



14

ENVIRONMENTAL CHEMISTRY I: ATMOSPHERE



After completing this lesson, you will be able to:

This is 12 days lesson
(period including homework)

- Define atmosphere.
- Explain composition of atmosphere.
- Differentiate between stratosphere and troposphere.
- Summarize the components of stratosphere and troposphere.
- Describe major air pollutants.
- Describe sources and effects of air pollutants.
- Explain ozone formation.
- Describe acid rain and its effects
- Describe ozone depletion and its effects.
- Describe global warming.
- Perform filtration experiments in the lab on different water samples having suspended impurities.
- Explain how incineration of waste material contributes to the problem of air pollution.
- Debate whether the government should do more to control the pollution resulting from auto exhaust.



Reading

INTRODUCTION

Many times in a day you come across mixtures, for instance you start your day by drinking a cup of tea at breakfast, tea is a mixture, it is composed of water, milk, tea leaves and sugar, or if you take milk instead of tea, it also is a mixture of water, minerals, proteins, vitamins and fats. You also know that if some mud is added to a cup of tea, the tea does not remain fit for drinking. If you drink you will feel ill. Similarly from your previous knowledge of grade VI you know that air is a mixture of various gases i.e. nitrogen, oxygen, hydrogen, carbon dioxide, noble gases, and water vapour. This chapter will enable you to understand what is meant by atmosphere? You will also learn about the types and composition of different layers of atmosphere. How the atmosphere gets unhealthy or polluted? Which substances make the atmosphere unhealthy or polluted? What are the sources of common air pollutants and what are their harmful effects on living things and the environment? You will also learn why the span of summer season has extended and why the summer is getting hotter all over the world than it



was about ten years before? You will also be able to know why the iron nails get rusty more quickly in rain water than in tap water or in mineral water. This knowledge will help you in grade XII to understand.

- Chemistry of Troposphere and Stratosphere
- Green house effect and global warming as resulting in climatic changes.

14.1 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 14.1)

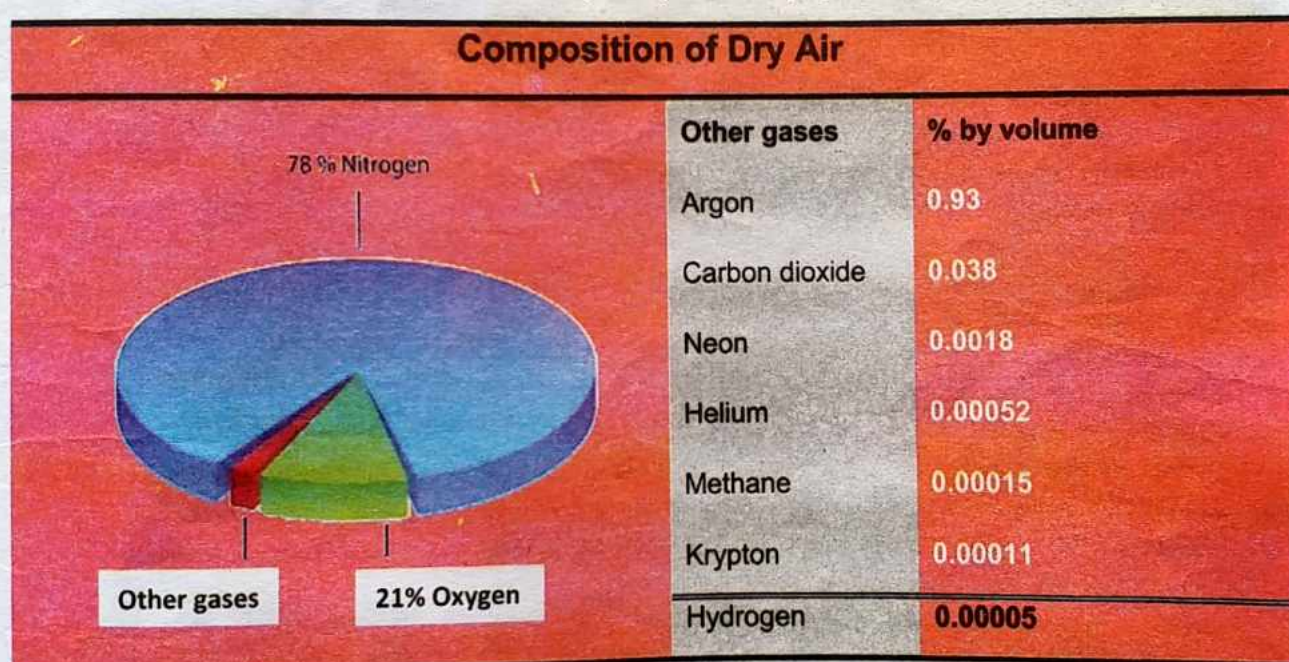


Figure 14.1 Composition of dry air

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

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



Self-Assessment Exercise 14.1

1. What two gases make up most of the air?
2. Which gas has highest percentage in the air?
3. Which gas has lowest percentage in the air?
4. Why the percentage of water has not been mentioned in the pie chart?



