Roll No. | | | | |

Internal Assessment Test 2 – March 2023

Sub:	Applied Chemistry					Sub Code:	BCHES102	Branch:	CSE & CSE(DS)
Date:	03-03-2023	Duration:	90 min's	Max Marks:	50	Sem / Sec:	I / I,J, K & L		OBE

Question no. 1 is COMPULSORY and answer any THREE FULL Questions from the rest.

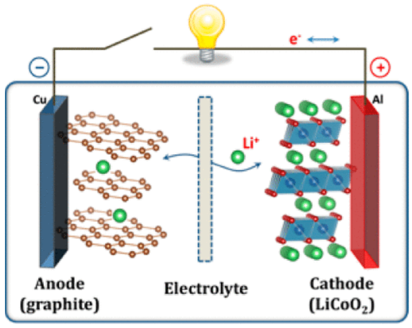
Q. No.		Question	MARKS	CO	RBT
1	(a)	Define battery. Explain construction and working of Li-ion battery with charge and discharge reactions and mention its applications.	[7]	CO2	L3
	(b)	What is direct recycling approach? Discuss in detail the process of extraction of gold from e-waste.	[7]	CO3	L2
2	(a)	Describe the working, principle and applications of conductometric sensors.	[6]	CO4	L2
	(b)	Explain the significance of an electrochemical NOx sensors through its working and applications.	[6]	CO4	L3
3	(a)	What are thermometric sensors? Describe their working principle and applications.	[6]	CO4	L3
	(b)	What are quantum dot solar cells? Explain its working principle with four applications.	[6]	CO2	L3
4	(a)	Explain the pyrometallurgical and hydrometallurgical methods of recycling of e-waste.	[6]	CO3	L2
	(b)	Explain construction, working and applications of Na-ion battery.	[6]	CO2	L3
5	(a)	Explain the determination of dissolved oxygen (DO) using an optical or electrochemical sensor.	[6]	CO4	L3
	(b)	Write a note on the toxic components present in E-Waste, discuss their health hazards.	[6]	CO3	L2
6	(a)	What are different sources of E-Waste, discuss its characteristics and composition.	[6]	CO3	L2
	(b)	Define disposable sensors. Explain the detailed working principle of the disposable sensor in the detection of pesticides with an example.	[6]	CO4	L3
7	(a)	Explain the working principle of electrochemical sensors for pharmaceuticals with an example.	[6]	CO4	L3
	(b)	What is e-waste? Discuss the different roles of stakeholders in the environmental management of e-waste.	[6]	CO3	L2

(Chief Course Instructor)

1a. Define battery. Explain construction and working of Li-ion battery with charge and discharge reactions and mention its applications.

It is a device consisting of two or more galvanic cells connected in series or parallel or both.

The batteries in which lithium ions are used instead of lithium metal and movement of lithium ion takes place through the electrolyte from one electrode to another electrode are called lithium-ion batteries. In general the battery consists of soluble lithium intercalated carbon/graphite is used as anode. The cathode material is made up of lithium liberating compounds.



Construction and working principle

During discharging lithium ions are dissociated from the anode and migrate through electrolyte to cathode. During charging, lithium from cathode material is ionized and moves towards the anode. At the same time the electrons travel through external circuit. The discharge and charge reactions are given below,

Anode: Lithium intercalated graphite layer having thin copper foil.

Cathode: Lithium cobalt oxide layer having aluminium foil as current collector.

Electrolyte: Li salts i.e., LiCl, LiBr, $LiAlCl_4$ dissolved in propylene carbonate and 1,2 dimethoxy ethane.

Representation: Graphite/$LiPF_6$ in organic solvent/$LiCoO_2$

$$\text{At Anode : } Li_XC_6 \longrightarrow XLi^+ + xe^- + 6C$$

$$\text{At Cathode: } Li_{1-X}CoO_2 + XLi^+ + xe^- \longrightarrow LiCoO_2$$

$$\text{Net Reaction: } Li1_{-X}CoO_2 + Li_XC_6 \longrightarrow LiCoO_2 + 6C$$

Applications: Li-ion batteries are used in cardiac pacemakers, laptops, cell phones and aerospace applications.

1b. What is direct recycling approach? Discuss in detail the process of extraction of gold from e-waste.

Direct recycling of e-waste refers to the process of refurbishing and reusing electronic devices, such as computers, smartphones, and televisions, without disassembling them into individual components.

