Module IV- FUEL AND ENVIRONMENTAL CHEMISTRY

1) Define fuel

Fuel may be defined as a substance which on proper burning in air gives large amount of heat that can be used economically for domestic and industrial purposes.

2) Define calorific value

Calorific value of a fuel is defined as the quantity of heat liberated by the complete combustion of a unit mass of the fuel in air, with the subsequent cooling of the products to the initial temperature.

3) What are the characteristics of a good fuel?
   a. High calorific value
   b. Moderate ignition temperature
   c. Moderate velocity of combustion
   d. Low moisture content
   e. Low non-combustible content
   f. No production of harmful products
   g. Controllable combustion
   h. No pollution
   i. Low storage cost and Easy transportation
   j. Free from fire hazards

4) Compare Solid, Liquid and gaseous fuels

Quality	**Solid**	**Liquid**	**Gas**
Example	Coal, Firewood	Diesel, Petrol	LPG, Methane
Calorific value	Least	Higher	Highest
Thermal efficiency	Least	Higher	Highest
Cost	Cheap	Costlier	Costliest
Combustion	Slow	Quick	Rapid
Fire hazards	Least	Higher	Highest
Storage and Transport	Easy	Difficult	Most difficult
Ash/Smoke	Ash and Smoke	No ash, but smoke	No ash and smoke
Moisture content	Low	Lower	Lowest
Pollution	High	Lower	Lowest

5) What is a nuclear fuel? Give examples

Nuclear fuels are radioactive elements which can provide very large amount of energy by radioactive disintegration or nuclear fission. Eg. Thorium, Natural Uranium, Enriched Uranium, Plutonium, etc

6) Write notes on water gas and producer gas.

Water gas

It is a mixture of Carbon Monoxide and Hydrogen. It is made by passing steam over red hot coke at 1000^0C.

$$C+H_2O \rightarrow CO+H_2$$

Its average composition is CO = 41%, H_2 = 51%. Its calorific value is 2800 KCal/m^3

Uses: - It is used as (i) fuel gas, (ii) illuminating gas and (iii) source of hydrogen gas

Producer gas

It is a mixture of Carbon Monoxide and Nitrogen. It is prepared by blowing air through red hot coke at 1100^0C. Its average composition is CO = 30%, N_2 = 52%, H_2 = 13%. Its calorific value is 1300 KCal/m^3. It is used as a fuel gas for controlled heating.

7) Define cracking.

Cracking is the process of breaking up of less volatile bigger molecules of hydrocarbons in petroleum into more volatile lower molecules of hydrocarbons.

8) Compare thermal and catalytic cracking

Thermal	Catalytic
High temperature pyrolysis at 770 K	Heating at 600 K
No catalyst	Catalyst- Mixture of silica and alumina in the molar ratio 4:1
Efficiency is less	Efficiency is high
Difficult to control	Easy to control
Gives rise to complex product mixtures	Better gasoline is the product
Produces higher hydrocarbons	Produces lower hydrocarbons

9) What is Environmental Chemistry?

It is the branch of chemistry which deals with various chemical processes occurring in the environment. It mainly includes the study of sources and effects of certain chemical species called pollutants.

10) Define Environment?

The term environment means the surroundings or conditions in which a person, animal, or plant lives or operates. The surroundings include the land, water and the atmosphere, ie the entire universe. The environment has four sections. Atmosphere, Hydrosphere, lithosphere and biosphere

11) Define Atmosphere?

The thick protective gaseous envelope surrounding the earth is called the atmosphere.

