INTRODUCTION

The lead–acid battery was invented in 1859 by French physicist Gaston Planté and is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by automobile starter motors.

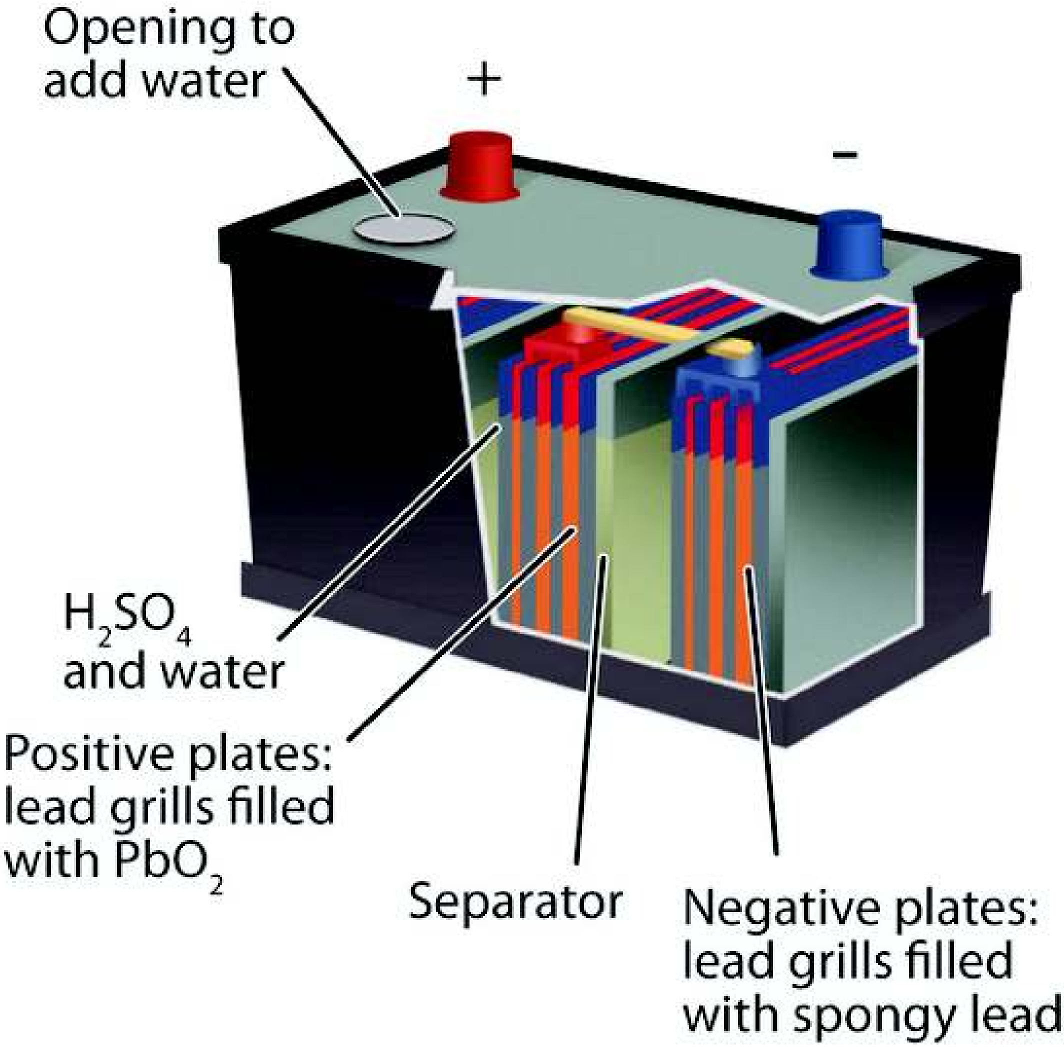
A lead-acid cell is a basic component of a lead-acid storage battery (e.g., a car battery). A 12.0 Volt car battery consists of six sets of cells, each producing 2.0 Volts. A lead-acid cell is an electrochemical cell, typically, comprising of a lead grid as an anode and a second lead grid coated with lead oxide, as a cathode, immersed in sulfuric acid. The concentration of sulfuric acid in a fully charged auto battery measures a specific gravity of 1.265 – 1.285. This is equivalent to a molar concentration of 4.5 – 6.0 M. The cell potential (open circuit potential or battery voltage, OCV) is a result of the electrochemical reactions occurring at the cell electrode interfaces.