Extraction of gold from E-waste

Gold can be extracted from electronic waste (e-waste) using a variety of methods, including *hydrometallurgical* and *pyrometallurgical* methods. The most commonly used method for extracting gold from e-waste is ***hydrometallurgical extraction***, which involves the use of chemical reactions and water-based solutions to extract the gold.

The process of hydrometallurgical extraction of gold from e-waste typically involves the following steps:

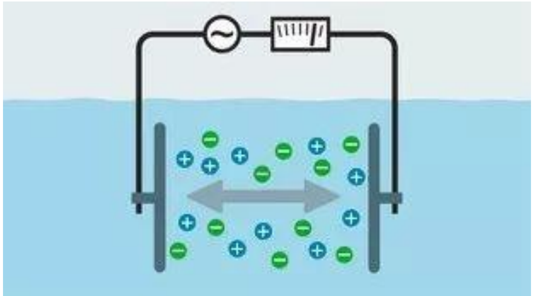
- **Collection and sorting**: Electronic waste is collected and sorted into different categories based on the materials present.
- **Shredding or grinding**: The electronic waste is shredded or ground into small particles to increase the surface area for the extraction process.
- **Leaching**: The crushed electronic waste is then treated with a solution, such as cyanide or thiourea that dissolves the gold. This solution is referred to as the leachant.
- **Separation**: The gold-rich solution is then separated from the solid waste. The gold present in the solution is then recovered using a variety of techniques, such as precipitation, ion exchange, and solvent extraction.
- **Purification**: The recovered gold is then purified to remove impurities.

2a. Describe the working, principle and applications of conductometric sensors.

A conductometric sensor is a type of chemical sensor that measures the conductivity of a solution to determine the concentration of ions in the solution.

Working principle:

- The working principle of a conductometric sensor is based on the measurement of electrical conductivity.
- The conductivity of a solution is directly proportional to the concentration of ions in the solution.
- When an electric current is passed through the solution, the ions in the solution carry the current, resulting in an increase in the conductivity of the solution.
- This conductivity measurement is then used to determine the concentration of ions in the solution.



Application:

i. **Water quality analysis**: Conductometric sensors are used to monitor the conductivity and ionic composition of water, which can be used to determine the quality and purity of the water.

ii. **Medical diagnostics**: Conductometric sensors are used in medical applications to measure the conductivity of body fluids, such as blood and urine, to monitor the concentration of ions and to diagnose various health conditions.

iii. **Environmental monitoring**: Conductometric sensors are used to monitor the conductivity and ionic composition of environmental samples, such as soil and groundwater, to assess the impact of pollutants on the environment.

iv. **Food and beverage industry**: Conductometric sensors are used to monitor the quality and composition of food and beverage products, such as wine and beer, to ensure their quality and consistency.

v. **Chemical analysis**: Conductometric sensors are used in chemical analysis to determine the concentration of ions in a solution, such as in titration experiments and in the analysis of metal ions.

2b. Explain the significance of an electrochemical NOx sensors through its working and applications.

The most common air pollutants in urban areas are nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter arising from the combustion of fossil fuels and bio-mass. Nitrogen oxides (NOx: mainly NO and NO_2) as an extremely harmful environmental pollutant not only contribute to the formation of acid rain and photochemical smog, but also cause damage to human health.

Detection of NO_x

Mixed potential electrochemical sensors (MPES) are an alternative technology for air quality monitoring. Mixed potentials arise when two dissimilar electrodes with different reaction kinetics towards the analyte gases are exposed to them. Pt is mostly used as the reference electrode with higher electrode kinetics. When NO_2 (or NO) and O_2 coexist, the electrode reactions occur at the triple-phase boundary between solid electrolyte, electrode and gas.

For NO_2

Anodic reaction: $O_2^{-} \rightarrow \frac{1}{2} O_2 + 2e^{-}$

Cathodic reaction: $NO_2 + 2e^{-} \rightarrow NO + O_2^{-}$

For NO

Anodic reaction: $NO + O_2^{-} \rightarrow NO_2 + 2e^{-}$

Cathodic reaction: $\frac{1}{2} O_2 + 2e^{-} \rightarrow O_2^{-}$

A mixed potential is generated at the sensing electrode when the anodic and cathodic reaction rates are equal.

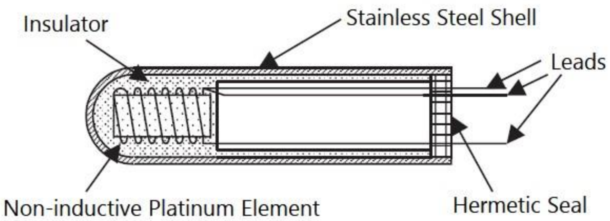
3a. What are thermometric sensors? Describe their working principle and applications.