12) Give the Importance of atmosphere

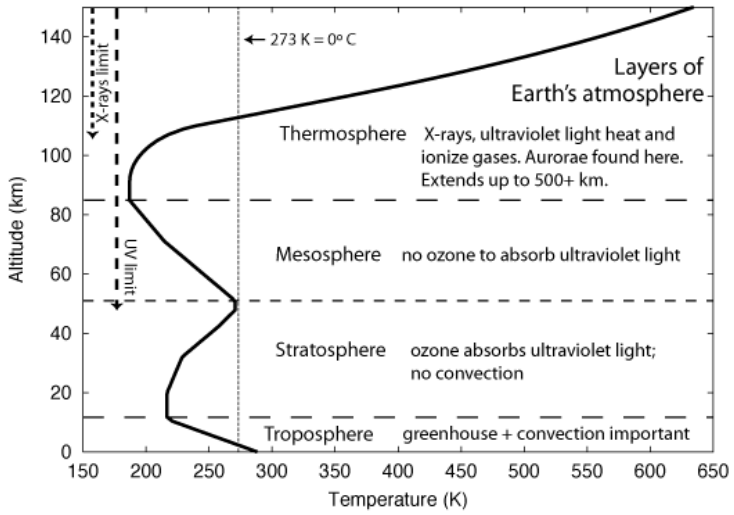
1. Provides oxygen for sustaining life
2. Supplies nitrogen for growth of plants
3. Provides carbon dioxide for photosynthesis
4. Stores water vapour required for rain fall
5. Absorbs harmful radiations from sun and space

13) What are the regions of atmosphere?

1. **Troposphere**
   - Lowest layer of the atmosphere which is in direct contact with earth's surface
   - It extends to a height of 12 km from earth surface.
   - It contains about 90% of the total mass of the atmosphere.
   - It is composed of mainly oxygen and nitrogen with small amounts of CO_2, H_2, CH_4, Argon etc.
   - All weather changes occur in this region.
   - In this layer the temperature gradually decreases with height at the rate of about 6.5°C/km.
   - The top layer of troposphere is called tropopause.
2. **Stratosphere**
   - It lies above the troposphere.
   - This layer extends from the top of the troposphere at roughly 12 km above earth's surface to an altitude of about 50 to 55 km
   - Contains ozone layer

- In this layer the temperature increases with height from -55°C to 5°C. This is due to the presence of ozone layer in the stratosphere. Ozone layer in the stratosphere blocks the harmful ultraviolet radiation from the sun.
- The stratosphere has no clouds, dust and water vapours. Region is dry

3. **Mesosphere.**
   - It extends from the stratopause at an altitude of about 50 km to 80–85 km above the earth's surface.
   - In this layer the temperature decreases with increase in height.
   - It is the coldest place on Earth and has an average temperature around −85 °C
4. **Thermosphere**
   - It lies above the mesosphere.
   - It extends from an altitude of about 80 km up to an altitude of 500km.
   - The temperature of the thermosphere gradually increases with height.
   - Gases like oxygen and nitric oxide get ionized by the absorption of solar radiations.
   - Ions like O^{2+}, O^{+}, NO^{+} are present in this zone.
   - Thermosphere is also known as **ionosphere**
   - Maximum temperature is about 1200°C



14) Define Pollution and Pollutant

Pollution is defined the undesirable change in the physical, chemical or biological characteristics of air, soil or water causing harmful effects on human life and environment.

Pollutants are chemical, physical or biological agents whose presence in the environment above a certain limit produce undesirable effect on life and environment.

15) Write a note on Air pollution

It is defined as the excessive presence of undesirable substances (Pollutants) in the atmosphere which causes damage to the life of animals and plants. The common gaseous pollutants are CO, CO_2, SO_2, SO_3, NO, NO_2, H_2S, NH_3, chlorofluorocarbons, hydrocarbons, carbon and dust particles, etc.

Sources of air pollution	**Impacts of air pollution**
1. Industrial emissions	1.Lung diseases
2. Automobiles	2.Respiratory disorders
3. Refrigerants	3.Acid rain
4. Combustion of coal	4.Global warming
5. Volcanic eruptions	5. Green House Effect
6. Forest fire	6.Ozone depletion
7. Metallic Industry	7. Smog

16) Explain the cause, impacts and remedial measures of Green House Effect

Visible light from sun passes through the atmosphere to warm the earth. About 66% of these radiations is absorbed by the earth and the remaining 34% is reflected back into the atmosphere at the lower frequencies of infrared radiation. The gases such as CO_2, N_2O, CH_4 and ozone absorb this IR radiation like a green house cover. This heat is transmitted back to earth's surface and hence increases the temperature of earth's surface. This phenomenon is called green house effect. The greenhouse effect results in heating up of the environment. This effect is known as global warming.