As they are inexpensive compared to newer technologies, lead–acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large-format lead–acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems. For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. Gel-cells and absorbed glass-mat batteries are common in these roles, collectively known as VRLA (valve-regulated lead–acid) batteries.

In 1999 lead–acid battery sales accounted for 40–45% of the value from batteries sold worldwide excluding China and Russia, and a manufacturing market value of about $15 billion.

The French scientist Gautherot observed in 1801 that wires that had been used for electrolysis experiments would themselves provide a small amount of "secondary" current after the main battery had been disconnected. In 1859, Gaston Planté's lead–acid battery was the first battery that could be recharged by passing a reverse current through it. Planté's first model consisted of two lead sheets separated by rubber strips and rolled into a spiral. His batteries were first used to power the lights in train carriages while stopped at a station. In 1881, Camille Alphonse Faure invented an improved version that consisted of a lead grid lattice, into which a lead oxide paste was pressed, forming a plate. This design was easier to mass-produce. An early manufacturer (from 1886) of lead–acid batteries was Henri Tudor.

Using a gel electrolyte instead of a liquid allows the battery to be used in different positions without leakage. Gel electrolyte batteries for any position date from the 1930s, and even in the late 1920s portable suitcase radio sets allowed the cell vertical or horizontal (but not inverted) due to valve design (see third Edition of Wireless Constructor's Encyclopedia by Frederick James Camm). In the 1970s, the valve-regulated lead–acid battery (often called "sealed") was developed, including modern absorbed glass mat types, allowing operation in any position.



ELECTROCHEMISTRY OF LEAD STORAGE BATTERY

Discharge Chemistry

*T*he electrodes of the cells in a lead storage battery consist of lead grids. The openings of the anodic grid are filled with spongy (porous) lead. The openings of the cathodic grid are filled with lead dioxide {PbO_2}. Dilute sulfuric acid {H_2SO_4} serves as the electrolyte. When the battery is delivering a current, i.e. ***discharging***, the lead at the *anode* is oxidized:

$$\mathbf{Pb \longrightarrow Pb^{2+} + 2\ e^-}$$

*B*ecause the lead ions are in the presence of aqueous sulfate ions (from the sulfuric acid), insoluble lead sulfate precipitates onto the electrode. The overall reaction at the *anode* is therefore:

$$\mathbf{Pb + SO_4^{2-} \longrightarrow PbSO_4\ (electrode) + 2\ e^-}$$

*E*lectrons that flow from the anode simultaneously reduce the lead dioxide at the **cathode**:

$$\mathbf{2\ e^- + PbO_2 + 4\ H^+ \longrightarrow Pb^{2+} + 2\ H_2O}$$

*A*gain, the lead ions that are formed react with aqueous sulfate ions to form insoluble lead sulfate on the electrode, and the overall reaction at the **cathode** is:

$$\mathbf{2\ e^- + PbO_2 + 4\ H^+ + SO_4^{2-} \longrightarrow PbSO_4\ (electrode) + 2\ H_2O}$$

Charge Chemistry

*T*he lead storage cell can be ***recharged*** by passing a current in the reverse direction. The half-reactions are the exact reverse of those that occur when the cell is operating as a voltaic cell.

This type of battery can be recharged. In the charged state, each cell contains negative plates of elemental lead (Pb) and positive plates of lead(IV) oxide (PbO_2) in an electrolyte of approximately 4.2 M sulfuric acid (H_2SO_4). The charging process is driven by the forcible removal of electrons from the positive plate and the forcible introduction of them to the negative plate by the charging source.

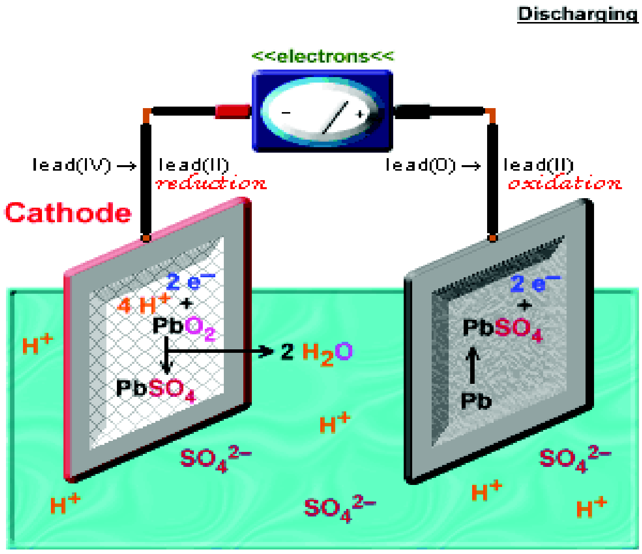
Negative plate reaction: $PbSO_4(s) + H^+(aq) + 2e^- \rightarrow Pb(s) + HSO_4^-(aq)$