A thermometric sensor is a type of sensor that measures temperature. It works by converting the temperature of a substance into an electrical signal that can be read and interpreted by a measuring device, such as a thermometer or data logger.

Working principle:

The working principle of a thermometric sensor is based on the relationship between temperature and a physical property, such as resistance, voltage, or infrared radiation.

For example, in a Resistance Temperature Detector (RTD), the working principle is based on the fact that the resistance of a material changes with temperature. RTDs consist of a wire made of a material, such as platinum, with a predictable resistance-temperature relationship. When the temperature of the RTD changes, the resistance of the wire changes, and this change in resistance can be used to determine the temperature of the RTD.



Application:

Thermometric sensors are widely used in a variety of applications, including industrial process control, heating and cooling systems, medical equipment, and environmental monitoring. They are accurate, reliable, and can measure temperature over a wide range of temperatures, making them a valuable tool for a wide range of applications.

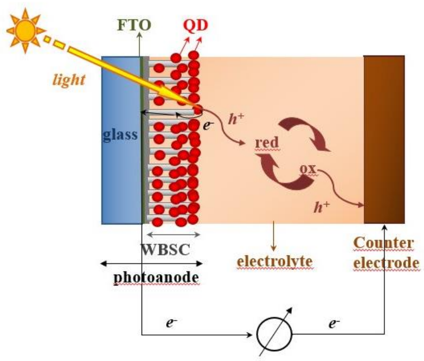
3b. What are quantum dot solar cells? Explain its working principle with four applications.

Quantum dots are tiny semiconductor particles with a size ranging from 2 to 10 nanometers. Quantum dot sensitized solar cells (QDSSCs) are a type of solar cell that utilizes quantum dots (QDs) to increase the efficiency of energy conversion from light to electrical energy.

Principle:

The key principle of QDSCs is the ability of QDs to tune their bandgap, which is the energy required to excite an electron from the valence band to the conduction band, based on their size.

- When sunlight strikes the QDs, the absorbed photons excite electrons in the QDs to higher energy levels, creating electron-hole pairs.
  Excitation process: QDs + hv → QDs*
  Exciton dissociation: QDs* → e^- + h^+* (free energy)
- The electrons and holes then separate due to the built-in electric field of the QDSC, and the electrons move towards the electron acceptor while the holes move towards the electrode.
  Injection process: QDs* + TiO_2 → TiO_2e-* + QDs^+
- The electrons flowing through the electron acceptor are collected by the electrode and routed to an external circuit, generating a flow of electric current.
  Energy generation: TiO_2e-* + C.E → TiO_2 + e* (CE)
- The holes, on the other hand, combine with the electrolyte or the hole acceptor material to complete the circuit.



Applications:

- **Solar energy conversion**: QDSSCs make them suitable for use in solar energy conversion systems, such as photovoltaic panels and solar-powered devices.

- **Portable electronics**: QDSSCs are lightweight and flexible, making them suitable for use in portable electronic devices, such as smartphones, laptops, and wearable devices.
- **Building-integrated photovoltaics** (BIPV): QDSSCs can be integrated into building materials, such as windows, roofs, and walls, allowing for the conversion of light into electrical energy within a building.
- **Stand-alone power systems**: QDSSCs can be used in stand-alone power systems, such as remote solar-powered systems, to provide electrical power without the need for a grid connection.

4a. Explain the pyrometallurgical and hydrometallurgical methods of recycling of e-waste.

Hydrometallurgical extraction:

Hydrometallurgical extraction is a process used to extract valuable metals and minerals from electronic waste using chemical reactions and water-based solutions. This process involves the following steps:

- **Collection and sorting**: Electronic waste is collected and sorted into different categories based on the materials present.
- **Shredding or grinding**: The electronic waste is shredded or ground into small particles to increase the surface area for the extraction process.
- **Leaching**: The crushed electronic waste is then treated with a solution, such as sulfuric acid, that dissolves the metals and minerals. This solution is referred to as the leachant.
- **Separation**: The metal-rich solution is then separated from the solid waste. The metals and minerals present in the solution are then recovered using a variety of techniques, such as precipitation, ion exchange, and solvent extraction.
- **Purification**: The recovered metals and minerals are then purified to remove impurities.