Greenhouse effect is the phenomenon of heating up of earth's atmosphere due to the absorption of infrared radiations by green house gases. The rise in temperature of the environment due to green house effect is known as global warming.

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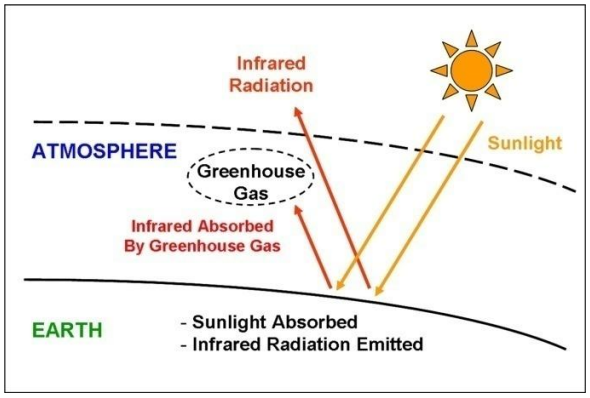

Impacts of green house effect	**Methods to control Green house effect**
1) Global warming 2) Summer will be hotter and longer and winter will be shorter and warmer 3) Desertification, drought and soil erosion will become more intense. 4) Melting of ice in Polar Regions endanger animals and plants living there. 5) Rise of the sea levels 6) Skin diseases for humans 7) Change in pattern of rainfall	1. By minimizing the use of fossil fuels to reduce the production of CO_2 2. Use alternate energy sources like solar, wind, tidal, geothermal, etc. 3. Conserve forests and plant more trees. 4. Reduce the use of automobiles. 5. Ban of CFC and nuclear explosions

17) Write a note Ozone layer depletion

The **ozone layer** is a layer in Earth's atmosphere which contains relatively high concentrations of ozone. Over 91% of the ozone in Earth's atmosphere is present here. It is mainly located in the lower portion of the stratosphere from approximately 19 to 30 km above the Earth's surface. Ozone layer protects the life on earth from the harmful Ultra-Violet rays coming from the Sun.

Ozone is created primarily by sunlight. When high-energy ultraviolet rays strike an oxygen molecule (O_2), they split the molecule into two single oxygen atoms, known as atomic oxygen. A free oxygen atom then combines with another oxygen molecule to form a molecule of ozone (O_3). Ozone molecules can be decomposed to oxygen by absorbing UV-light.

$O_2 + h\nu \rightarrow O + O$	$O_2 + O \rightarrow O_3$	$O_3 + h\nu \rightarrow O_2 + O$

There exists an equilibrium between oxygen and ozone molecules. This ozone-oxygen cycle is continuously absorbing high energy UV radiation and completely blocking

it from reaching the surface. The presence of choro fluoro carbons (CFC) in the stratosphere can destroy ozone by photochemical chain reactions. They generate chlorine free radical by absorbing UV radiation.

$CFCl_3 + h\nu \rightarrow CFCl_2 + Cl$	$O_3 + Cl \rightarrow O_2 + ClO$	$ClO + O_3 \rightarrow Cl + Cl$

The thinning of ozone layer in the stratosphere due to the effect of CFCs and other ozone-depleting gases generated by human activities is called ozone depletion**.** This depletion of ozone increases human exposure to dangerous UV radiation reaching Earth's surface from the sun. The most severe ozone loss was discovered in springtime over Antarctica. The loss in this region is commonly called the **"ozone hole"**

Consequences of Ozone layer depletion

1) More ultraviolet radiation would come to the Earth and may cause severe damage to life.
2) UV radiation causes skin cancer.
3) UV radiation can cause sunburn.
4) Proteins in the eye's lens can be damaged by being exposed to excessive ultraviolet light, which will result in Cataract.
5) UV radiation damages immune system and cause viral infection.
6) UV radiation may damage plants, animals and crops.
7) UV radiation result in mutations and brain cancer.
8) UV radiation causes increase in atmospheric temperature (Global Warming)