14.2 LAYERS OF ATMOSPHERE

The atmosphere is divided into four layers, the troposphere, the stratosphere, the mesosphere and the thermosphere (Figure 14.2). The thermosphere is further divided into the ionosphere and the exosphere. Each atmospheric layer has its own temperature and precise chemical composition.

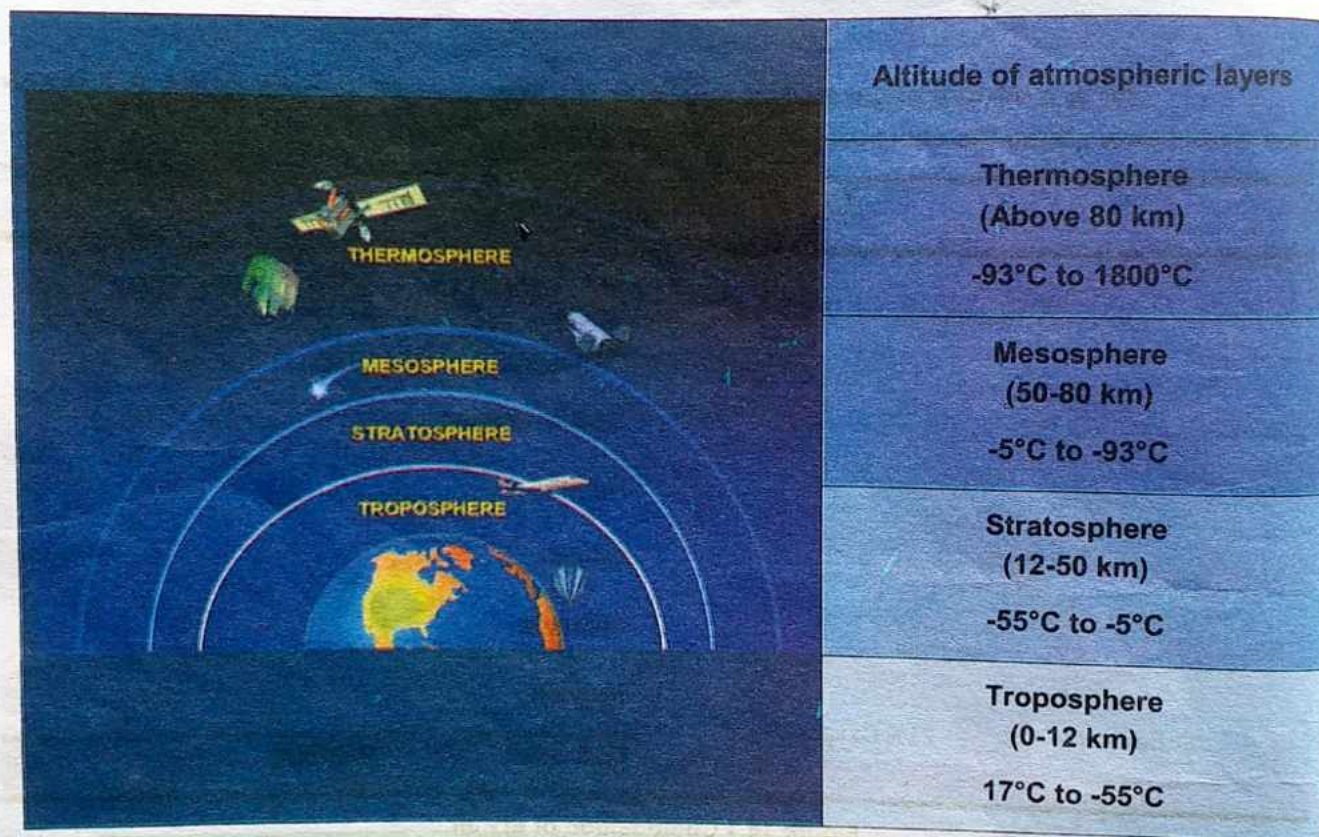


Figure 14.2 Layers of Atmosphere

The Troposphere

Tropo- means "turning" or "changing". Conditions in troposphere are more variable than in the other layers. Troposphere extends to about 12km above Earth's surface. The atmospheric layer closest to the Earth's surface is called troposphere. What is the height of the troposphere? What is the minimum and maximum temperature of this layer?

Troposphere contains most of the mass (75-80%) of the atmosphere. It is the layer of atmosphere in which we live. Nearly all the dust particles and water vapour are in the troposphere. Weather occurs in this layer. Most of the clouds are formed in the troposphere. Aircrafts fly in this region. As altitude increases in the troposphere, the temperature decreases from 17°C to about -55°C. On average, for every 1 km increase in altitude, the air gets about 6.5°C cooler.



The Stratosphere

The second layer as one moves upward from the Earth's surface is called stratosphere. The stratosphere extends from top of the troposphere to about 50km above Earth's surface. Strato- means "layer" or "spread out". What is the height of the stratosphere? What are the minimum and the maximum temperature of this layer?