Pyrometallurgical methods:

Pyrometallurgical methods of e-waste recycling involve the use of high temperatures to extract metals and minerals from electronic waste. The following are the steps involved in a typical pyrometallurgical process:

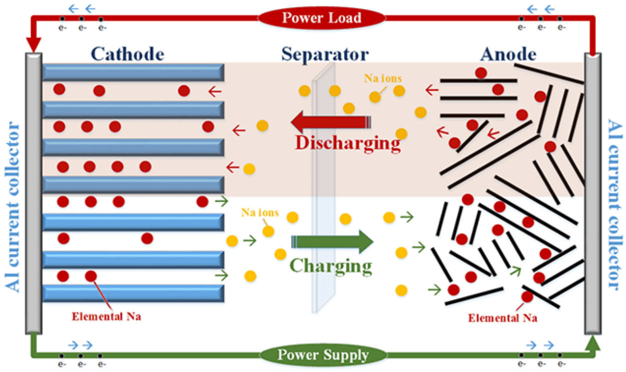
- **Collection and sorting**: Electronic waste is collected and sorted into different categories based on the materials present.
- **Shredding or grinding**: The electronic waste is shredded or ground into small particles to increase the surface area for the extraction process.
- **Smelting**: The shredded electronic waste is then heated in a furnace, along with a fluxing agent, to extract the metals. The fluxing agent helps to separate the metals from the other components of the waste.
- **Separation**: The melted waste is then cooled, and the metals are separated from the slag (non-metallic waste) using a variety of techniques, such as skimming, tapping, and slag fuming.
- **Purification**: The extracted metals are then purified to remove impurities.

4b. Explain construction, working and applications of Na-ion battery.

Sodium-ion batteries (SIBs) are energy conversion and storage devices that use sodium-ions to shuttle positive charge between the anode & cathode in order to convert electrical energy to chemical energy and vice versa.

Construction and working principle

During discharging sodium ions are dissociated from the anode and migrate through electrolyte to cathode. During charging, sodium from cathode material is ionized and moves towards the anode. At the same time the electrons travel through external circuit. The discharge and charge reactions are given below,



Anode: Disordered carbon (hard carbon)

Cathode: sodium transition metal oxides or Prussian blue analogs

Current collector: Aluminium foil is used in both anode and cathode.

Electrolyte: Sodium salts i.e., Sodium hexafluorophosphate ($NaPF_6$) dissolved in carbonate based solvents such as ethylene carbonate.

Separator: polymer separators such as Solupor or Celgard, or fiber-based separators such as Dreamweaver or glass fiber.

Cell Potential: 1.85 to 3.45 V

Representation: Hard carbon/$NaPF_6$ in organic solvent/$NaCoO_2$

At anode : $Na_xC_6 \rightarrow x\,Na^+ + x\,e^- + 6C$

At cathode : $Na_{1-x}CoO_2 + x\,e^- + x\,Na^+ \rightarrow NaCoO_2$

Over all reaction : $Na_xC_6 + Na_{1-x}CoO_2 \rightarrow NaCoO_2 + 6C$

Application:

i. Used in cellular phones and laptops.
ii. In electric vehicles and power tools.

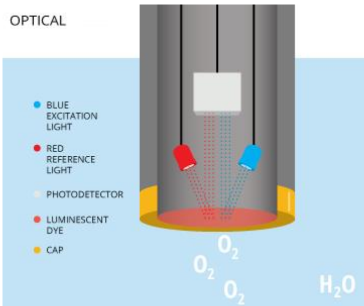
5a. Explain the determination of dissolved oxygen (DO) using an optical or electrochemical sensor.

There are three methods available for measuring dissolved oxygen concentrations.

- **Electrochemical or optical sensor**.
- **Colorimetric method**
- **Winkler titration**.

Optical Dissolved Oxygen Sensors

Optical dissolved oxygen sensors are sensors that use optical methods to measure the amount of dissolved oxygen in a liquid. They are commonly used in a variety of applications, including wastewater treatment, aquaculture, and environmental monitoring.



Construction:

An optical DO sensor consists of a

i. Semi-permeable membrane,
ii. sensing element,
iii. light-emitting diode (LED) and
iv. photodetector

Working:

- The sensing element contains a luminescent dye that is immobilized in sol-gel, xerogel or other matrix.
- When it is exposed to blue light, these dyes become excited and emit light as the electrons return to their normal energy state.
- When dissolved oxygen is present, the returned wavelengths are limited or altered due to oxygen molecules interacting with the dye.
- Optical dissolved oxygen sensors can measure either the intensity or the lifetime of the luminescence, as oxygen affects both.