Methods to control Ozone layer depletion

1) Control the production and use of Freons.
2) Replace Freons by compounds having lesser destructive effects e.g. hydrochlorofluorocarbons (HCFCs)
3) Suppression of chlorine atoms by chemical technologies

18) Write a note on Acid rain

The phenomenon of the presence of excessive acid in rain water is called **acid rain**. The normal pH of water is 5.6. That is, normal rain water is slightly acidic in nature. This is due to the presence of protons formed by reaction of water with carbon dioxide present in the air. When pH of rain water drops anywhere below 5.6, it is said to be **acid rain**. The main cause for acid rain is the presence of high levels of oxides of sulphur and nitrogen, which are already acidic in nature. These oxides are produced as a result of combustion of fossil fuels and from automobile emissions. Sulphur dioxide and nitrogen dioxide on oxidation followed by reaction with water forms sulphuric acid and nitric acid respectively. These acids combine with rain to form acid rain.

$$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Harmful effects of acid rain	Remedial measures
1. Causes irritation to eyes, skin. 2. Causes damage to plants (leaf bleaching) 3. Acid increases the rate of corrosion of metals 4. Causes damage to buildings, statues etc. (Stone Leprosy damage to monuments like Taj Mahal.) 5. Causes damages to fresh-water life. 6. Decrease crop yield. 7. Harmful to fabric, paper and leather products 8. Change in pH of soil 9. Kills useful soil microorganisms	1. Desulphurization and denitrification of fossil fuels before combustion. 2. Remove SO_2 by converting to $CaSO_4$. 3. Controlling automobile emissions by using catalytic converters 4. Remove Sulphur from fuels for combustion 5. Controlling production of SO_2 and NO_2

19) Write a note on Smog

Smog is a mixture of smoke, dust particles and fog. (smoke + fog = smog)

There are two types of smog

a. Classical smog Is formed by the combination of smoke, dust particles and fog containing SO_2 from polluted air. The principal source of classical smog is the combustion of industrial and domestic fuels. Because of the presence of SO_2 and carbon particles, classical smog has a reducing character. It occurs in winter months particularly in early morning hours. It is also known as London smog, as it has occurred in London earlier

b. Photochemical Smog

Photochemical Smog is formed by the combination of smoke, dust particles and fog containing secondary air pollutants such as peroxy acetyl nitrate (PAN), ozone and oxides of nitrogen formed by the photochemical reactions between primary pollutants. It is oxidizing in nature. It is formed around mid day of summer months when the intensity of solar radiations is very high. It is also known as 'Los angeles smog as it has occurred there earlier.

Harmful effects of Photochemical Smog

1) Causes irritation to eyes, nose and throat leading to chronic diseases.

2) It damages vegetation, affect plant growth, reduce crop production

3) Reduces visibility.

4) Ozone attacks rubber and photochemical smog increases rate of corrosion of metals.

12) Write a note on major air pollutants, their sources and effects

Pollutant	Source	Effects
Carbon monoxide	Automobile exhaust, photochemical reactions in the atmosphere, forest fire	Affects the respiratory activity as hemoglobin has more affinity for CO than for oxygen. Thus, CO combines with HB and thus reduces the oxygen-carrying capacity of blood. This results in blurred vision, headache, unconsciousness and death due to asphyxiation (lack of oxygen).
Carbon dioxide	Carbon burning of fossil fuels, depletion of forests	Causes global warming.
Sulphur dioxide	Industries, burning of fossil fuels, forest fires, petroleum refineries, vocanic eruptions	Respiratory problems, severe headache, reduced productivity of plants, Acid rain
Nitrogen Oxides	Automobile exhausts, burning of fossil fuels, forest fires, electric generation plants, smelting plants, industrial boilers, petroleum refineries and volcanic eruptions	Forms photochemical smog, at higher concentrations causes leaf damage or affects the photosynthetic activities of plants and causes respiratory problems in mammals, Acid rain

13) What are the causes, impacts and preventive measures of water pollution?