The lower stratosphere is cold about -55°C , but the upper stratosphere is warmer than the lower stratosphere. This layer contains little water vapour. Interesting information about this layer is that it contains maximum amount of ozone (about 10ppm). The presence of ozone is responsible for the rise in temperature in stratosphere. (Ozone saves us from harmful effects of incoming ultraviolet radiations from the sun. When ozone absorbs energy from the sun, the energy is converted into heat, warming the air. The ozone layer protects the living things on the Earth from dangerous ultraviolet radiation from the sun.) In the stratosphere, temperature varies from -55°C to -5°C

O₂ (iii)

The Mesosphere

The mesosphere extends from the top of stratosphere to about 80 km from the earth's surface. Meso- means "middle", so the mesosphere is the middle layer of the atmosphere. Above the stratosphere, a drop in temperature is observed. In the outer mesosphere, temperature approaches -93°C . This layer protects Earth's surface from being hit by most meteoroids.

The Thermosphere

The outermost layer of atmosphere is the thermosphere. It extends from 80 km above Earth's surface outward into space. Thermo- means heat. This layer is very hot up to 1800°C . This is because sunlight strikes the thermosphere first. Oxygen and nitrogen molecules convert this energy into heat.

The thermosphere is divided into two layers. The lower layer called the ionosphere extends from 80 km to 400 km above the surface of Earth. The outer layer of thermosphere is the exosphere. It extends from 400 km to thousands of kilometer from Earth's surface.

Do you know?

Aurora Borealis

In the northern hemisphere, brilliant light displays, such as shown in the figure occur in the ionosphere.

These light displays are called aurora borealis. Auroras are caused by particles from the sun that enter the ionosphere near the poles. These particles strike atoms in the ionosphere, causing them to glow.





Activity 14.1

Shows how the temperature changes with altitude?

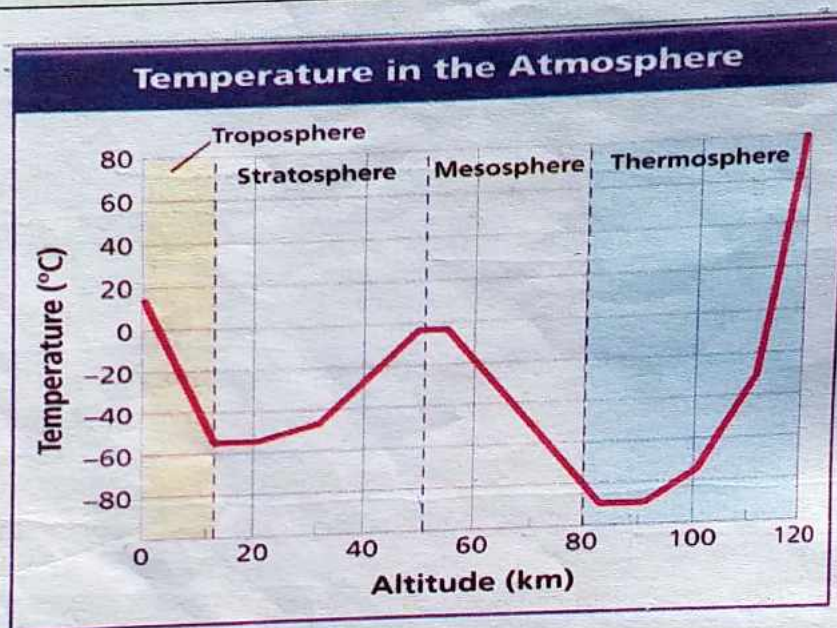


Figure 14.3 Temperature variations in the troposphere and the stratosphere.

Complete the following table.

Layer of atmosphere	Temperature (°C)	
	At the bottom	At the highest point
Troposphere		
Stratosphere		



Self-Assessment Exercise 14.2

Describe how temperature changes as one moves from Earth's surface into the atmosphere up to 50 km?

14.3 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



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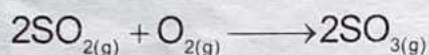
containing paints. These things have a negative impact on the environment. Such substances effect environment as a result of human activity.

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:

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? In the air sulphur dioxide is converted into sulphur trioxide, which is responsible for acid rain.



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.

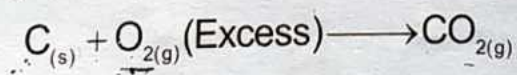
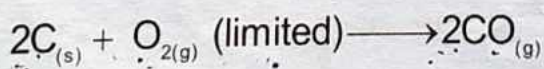


Self-Assessment Exercise 14.3

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

Carbon Monoxide

When you burn a piece of wood or any other organic material, mainly two types of gases, carbon monoxide and carbon dioxide are produced. Carbon monoxide is a poisonous gas. It causes headache and dizziness, when inhaled for a long time it may cause death. It is soluble in water.



Carbondioxide is not an air pollutant. Rather, plants consume CO₂ in photosynthesis and produce O₂. It is also not poisonous. However, it causes global warming (see section 14.3.1).

