Unit: Green Chemistry

Important Questions with Hints

1. **What is green Chemistry? What are the twelve principles of green chemistry?**

Hints: Green Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.
Green Chemistry is based on Twelve Principles:

1. **Pollution Prevention**
It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy**
Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Synthesis**
Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals**
Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. **Safer Solvents and Auxiliaries**
The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. **Design for Energy Efficiency**
Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks**
A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce Derivatives**
Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis**
Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. **Design for Degradation**
Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. **Real-time analysis for Pollution Prevention**

Analytical methodologies need to be further developed to allow for real-time in process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention

Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

2. "Green Chemistry is sustainable chemistry"- Explain the statement

Hints: Green chemistry is sustainable chemistry. There are several important respects in which green chemistry is sustainable:

• **Economic:** At a high level of sophistication green chemistry normally costs less in strictly economic terms (to say nothing of environmental costs) than chemistry as it is normally practiced.

• **Materials:** By efficiently using materials, maximum recycling, and minimum use of virgin raw materials, green chemistry is sustainable with respect to materials.

• **Waste:** By reducing insofar as possible, or even totally eliminating their production, green chemistry is sustainable with respect to wastes.

3. Write a comparative statement on green chemistry and synthetic chemistry.

Hints: Synthetic chemistry is the branch of chemical science involved with developing means of making new chemicals and developing improved ways of synthesizing existing chemicals. Chemicals or feedstocks which are used and products may be toxic, explosive, non biodegradable nature. They even may not be cost effective materials.

A key aspect of green chemistry is the involvement of synthetic chemists in the practice of environmental chemistry. Synthetic chemists, whose major objective has always been to make new substances and to make them cheaper and better, have come relatively late to the practice of environmental chemistry. Other areas of chemistry have been involved much longer in pollution prevention and environmental protection.

Environmental and health and safety issues gained their current prominence; the economic aspects of chemical manufacture and distribution were relatively simple and straightforward. The economic factors involved included costs of feedstock, energy requirements, and marketability of product. Now, however, costs must include those arising from regulatory compliance, liability, end-of-pipe waste treatment, and costs of waste disposal. By eliminating or greatly reducing the use of toxic or hazardous feedstocks and catalysts and the generation of dangerous intermediates and byproducts, green chemistry eliminates or greatly reduces the additional costs that have come to be associated with meeting environmental and safety requirements of conventional chemical manufacture.

4. "Green Chemistry is important in alternate reaction pathways"-Explain

Hints: Green chemistry involves making decisions about alternative chemical reactions to choose a reaction or reaction sequence that provides maximum safety, produces minimum byproduct, and utilizes readily available materials.

Consider two possible ways of making $FeSO_4$. The first of these was shown earlier and consists of the reaction of iron metal with sulfuric acid:

$$Fe(s) + H_2SO_4(aq) = H_2(g) + FeSO_4(aq)$$

A second pathway would be to react iron oxide, FeO, with sulfuric acid:

$$FeO(s) + H_2SO_4(aq) = FeSO_4(aq) + H_2O(aq)$$

The first reaction generates elemental H_2 gas as a byproduct. That has a potential downside because elemental hydrogen is highly explosive and flammable and could cause an explosion or fire hazard. The second reaction also gives the desired product. Its only byproduct is innocuous water. And there is no hazard from elemental hydrogen.

There are several ways in which HCl can be prepared. One of these commonly used in the laboratory is the reaction of concentrated sulfuric acid, H_2SO_4, with common table salt, NaCl, accompanied by heating to drive off the volatile HCl vapor:

$$2NaCl(s) + H_2SO_4(l) = 2HCl(g) + Na_2SO_4(s)$$

This reaction can be performed so that all of the NaCl and H_2SO_4 react, which gives a 100% yield. But it produces Na2SO4 byproduct, so the atom economy is less than 100%. In contrast, the direct reaction of hydrogen gas with chlorine gas to give HCl gas,

$$H_2(g) + Cl_2(g) = 2HCl(g)$$

can be carried out with 100% atom economy if all of the H_2 reacts with Cl_2. There is no waste byproduct.

Carbon monoxide will certainly burn in the presence of oxygen from air as shown by the reaction

$$2CO + O_2 = 2CO_2$$

Carbon monoxide is a product of automobile exhausts and an undesirable, toxic air pollutant. One way of ridding automobile exhaust gases of this pollutant is to pump air into the exhaust and convert the carbon monoxide to carbon dioxide as shown by the reaction above. However, even in the presence of oxygen, this reaction does not proceed to completion in an ordinary automobile exhaust system. It is enabled to occur, however, by passing the exhaust mixed with air over a solid honeycomb-like surface of ceramic coated with a metal that enables the reaction to occur, but is not itself consumed in the reaction. Such a substance is called a catalyst.

5. **Write the principles of sustainability of green chemistry**

Hints: The achievement of sustainability will require adherence to some important principles. These can be condensed into ten commandments of sustainability, which are listed below:

1. Human welfare must be measured in terms of quality of life, not just acquisition of material possessions, which demands that economics, governmental systems, creeds, and personal life-styles must consider environment and sustainability.
2. Since the burden upon Earth's support system is given by the relationship

   Burden = (number of people)x(demand per person)

it is essential to address both numbers of people on Earth and the demand that each puts on Earth's resources.
3. Given that even at the risk of global catastrophe, *technology will be used* in attempts to meet human needs, it is essential to acknowledge the anthrosphere as one of the five basic spheres of the environment and to design and operate it with a goal of zero environmental impact and maximum sustainability.
4. Given that energy is a key to sustainability, the development of efficiently used, abundant sources of energy that have little or no environmental impact is essential.
5. Climate conducive to life on Earth must be maintained and acceptable means must be found to deal with climate changes that inevitably occur.
6. Earth's capacity for biological and food productivity must be maintained and enhanced, considering all five environmental spheres.

7. Material demand must be drastically reduced; materials must come from renewable sources, be recyclable and, if discarded to the environment, be degradable
8. The production and use of toxic, dangerous, persistent substances should be minimized and such substances should not be released to the environment; any wastes disposed to disposal sites should be converted to nonhazardous forms.
9. It must be acknowledged that there are risks in taking no risks.
10. Education in sustainability is essential; it must extend to all ages and strata of society, it must be promulgated through all media, and it is the responsibility of all who have expertise in sustainability.