Positive plate reaction: $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^-$

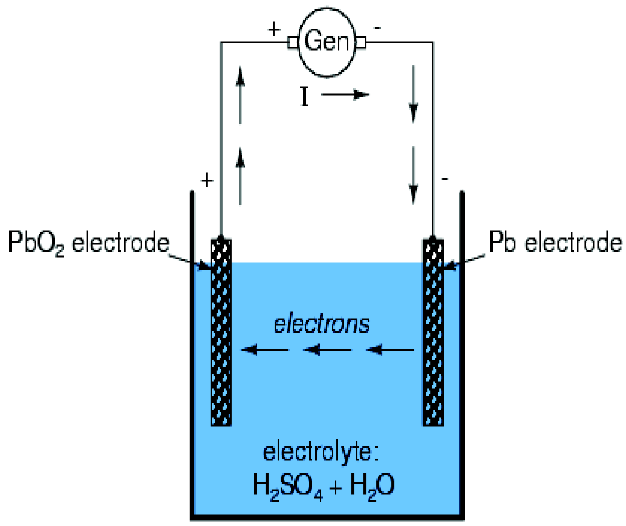
Combining these two reactions, the overall reaction is the reverse of the discharge reaction:

$$2PbSO_4(s) + 2H_2O(l) \rightarrow Pb(s) + PbO_2(s) + 2H^+(aq) + 2HSO_4^-(aq)$$

Note: an important aspect of the *lead storage cell* is that the products of the reactions at the anode and cathode are insoluble (lead sulfate in each case). This means that these substances are readily available to participate in the reverse reactions that recharge the cell!



Lead-acid cell charging



At (+) electrode: $Pb(II)SO_4 + 2H_2O \rightarrow Pb(IV)O_2 + 3H^+ + HSO_4^- + 2e^-$

At (-) electrode: $Pb(II)SO_4 + H^+ + 2e^- \rightarrow Pb + HSO_4^-$

Overall cell: $2PbSO_4 + 2H_2O \rightarrow PbO_2 + Pb + 2H_2SO_4$

ADVANTAGES OF LEAD STORAGE BATTERY

- Technology progresses in the mid-1970s when researchers developed a maintenance-free lead acid battery that was able to operate in any position. The liquid electrolyte was transformed into moistened separator and the enclosure was sealed. In addition, safety valves were added to allow venting of gas during charge and discharge. Nowadays, life without lead acid batteries seems implausible. They have myriad uses and are one of the most useful batteries with the longest life cycle, the greatest energy density per pound, and the most mature recycling infrastructure of similarly priced batteries. Some of its advantages are:-
- Low cost
- Reliable. Over 140 years of development.
- Robust.
- Tolerant to overcharging.
- Low internal impedance.
- Can deliver very high currents.
- Indefinite shelf life if stored without electrolyte.
- Can be left on trickle or float charge for prolonged periods.
- Wide range of sizes and capacities available.
- The world’s most recycled product.

DISADVANTAGES OF LEAD STORAGE BATTERY

Lead-acid batteries are generally reliable for everyday use; however, these batteries do have their shortcomings. It is important to be aware of the dangers and disadvantages of lead-acid batteries before including one in your electrical circuit. Some of these are:-

- Very heavy and bulky.
- Flammable gases while charging
- Typical columbic charge efficiency only 70% but can be as high as 85% to 90% for special designs.
- Danger of overheating during charging
- Not suitable for fast charging
- Typical cycle life 300 to 500 cycles.
- Must be stored in a charged state once the electrolyte has been introduced to avoid deterioration of the active chemicals.

APPLICATIONS OF LEAD STORAGE BATTERY

Most of the world's lead-acid batteries are automobile starting, lighting and ignition (SLI) batteries, with an estimated 320 million units shipped in 1999. In 1992 about 3 million tons of lead was used in the manufacture of batteries.