Nitrogen Oxides (NO_x)

The important oxides of nitrogen that cause air pollution are nitric oxide (NO) and nitrogen dioxide (NO₂). Collectively they are represented as NO_x. Nitric oxide is a colourless, odourless gas. It is heavier than air and sparingly soluble in water. Nitrogen dioxide is a reddish brown gas



with pungent odour. It dissolves readily in water. Both these oxides are highly toxic gases, damage lungs, cause headache, and cough.

Methane

Methane is produced when dead plant material decays in the absence of air. It is released in the air from marshes, swamps and rice paddy- fields. As a result of photochemical reactions in the air, methane forms irritating and toxic compounds. Methane is excellent heat absorber and cause global warming. (See section 14.3.1)

Chlorofluorocarbons (CFCs)

Chlorofluorocarbons are a group of chemically uncreative compounds that have been widely used as solvents. CFCs trap heat in the atmosphere and cause global warming. They have been attacking the ozone layer in the stratosphere very badly for the last three decades. CFCs may also cause skin allergy, damage to liver, kidneys and nervous system.

Lead Compounds

Lead particles in the air come mainly due to the combustion of leaded petrol or fuel used in motor vehicles or from the lead based paints etc. Lead and its compounds in the air affect the brain development in human beings especially among children. At high level it can be fatal.

Ozone

Ozone is a light blue gas and has an unpleasant odour. In the troposphere, ozone causes breathing difficulties, asthma and eye irritation.

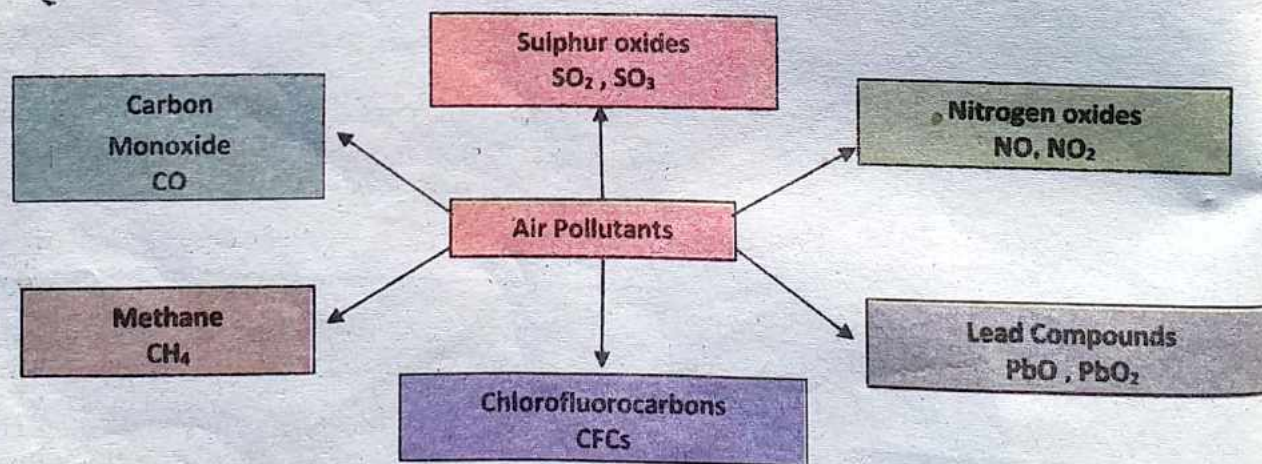
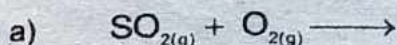


Figure 14.4 Air pollutants

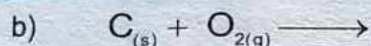


Self-Assessment Exercise 14.4

1. Write the names of main pollutants in the air.
2. Complete the following reactions.



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14.3.1 Sources of Air Pollution

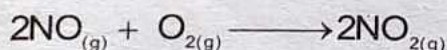
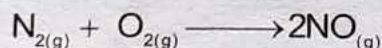
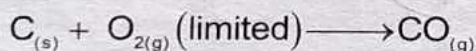
Air that contains harmful particles and gases is said to be polluted. Some air pollution occurs naturally. But many types of air pollution are the result of human activities.

Natural Sources

Many natural processes such as forest fires and dust storms release smoke and dust particles into the air. Volcanos 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.

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).



Chlorofluorocarbons have been widely used as solvents for cleaning electronic circuit boards, as refrigerant in fridges and air-conditioning units and as propellants in aerosol sprays (air fresheners, hairsprays, deodorants, spray paints). Such products are not "Environment friendly". During manufacture, in use and after disposal, these compounds escape into the air. Lead particles in the air come mainly due to the combustion of leaded petrol or fuel used in motor vehicles or from lead based paints.

Ozone is produced when electrical discharges pass through oxygen in the air. You can feel its presence near photocopier, television set, microwave oven and other electrical equipment.

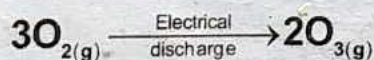


Table 14.1 shows effect produced by air pollutants.