The concentration of dissolved oxygen (as measured by its partial pressure) is inversely proportional to luminescence lifetime as shown by the Stern-Volmer equation,

$$\mathbf{I_o / I = 1 + k_q * t_0 * O_2}$$

I_o= Intensity or lifetime of dye luminescence without oxygen

I = Intensity or lifetime of luminescence with oxygen present

k_q = Quencher rate coefficient

t_0 = Luminescence lifetime of the dye

O_2 = oxygen concentration as a partial pressure

5b. Write a note on the toxic components present in E-Waste, discuss their health hazards.

The manufacturing of electronic and electrical products often involves the use of toxic materials that can be harmful to human health and the environment. Some of the most commonly used toxic materials include:

- **Lead**: Lead is commonly used in the manufacture of batteries and as a component of solder on printed circuit boards. Lead is a toxic heavy metal that can cause serious health problems, including neurological damage and developmental disorders.
- **Cadmium**: Cadmium is used in the manufacture of rechargeable batteries, as well as in electronic components such as capacitors and resistors. Cadmium is a toxic heavy metal that can cause cancer and other health problems.
- **Mercury**: Mercury is used in the manufacture of switches, relays, and fluorescent light bulbs. Mercury is a toxic heavy metal that can cause neurological damage and other health problems.

- **Brominated flame retardants**: Brominated flame retardants are used in the manufacture of electronic devices to reduce the risk of fire. Some types of brominated flame retardants are toxic and can harm human health and the environment.
- **Phthalates**: Phthalates are used as plasticizers in the manufacture of electronic devices. Some types of phthalates are toxic and can harm human health and the environment.

6a. What are different sources of E-Waste, discuss its characteristics and composition.

Electronic waste, or e-waste, can come from a variety of sources, including:

- **Households**: A significant portion of e-waste is generated from homes, as people upgrade their electronics and dispose of their old devices. This includes items such as computers, televisions, mobile phones, and other household appliances.
- **Businesses**: Companies and organizations also generate a large amount of e-waste, as they upgrade their computer systems and replace old equipment.
- **Government agencies**: Government agencies and institutions, such as schools and hospitals, also contribute to the e-waste stream as they upgrade and replace their electronics.

Characteristics of E-waste:

Electronic waste, or e-waste, has several characteristics that make it unique compared to other forms of waste:

- **Complex composition**: E-waste is made up of a complex mixture of materials, including metals, plastics, glass, and hazardous materials, which can make it difficult to manage and recycle.
- **Rapidly changing technology**: The rapid pace of technological advancement means that many electronic devices have a short lifespan and are quickly replaced with newer models, contributing to the growing volume of e-waste.
- **Hazardous components**: Many electronic devices contain hazardous materials, such as lead, cadmium, and mercury, which can be harmful to human health and the environment if not properly managed.

Composition of E-waste:

The composition of electronic waste, or e-waste, can vary depending on the type and age of the devices, but typically it contains a mixture of materials, including:

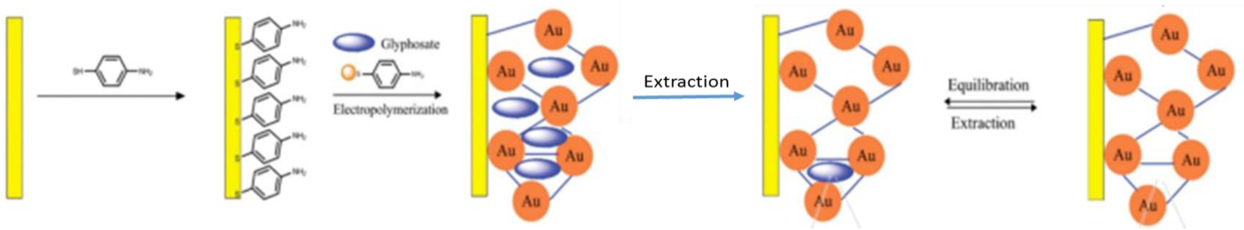
- **Metals**: Electronic devices contain a variety of metals, including iron, steel, aluminum, copper, gold, silver, and others. These metals are valuable resources and can be recovered and recycled.
- **Plastics**: Many electronic devices contain different types of plastic, such as polyvinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), and others.
- **Glass**: Electronic devices also contain glass, often in the form of screens and lenses.
- **Hazardous materials**: Many electronic devices contain hazardous materials, such as lead, cadmium, and mercury, which can be harmful to human health and the environment if not properly managed.

