks of flooding in some regions and drought in others.
- Polar ice may melt and cause significant increase in sea levels.
- So the atmosphere becomes hotter.

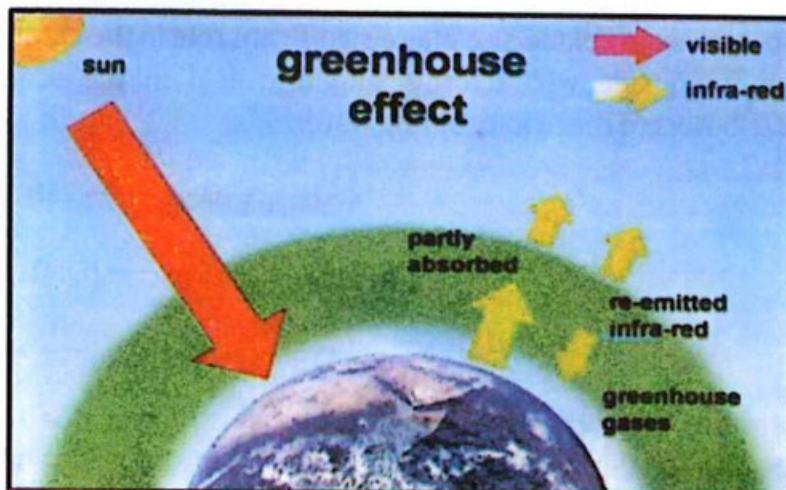


Figure 11.3 Greenhouse effect

CONCEPT ASSESSMENT EXERCISE 11.5

1. Define global warming
2. List some effects of global warming
3. List some substances that are responsible for global warming.
4. Establish the link between greenhouse effect and global warming.

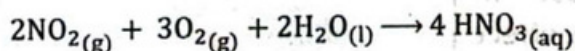
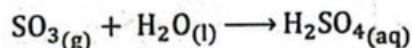
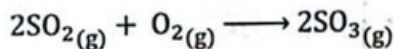
Society, Technology and Science

Incineration is a waste treatment process in which solid waste is burned at high temperature. Incineration consumes all combustible materials, leaving behind ash residue and non-combustible material. This process generally reduces the volume of waste by two third, but it is not a clean process. It produces air pollution. It generates considerable smoke and odour. This smoke may contain oxides of nitrogen and sulphur

11.5 ACID RAIN AND ITS EFFECTS

Normal rainwater is saturated with carbon dioxide. It has a pH of 5.6. However, the acidity of rain increases during thunderstorms in polluted areas. Fossil fuels contain compounds of sulphur and nitrogen. Sulphur dioxide from fossil fuels used in power plants and nitrogen oxides from car exhausts dissolve in rainwater, creating acids, such as sulphuric acid, nitrous acid, and nitric

acid. Nitrogen dioxide also play a significant role in the catalytic oxidation of sulphur dioxide into sulphur trioxide which forms sulphuric acid in the atmosphere. These reactions are key contributors to the acidity of rain water.



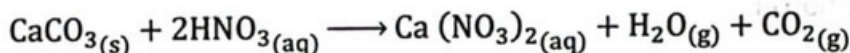
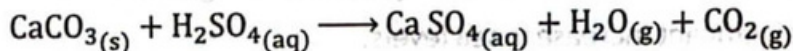
Therefore, the pH of rainwater can be much lower due to sulfuric acid and nitric acid from precipitation during thunderstorms. The pH of this rain can be as low as 2.1. This value is lower than the pH of vinegar or lemon juice.

Acid rain is defined as rain having pH less than 5.6.

Acid rain can often fall hundreds of kilometres from its source. Acid rain corrodes metals, stone structures and statues (Figure 11.4). Sulphuric acid eats metals and forms water-soluble salts and hydrogen.



Marble buildings and statues are disintegrated by acid rain.



Acid rain also kills fish, and destroys trees. Lakes and river may become too acidic for living things to survive. (Figure 11.5 and 11.6)



Figure 11.4 Marble statues are slowly eroded by acid



Figure 11.5: Trees destroyed by acid rain



Figure 11.6 Fish are killed by acid rain

CONCEPT ASSESSMENT EXERCISE 11.6

1. Define acid rain.
2. Write names of gases that cause acid rain.
3. What is the effect of acid rain on iron and marble? Give balanced chemical equation.
4. List some effects caused by acid rain.
5. Justify that acid rain is dangerous than normal rain

11.6 CATALYTIC CONVERTERS

Catalysts are installed in the exhaust system of cars. They contain catalysts that facilitate chemical reactions that convert nitrogen oxides into less harmful substances. The catalyst transforms CO to CO₂, NO to N₂ and O₂, and unburned hydrocarbons to CO₂ and H₂O. Metals such as platinum, palladium and rhodium are used as catalysts in the transformer.