Self-Assessment Exercise 14.5

- 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.
 - SO_2
 - CO
 - NO_2

Table 14.1 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)
CFCs chlorofluorocarbons	Colourless gases	Aerosol sprays foams, refrigerants, air-conditioning systems.	Green house effect (Global warming), thinning of ozone layer
Lead compounds	Poisonous solid particles	Exhaust fumes from motor vehicles	Brain damage, forest decline

Global Warming

The increasing use of fossil fuels and the deforestation have led to an increase in the

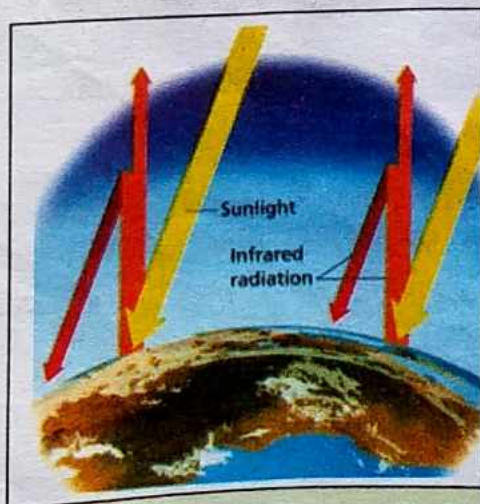


Figure 14.5 Greenhouse effect

levels of CO_2 in the air. Gases like water vapour, methane and CFCs also act in a similar way in the atmosphere. These gases are called greenhouse gases. Molecules of these gases absorb much of the infrared radiation given out by the surface of earth. (See figure 14.5). This increases

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 10°C to 15°C higher than outside.



their kinetic energy. So the atmosphere becomes hotter. The higher the concentration of greenhouse gases in the air, the greater is the greenhouse effect, and greater will be the increase in temperature. The green-house effect is a natural phenomenon of the energy distribution mechanism of the earth. However, certain human activity is threatening to cause a significant increase in the greenhouse effect. What are such activities?

The warming of the atmosphere which is due to our influence on the greenhouse effect is known as global warming.

Global warming is due to an upset in the natural balance of the concentration of greenhouse gases in the atmosphere. If global warming continues, then

- Temperature of the earth will gradually increase.
- The earth climate may change, affecting both where there is rainfall and how much there is of it. 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.



Self-Assessment Exercise 14.6

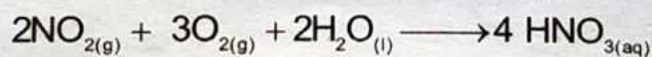
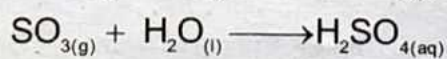
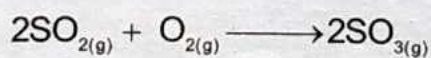
1. Define global warming
2. List some effects of global warming
3. List some substances that are responsible for global warming.

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.

14.3.2 Acid Rain and Its Effects

Normal rain water is saturated with carbon dioxide. It has pH of 5.6. However, the acidity of rain greatly increases in polluted areas during thunderstorm. Sulphur dioxide from power plants using fossil fuels and nitrogen oxides from exhaust fumes of automobiles dissolve in rain water producing acids.





Therefore, during thunderstorm, the pH of rain water can be much lower because of sulphuric acid and nitric acids formed by lightening. This rain may have pH as low as 2.1. This value is lower than the pH of vinegar or lemon juice.



Figure 14.6 Marble statues are slowly eroded by acid rain.

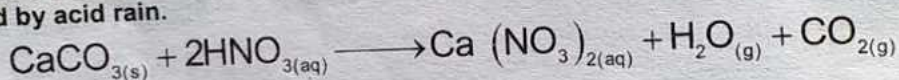
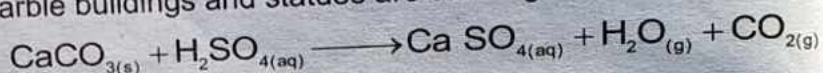
Acid rain is defined as rain having pH less than 5.6.

Acid rain may often fall hundreds of kilometers away from their sources. Acid rain corrodes metals, stone buildings and statues (Figure 14.6)

Sulphuric acid eats away metals to form water soluble salts and hydrogen



Marble buildings and statues are disintegrated by acid rain



Acid rain also kills fish, and destroys trees. Lakes and rivers may become too acidic for living things to survive. (Figure 14.7 and 14.8)



Figure 14.7 Trees destroyed by acid rain



Figure 14.8 Fish are killed by acid rain



Self-Assessment Exercise 17.7

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.

Society, Technology and Science

A catalytic converter transforms CO into CO_2 , NO into N_2 and O_2 , and unburned hydrocarbons to CO_2 and H_2O . Metals like platinum, palladium and rhodium are used as catalyst in the converter. Government of Pakistan should direct car manufacturers to install catalytic converters in car exhaust system. Government should make strict laws in this regards. This would help to reduce the emission of air pollutants from car exhaust system.