Wet cell stand-by (stationary) batteries designed for deep discharge are commonly used in large backup power supplies for telephone and computer centers, grid energy storage, and off-grid household electric power systems.[20] Lead–acid batteries are used in emergency lighting and to power sump pumps in case of power failure.

Traction (propulsion) batteries are used in golf carts and other battery electric vehicles. Large lead-acid batteries are also used to power the electric motors in diesel-electric(conventional) submarines when submerged, and are used as emergency power on nuclear submarines as well. Valve-regulated lead acid batteries cannot spill their electrolyte.

They are used in back-up power supplies for alarm and smaller computer systems (particularly in uninterruptible power supplies; UPS) and for electric scooters, electric wheelchairs, electrified bicycles, marine applications, battery electric vehicles or micro hybrid vehicles, and motorcycles.

Lead-acid batteries were used to supply the filament (heater) voltage, with 2 V common in early vacuum tube (valve) radio receivers.

Portable batteries for miners' cap lamps headlamps typically have two or three cells.

LITHIUM ION BATTERY

INTRODUCTION

The term *lithium-ion* points to a family of batteries that shares similarities, but the chemistries can vary greatly. Li-cobalt, Li-manganese, NMC and Li-aluminum are similar in that they deliver high capacity and are used in portable applications. Li-phosphate and Li-titanate have lower voltages and have less capacity, but are very durable. These batteries are mainly found in wheeled and stationary uses.

Octagon Battery – What makes a Battery a Battery

To make a battery viable as an electric storage device, eight basic requirements must be met and a battery is fittingly called the octagon battery

1. High specific energy

A key feature in consumer products is long runtime and device manufacturers achieve this by building batteries with high ampere-hour (Ah). The term lithium-ion is synonymous with a high specific energy. This does not mean that all Li-ion batteries have high Ah ratings.

2. High specific power

Batteries made for power tools and electric powertrains provide high load capabilities but the specific energy is low.
The water in the bottle represents specific energy (capacity); the spout pouring the water govern specific power (loading).

3. Affordable price

Materials, refining processes, manufacturing, quality control and cell matching add cost for battery manufacturing; volume production only assists in part to reduce costs. Single cell use in mobile phones when no cell matching is required also lowers costs.

4. Long life

Nowhere is longevity more important than in large, expensive battery packs.Longevity does not depend on battery design alone but also on how the battery is used. Adverse temperature, fast charge times and harsh discharge conditions stress the battery.

5. Safety

Lithium-based batteries can be built with high specific energy, but these systems are often reactive and unstable.. Most manufacturers stopped production of these systems because of safety issues. When used correctly, brand-name Li-ion is very safe.

6. Wide operating range

Batteries perform best at room temperature as cold temperatures slow the electrochemical reaction of all batteries. Li-ion cannot be charged below freezing, and heating blankets are often added to facilitate charging. High heat shortens battery life and compromises safety.

7. Toxicity

Cadmium- and mercury-based batteries have been replaced with alternative metals for environmental reasons.

8. Fast charging

Lithium- and nickel-based batteries should be charged at 1C or slower. At 1C, a nickel-based battery fully charges in about 90 minutes and Li-ion in 2–3 hours. Lead acid cannot be fast charged. NiCd is the only battery that accepts ultra-fast charge with minimal stress.

In addition to the eight basic requirements of the octagon battery, a battery must have low self-discharge to allow long storage and provide an instant start-up when needed. A further requirement is a long shelf-life with little performance degradation.

WORKING PRINCIPLE

How lithium-ion batteries work

Like any other battery, a rechargeable lithium-ion battery is made of one or more power-generating compartments called **cells**. Each cell has essentially three components: a **positive electrode** (connected to the battery's positive or + terminal), a **negative electrode** (connected to the negative or − terminal), and a chemical called an **electrolyte** in between them. The positive electrode is typically made from a chemical compound called lithium-cobalt oxide ($LiCoO_2$) or, in newer batteries, from lithium iron phosphate ($LiFePO_4$). The negative electrode is generally made from carbon (graphite) and the electrolyte varies from one type of battery to another—but isn't too important in understanding the basic idea of how the battery works.

All lithium-ion batteries work in broadly the same way. When the battery is charging up, the lithium-cobalt oxide, positive electrode gives up some of its lithium ions, which move through the electrolyte to the negative, graphite electrode and remain there. The battery takes in and stores energy during this process. When the battery is discharging, the lithium ions move back across the electrolyte to the positive electrode, producing the energy that powers the battery. In both cases, electrons flow in the opposite direction to the ions around the outer circuit. Electrons do not flow through the electrolyte: it's effectively an insulating barrier, so far as electrons are concerned.