6b. Define disposable sensors. Explain the detailed working principle of the disposable sensor in the detection of pesticides with an example.

A disposable sensor is a type of sensor that is designed to be used once and then disposed of. These sensors are commonly used in applications where the cost of cleaning and reusing a sensor is not feasible, or where contamination is a concern.

Glyphosate [N-(phosphonomethyl)glycine] is one of the most commonly used agricultural herbicides globally. Due to risks associated with human exposure to glyphosate and its potential harmfulness, the need to develop specific, accurate, online, and sensitive methods is imperative.

- ➢ Molecularly imprinted polymers (MIPs) based electrochemical sensors has been used for the detection of glyposate due to low cost of preparation, high specificity, good stability, and suitable sensitivity.
- ✓ The MIP electrodes are prepared via electropolymerization of p-amino thiophenol-functionalized with AuNPs in the presence of GLYP as a template molecule.
- ✓ This template is subsequently extracted from the resulting polymer matrix, generating a film filled with complementary cavities in the shape and size of the template molecule.
- ✓ The electrochemical determination was based on the change in the electron transfer rate for Fe (II)/Fe (III), which flows through the MIP sensor flim after incubation with GLY.

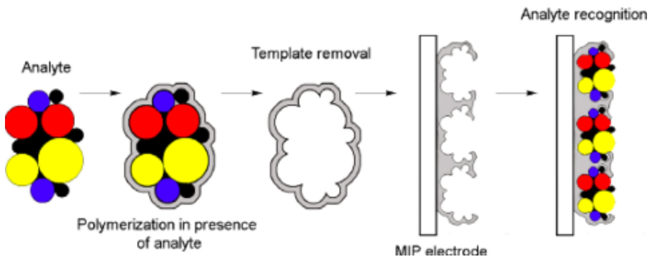


7a. Explain the working principle of electrochemical sensors for pharmaceuticals with an example.

Diclofenac is a non-steroidal anti-inflammatory drug of wide use around the world for the treatment of several diseases such as ankylosing spondylitis, acute muscle pain conditions, and osteoarthritis.

Detection of DCF:

- ✓ Molecularly imprinted polymers (MIPs) based electrochemical sensors has been used for the detection of various pharmaceutical compounds due to low cost of preparation, high specificity, good stability, and suitable sensitivity.
- ✓ The MIP electrodes are prepared via polymerization of certain functional monomers in the presence of template molecules.
- ✓ This template is subsequently extracted from the resulting polymer matrix, generating a film filled with complementary cavities in the shape and size of the template molecule.
- ✓ For E.g., at pH 7.0, DCF is irreversibly oxidized by releasing $2e^-$ and $2H^+$ in the surface of the sensor giving rise to an oxidation process at + 540 mV, which was used as analytical signal.



7b. What is e-waste? Discuss the different roles of stakeholders in the environmental management of e-waste.

Electronic waste, or E-waste, refers to discarded electrical or electronic devices, such as computers, televisions, mobile phones, and household appliances.

Role of stake holders in environmental management of e-waste:

The following are some of the key stakeholders in the environmental management of e-waste:

- **Government**: The government plays a critical role in establishing and enforcing regulations and policies that govern the collection, transportation, treatment, and disposal of e-waste. This includes setting standards for the management of e-waste, establishing collection systems, and ensuring that e-waste is properly disposed of.
- **Manufacturers**: Manufacturers have a responsibility to design and produce products that are environmentally friendly and can be easily recycled or reused at the end of their useful lives. They should also participate in e-waste collection and recycling programs and contribute to the development of sustainable e-waste management systems.
- **Consumers**: Consumers play a critical role in reducing e-waste by choosing to purchase products that are designed to be environmentally friendly, and by properly disposing of their old electronics. Consumers can also participate in e-waste collection and recycling programs, and can advocate for the development of more sustainable e-waste management systems.
- **Recyclers and waste management companies**: Recyclers and waste management companies are responsible for collecting, treating, and disposing of e-waste in a safe and responsible manner. They should use environmentally friendly methods for extracting valuable materials from e-waste, and should properly dispose of any hazardous waste generated during the process.
- **Environmental organizations**: Environmental organizations play an important role in advocating for sustainable e-waste management practices and in raising awareness about the environmental impacts of e-waste. They can also participate in the development of policies and regulations related to e-waste management.