14.4 OZONE DEPLETION AND ITS EFFECTS

Ozone is an allotropic form of oxygen comprising three oxygen atoms, O_3 . Ozone is an important gas in the stratosphere. (Figure 14.9)

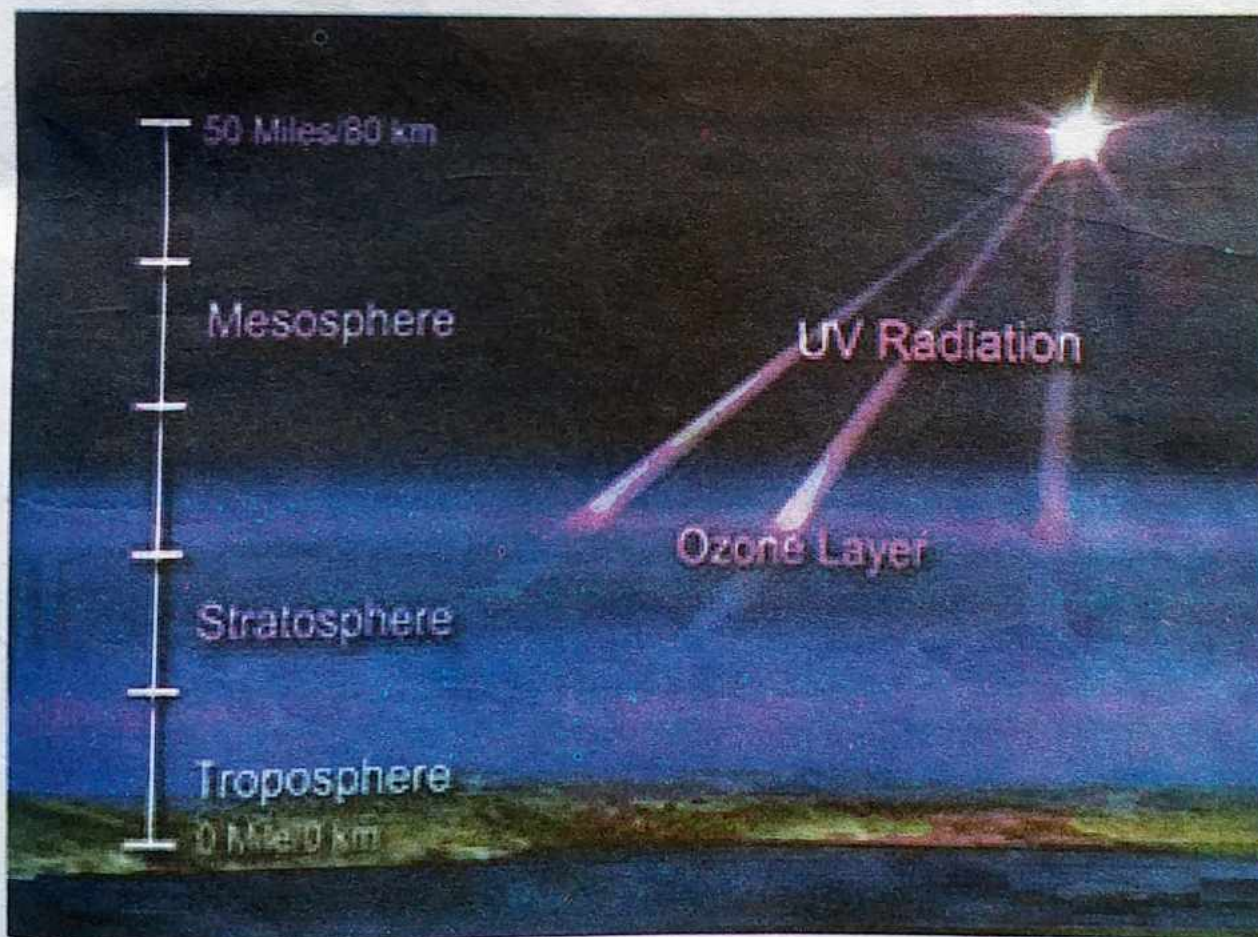
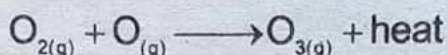


Figure 14.9: Ozone Layer

Most of the ultraviolet (UV) radiations coming from sun are **filtered** or **screened** out by the ozone layer. Otherwise, sunlight would be much more hazardous for human beings, animals and plants. On absorbing UV radiation, ozone molecule breaks up to form a oxygen molecule and atomic oxygen.



Atomic oxygen is very reactive. Atomic oxygen reacts readily with an oxygen molecule to form ozone, thereby releasing heat

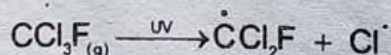


These reactions maintain level of ozone in the stratosphere. Both the destruction and the reformation of ozone are powered by UV radiation. In the absence of outside intervention, the rates of ozone destruction and formation are equal. However, human activities disturb this natural balance.

Human activity releases many compounds in the atmosphere. Such compounds threaten the stability of ozone layer. Over recent years, scientists have discovered a reduction in the amount of ozone in the stratosphere.