Sources of water pollution

1. Untreated sewage and municipal wastes.
2. Agricultural wastes
3. Oil pollution
4. Industrial effluents.
5. Soap and detergents
6. Waste from hospitals, laboratories and research centres

Impacts of water pollution

1. Industrial waste containing acids leads to corrosion of pipes
2. Water pollution reduces the amount of dissolved oxygen in water. This is a serious threat to aquatic life.
3. Presence of bacteria that cause diseases like cholera, typhoid, dysentery, etc. are increased by water pollution.

4. Presence of agricultural wastes like pesticides, insecticides, fertilizers etc. cause damage to humans, aquatic life etc.

5. Presence of heavy metals like Hg, Cr, Pb, Cu etc. are toxic to animal and plant life.

Eg: Methylmercury caused Minamata disease in japan in 1956.

6. Water becomes unfit for drinking due to water pollution.

Methods to control water pollution

1. Reduce the dumping of industrial effluents into water bodies.
2. Reduce oil pollution
3. Reduce dumping of agricultural wastes.
4. Correct the faulty sewage systems.

14) What are the sources, impacts and control measures of Soil Pollution?

Sources of soil pollution

1. Disposal of industrial and agricultural wastes into soil.
2. Disposal of non-biodegradable wastes such as plastics, electronic wastes, etc. to the soil
3. Radioactive wastes discharged from nuclear reactors.
4. Chemicals like pesticides, insecticides etc.
5. Removal of upper fertile layer of sand
6. Acid rain

Impacts of soil pollution

1. Reduces the fertility of soil.
2. Causes diseases to humans and animals.
3. Leads to pollution of water bodies.

Control of soil pollution

1. Reduce the disposal of industrial and agricultural wastes.
2. Encourage organic farming and biofertilizers.
3. Reduce the discharge of radioactive wastes and follow correct measures.
4. Reduce the use of chemicals and pesticides and use biodegradable substituents.

15) Write a note on Green Chemistry

Green chemistry is the branch of chemistry deals with the design, development and implementation of chemical processes and products that reduce or eliminate the use or generation of hazardous substances harmful to the environment. It is also called sustainable

chemistry. The term green chemistry was first used in 1991 by Paul T. Anastas. He is considered as the father of green chemistry

The basic principles of green chemistry

These principles demonstrate the breadth of the concept of green chemistry:

1. **Prevent waste**: Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.
2. **Maximize atom economy**: Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.
3. **Design less hazardous chemical syntheses**: Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.
4. **Design safer chemicals and products**: Design chemical products that are fully effective yet have little or no toxicity.
5. **Use safer solvents and reaction conditions**: Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.
6. **Increase energy efficiency**: Run chemical reactions at room temperature and pressure whenever possible.
7. **Use renewable feedstocks**: Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
8. **Avoid chemical derivatives**: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
9. **Use catalysts, not stoichiometric reagents**: Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.
10. **Design chemicals and products to degrade after use**: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. **Analyze in real time to prevent pollution**: Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. **Minimize the potential for accidents**: Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Examples of green chemistry in action

- ✓ Using H_2O_2 for bleaching clothes and paper instead of using toxic chlorine
- ✓ Using liquid CO_2 for dry cleaning instead of using carcinogenic tetrachloroethane.
- ✓ Using catalysts and enzymes to increase rate of reaction instead of carrying out at high temperature.
- ✓ Super critical carbon dioxide can be used as solvents instead of organic solvents.
- ✓ Using biodiesel oil instead of diesel oil. Biodiesel oil is produced from cultivated plants oil, e.g. from soya beans. It's fuel from renewable resources and contrary to normal diesel oil.
- ✓ Adipic acid is usually synthesized from benzene which is carcinogenic. It can be prepared from glucose by the action of enzyme. Glucose is a renewable feed stock and makes no pollution.