The government of Pakistan should direct car manufacturers to install catalytic converters in car exhaust systems. The government should make strict laws on this matter. This would help reduce emissions of air pollutants from car exhaust systems.

11.7 STRATEGIES TO REDUCE ENVIRONMENTAL PROBLEMS

How to address environmental issues? Several strategies that can be implemented are as follows:

1. Climate change migration

- a) **Transition to renewable energy:** Increasing the use of renewable energy sources such as wind, solar, hydro and geothermal energy can help reduce greenhouse gas emissions.
- b) **Energy efficiency:** promoting energy-efficient technologies can reduce energy consumption and related gas emissions.
- c) **Reduce carbon dioxide emissions from transport:** Promoting electric vehicles and public transport systems and promoting walking and cycling can significantly reduce the use of fossil fuels.

2. Afforestation and reforestation.

- a) **Planting trees:** Increasing plantations can help reduce carbon dioxide through photosynthesis. This practice not only improves air quality, but also prevents soil erosion. It also increases biodiversity.
- b) **Forest Regeneration:** Look for initiatives to rehabilitate and restore damaged forests. This activity promotes carbon sequestration and wildlife habitat.

3. Sustainable land use.

- a) **Sustainable agriculture:** Promotion of sustainable and renewable agricultural techniques, promotion of organic fertilizers instead of chemical fertilizers and pesticides. This practice can reduce emissions, protect water supplies and improve soil health.

- b) **Reduce deforestation:** Taking steps to reduce deforestation and promote sustainable logging can help protect important carbon sinks.

4. **Move to a low-carbon economy**

- a) **Transition to a hydrogen economy:** promoting the use of hydrogen as a clean energy source can help reduce carbon dioxide emissions in transport, industry, and power plants.
- b) **Circular Economy:** Greenhouse gases can be controlled through measures to implement a circular economy model, minimizing waste and promoting recycling.

5. **International cooperation and politics**

- a) **Paris Agreement:** To combat climate change, it is important to increase global cooperation and maintain the Paris Agreements, which include limiting global warming to well below 2°C and reaching the 1.5°C target.
- b) **Policy support:** Implementation of strong and effective policies such as renewable energy incentives and emissions regulations can pave the way for visible change and promote sustainable practices.
- c) It is important to note that these strategies are interrelated. They require a holistic approach involving individuals, businesses and public officials. However, cooperation, education and public awareness are important to achieve meaningful results.

11.7.2 **Strategies to solve acid rain**

Some approaches to dealing with acid rain include:

1. **Acid rain mitigation:**

- a) **Emission control:** Measures to reduce emissions of sulfur dioxide, nitrogen oxides from industrial units, power plants, and vehicles are important for reducing acid rain. This can be achieved through the introduction of anti-pollution technologies and the use of cleaner fuels.
- b) **Flue gas desulfurization:** Flue gas desulfurization systems, such as wet or dry scrubbers in power plants and industrial units, can remove sulphur dioxide from flue gases before they are released into the atmosphere.
- c) **Low sulphur fuels:** Promoting low sulphur fuels can also minimize the amount of sulphuric acid in the atmosphere that causes acid rain.

2. **Catalytic converters in vehicles:**

- a) The promotion of catalytic converters in vehicle exhaust systems can reduce emissions of harmful gases and volatile organic compounds. Converters contain catalysts such as platinum, palladium, and rhodium, which transform harmful gases into less harmful substances

11.8 **PHOTOSYNTHESIS**

Photosynthesis is a biochemical process in which plants use solar energy to convert carbon dioxide and water into glucose in the presence of chlorophyll. It is an essential process that sustains most life on Earth by producing oxygen and organic compounds. Photosynthesis plays a key role in the

carbon cycle by removing carbon dioxide from the atmosphere and turning it into organic matter.



11.9 PERSONAL PROTECTIVE MEASURES AGAINST POLLUTION

How to reduce personal exposure to harmful pollutants? Several tools and strategies can be employed. For instance:

1. Masks and Respiratory Protection

- a) N95 masks are designed to filter out particles, including pollutants such as dust, smoke, and some airborne chemicals.
- b) Gas masks contain activated carbon filters that absorb certain gases and volatile organic compounds.