The region in which the amount of ozone has been reduced is called as ozone hole. Ozone hole was first observed in October, 1980 over Antarctica.

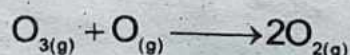
Chlorofluorocarbons (from aerosol cans, air conditioning systems, refrigerators etc) escape into the atmosphere. CFCs are gases or low boiling liquids. They are so inert that they do not react with any other chemicals in the troposphere. They slowly diffuse into the ozone layer. UV radiation break CFCs molecule producing chlorine free radicals.



Chlorine free radical reacts with ozone to form chlorine monoxide (ClO) and molecular oxygen. ClO reacts with atomic oxygen produced by the decomposition of ozone by UV radiations.



Net reaction:



The chlorine free radical that reacts in step 1 is regenerated in step 2. One $\text{Cl}^\cdot$ can, therefore, destroy thousands of ozone molecules. Is chlorine free a radical or a catalyst in the destruction of ozone? Figure 14.10 shows depletion of ozone layer over the years.



Figure 14.10 Satellite images, the blue area of normal ozone level is getting progressively smaller as time goes

SKILLS



Activity 14.2

To separate suspended impurities from water samples.

- Obtain sample of water from a lake, pond, stream or river.
- Pour this water onto the filter paper as shown in figure 14.11.
- What happens?

Recall that filtration is the process of separation of insoluble solid particles from a liquid.

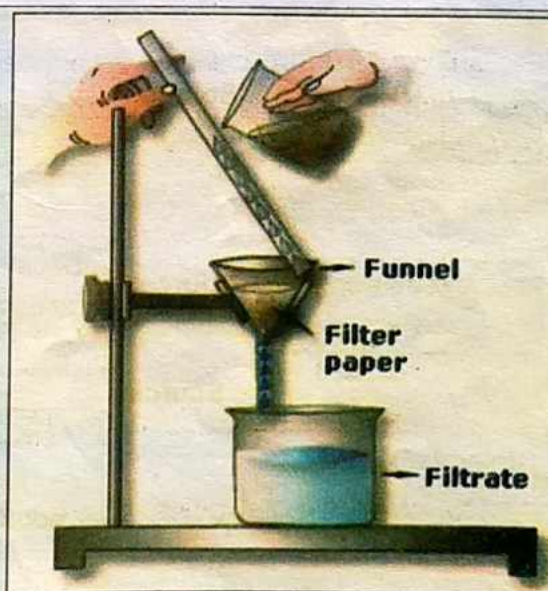
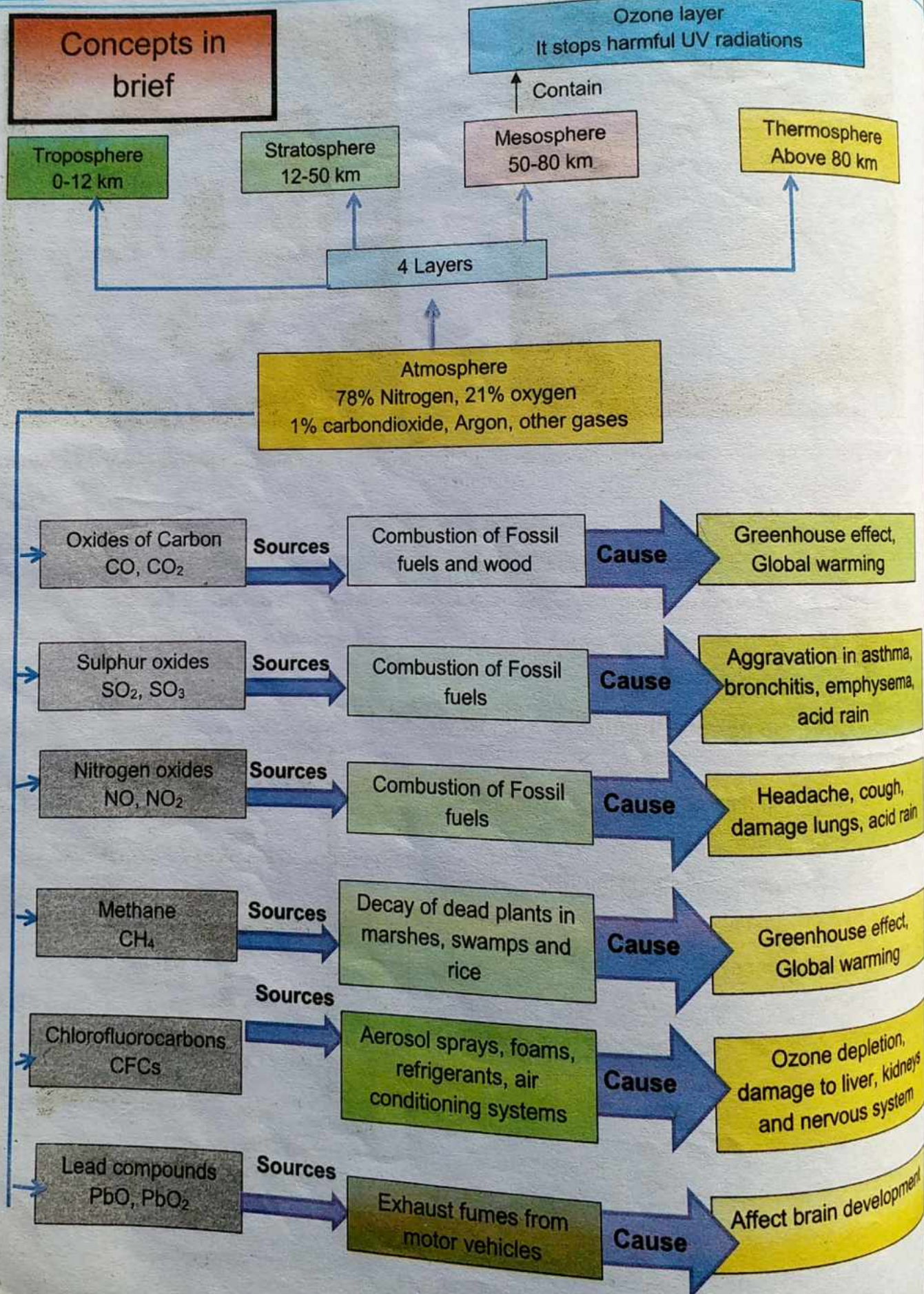


Figure 14.11: Filtration of water





Key Points

- ❖ The envelope of gases and water vapour surrounding the planet earth is called atmosphere.
- ❖ The atmosphere is divided into four layers, the troposphere, the stratosphere, the mesosphere and the thermosphere.
- ❖ The atmospheric layer closest to the Earth's surface is called troposphere. Earth's weather occurs in this layer.
- ❖ The stratosphere is the second layer of the atmosphere and contains the ozone layer.
- ❖ Each atmospheric layer has its own temperature and precise chemical composition.
- ❖ 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.
- ❖ Ozone is produced when electrical discharges pass through oxygen in the air.
- ❖ 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, O_3 .
- ❖ Most of the ultraviolet (UV) radiations coming from sun are filtered or screened out by the ozone layer.
- ❖ The region in which the amount of ozone has been reduced is called as ozone hole.

References for additional information

- ❖ Chemistry in context.
- ❖ Chemistry, Kelter, Carr, Scott.
- ❖ Environmental Sciences, Cheris D.D. 1991.



Review Questions

1. Select the correct answer.

- i) Which gas has highest percentage in the air

(a) O_2

(b) CO_2

(c) N_2

(d) O_3



- ii) Lowest temperature in stratosphere is
(a) -5°C (b) -55°C (c) 5°C (d) 55°C
- iii) Which is/are responsible for acid rain?
(a) SO_2 (b) NO_2 (c) Both NO_2 and SO_2 (d) O_3
- iv) Which is reddish brown gas?
(a) NO (b) NO_2 (c) SO_2 (d) O_3
- v) Troposphere extends up to
(a) 50 km (b) 12 km (c) 18 km (d) 80 km
- vi) Stratosphere extends up to
(a) 12 km (b) 15 km (c) 50 km (d) 80 km
- vii) The ozone layer is found in
(a) The troposphere (b) The mesosphere
(c) The thermosphere (d) The stratosphere
- viii) Most air pollution is caused by
(a) Ozone (b) Acid rain
(c) Carbon monoxide (d) The burning of fossil fuels
- ix) Which layer is closest to the Earth?
(a) The stratosphere (b) The troposphere
(c) The mesosphere (d) The thermosphere
- x) The outermost layer of earth atmosphere is
(a) The mesosphere (b) The stratosphere
(c) The troposphere (d) The thermosphere

2. Give short answer

- List two main sources of acid rain.
- List four human activities which contribute to air pollution.
- What is the importance of stratospheric ozone?
- What is the role of automobile in air pollution?
- Define atmosphere.

- Explain temperature variation in stratosphere and troposphere.
- List components of stratosphere and troposphere.
- Describe sources of air pollutants.
- Describe acid rain and its effects.
- Describe ozone depletion and its effects.



8. Describe global warming.
9. Differentiate between stratosphere and troposphere
10. Explain ozone formation.
11. Why is global warming often referred to as the greenhouse effect?
12. There is scientific evidence that CFCs contribute to the depletion of ozone. Why?
13. Sulphur dioxide is a common pollutant from burning coal. State two effects caused by this pollutant.



Think-Tank

14. Dibenzothiophene ($C_{12}H_8S$) is a common sulphur containing compound of coal. It is responsible for acid rain. Elaborate this statement.
15. There have been various attempts to remove sulphur from coal before it is burned. Illustrate.
16. Examine the option there are some ways to reduce pollution caused by cars?
17. Certain human activities are responsible for a significant increase in greenhouse effect, argue.
18. As a global citizen, how can you play a part to reduce air pollution at a personal level? Argue.
19. Compare and contrast between stratosphere and troposphere.



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.