NOTE. It is vital to choose masks certified by the relevant regulatory authorities and use precisely according to their instructions.

2. Air Quality Indices

Air quality indices provide information about the general air quality of a certain location. They usually use a numerical scale or a colour-coded system to indicate the level of air pollution. By regularly checking the air quality, you can take the necessary precautions.

3. Carbon monoxide detector

Installing carbon monoxide detectors in homes, offices and alerts people to carbon monoxide levels. This allows quick action to be taken, such as ventilating the area, sealing off potential sources or evacuating the area or enclosed spaces.

11.10 RISK FACTORS

High-risk life situations that can cause respiratory problems and reduced quality of life and life expectancy include:

1. **Long-term exposure to pollutants:** Breathing in polluted air containing nitrogen oxides, sulphur dioxide, particulate matter, ozone, and other harmful pollutants can damage the respiratory system. It can contribute to respiratory diseases such as asthma, lung cancer, and chronic obstructive pulmonary disease.
2. **Smoking:** Tobacco is another important risk factor for respiratory diseases. It damages the lungs and airways. This can increase the risk of chronic obstructive pulmonary disease and lung cancer. Cigarette smoke is also harmful to non-smokers.
3. **Indoor pollution:** Living in a home with poor ventilation, mold, dust, mites and pets, and household chemicals can cause respiratory problems, allergies and asthma.
4. **Allergens:** Prolonged exposure to allergens such as pollen, mold spores, pet dander, dust, and pet dander can cause respiratory allergies and asthma.
5. **Climate change:** Climate change affects air quality, which can worsen respiratory problems. Increased air pollution, forest fires, rising temperatures, and changes in pollen season can worsen respiratory symptoms. It is important to take protective measures such

as reducing exposure to pollutants, quitting smoking, maintaining good indoor air quality and wearing masks.

It is important to take protective measures such as reducing exposure to pollutants, quitting smoking, maintaining good indoor air quality and wearing masks.

KEY POINTS

- The envelope of gases and water vapour surrounding the planet earth is called atmosphere.
- Anything that is in the air, water or soil which has a harmful effect on some part of the environment is called pollutant.
- Some air pollution occurs naturally. But many types of air pollution are the result of human activities.
- Methane is produced when dead plant material decays in the absence of air.
- Air that contains harmful particles and gases is said to be polluted.
- The warming of the atmosphere which is due to our influence on the greenhouse effect is known as global warming.
- Acid rain is defined as rain having pH less than 5.6.
- Ozone is an allotropic form of oxygen comprising three oxygen atoms

References for additional information

- Chemistry in context.
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- Environmental Sciences, Cheris D.D. 1991.

REVIEW QUESTIONS

1. Encircle the correct answer.

- Which gas has the highest percentage in the air

(a) O_2	(b) CO_2
(c) N_2	(d) O_3
- Which is/are responsible for acid rain?

(a) SO_2	(b) NO_2
(c) Both NO_2 and SO_2	(d) O_3
- Which is reddish brown gas?

(a) NO	(b) NO_2
(c) SO_2	(d) O_3

(iv) Most air pollution is caused by

(a) Ozone

(b) Acid rain

(c) Carbon monoxide

(d) The burning of fossil fuels

2. Give short answer.

(i) List two main sources of acid rain.

(ii) List four human activities which contribute to air pollution.

(iii) What is the importance of catalytic converters?

(iv) What is the role of automobile in air pollution?

(v) Define global warming.

3. Describe sources of air pollutants.

4. Describe acid rain and its effects.

5. Describe global warming.

6. What is ground level ozone. Explain.

7. Why is global warming often referred to as the greenhouse effect? Justify your answer.

8. Sulphur dioxide is a common pollutant from burning coal. State two effects caused by this pollutant.

THINK TANK

1. Dibenzothiophene ($C_{12}H_8S$) is a common sulphur containing compound of coal. It is responsible for acid rain. Elaborate this statement.
2. There is dire need to remove sulphur from coal before it is burned. Give reason.
3. Examine the option there are some ways to reduce pollution caused by cars?
4. Certain human activities are responsible for a significant increase in greenhouse effect, argue.
5. As a global citizen, how can you play a part to reduce air pollution at a personal level? Argue.

PROJECT

Global warming has become one of the most serious environmental issues in the world in recent times. Prepare a report on this issue in terms of:

- (a) The gases contributing to the problem and their sources.
- (b) Which of these gases are causing the most concern?
- (c) Suggest some ways to reduce this problem.