The movement of ions (through the electrolyte) and electrons (around the external circuit, in the opposite direction) are interconnected processes, and if either stops so does the other. If ions stop moving through the electrolyte because the battery completely discharges, electrons can't move through the outer circuit either—so you lose your power. Similarly, if you switch off whatever the battery is powering, the flow of electrons stops and so does the flow of ions. The battery essentially stops discharging at a high rate (but it does keep on discharging, at a very slow rate, even with the appliance disconnected).

Unlike simpler batteries, lithium-ion ones have built in electronic controllers that regulate how they charge and discharge. They prevent the overcharging and overheating that can cause lithium-ion batteries to explode in some circumstances.

How a lithium-ion battery charges and discharges

As their name suggests, lithium-ion batteries are all about the movement of lithium ions: the ions move one way when the battery charges (when it's absorbing power); they move the opposite way when the battery discharges (when it's supplying power):

1. During charging, lithium ions flow from the positive electrode to the negative electrode through the electrolyte Electrons also flow from the positive electrode to the negative electrode, but take the longer path around the outer circuit. The electrons and ions combine at the negative electrode and deposit lithium there.

2. When no more ions will flow, the battery is fully charged and ready to use.

3. During discharging, the ions flow back through the electrolyte from the negative electrode to the positive electrode. Electrons flow from the negative electrode to the positive electrode through the outer circuit, powering your laptop. When the ions and electrons combine at the positive electrode, lithium is deposited there.

4. When all the ions have moved back, the battery is fully discharged and needs charging up again.

How are the lithium ions stored?

Again, the negative graphite electrode is shown on the left, the positive cobalt-oxide electrode on the right, and the lithium ions are represented by yellow circles. When the battery is fully charged, all the lithium ions are stored between layers of graphene (sheets of carbon one atom thick) in the graphite electrode (they have all moved over to the left). In this charged-up state, the battery is effectively a multi-layer sandwich: graphene layers alternate with lithium ion layers. As the battery discharges, the ions migrate from the graphite electrode to the cobalt-oxide electrode (from left to right). When it's fully discharged, all the lithium ions have moved over to the cobalt-oxide electrode on the right. Once again, the lithium ions sit in layers, in between layers of cobalt ions and oxide ions . As the battery charges and discharges, the lithium ions shunt back and forth from one electrode to the other.

Lithium ion battery advantages

- ***High energy density*** :   The much greater energy density is one of the chief advantages of a lithium ion battery or cell. With electronic equipment such as mobile phones needing to operate longer between charges while still consuming more power, there is always a need to batteries with a much higher energy density. In addition to this, there are many power applications from power tools to electric vehicles. The much higher power density offered by lithium ion batteries is a distinct advantage.

- ***Nature friendly*** : Lithium pollutes less than other batteries and last longer than those made of nickel or lead. Less pollution goes into their production, and because they last longer, there is less disposal of potentially hazardous batteries into landfill. They can also be more powerful than hp 484784-001 battery made from other substances.

- ***Self-discharge*** : One issue with batteries and ells is that they lose their charge over time. This self-discharge can be a major issue. One advantage of lithium ion cells is that their rate of self-discharge is much lower than that of other rechargeable cells such as Ni-Cad and NiMH forms.

- ***Quick Charging*** : Lithium-ion batteries take a fraction of the time taken by other batteries to charge. This is one of the main reasons why these batteries are preferred over the others, especially in gadgets and other devices that require frequent charging.

- ***Low maintenance*** : One major lithium ion battery advantage is that they do not require and maintenance to ensure their performance. Ni-Cad cells required a periodic discharge to ensure that they did not exhibit the memory effect. As this does not affect lithium ion cells, this process or other similar maintenance procedures are not required.

- ***No requirement for priming***: Some rechargeable cells need to be primed when they receive their first charge. There is no requirement for this with lithium ion cells and batteries.

- ***Small and Light*** : The relatively small size and weight of lithium-ion batteries make them conducive to power small light-weight devices. This is one reason why the automobile industry uses these batteries to power smaller vehicles like golf carts and electric cars. They are also widely used in aerospace applications.

What Are Lithium Batteries Used For?

Lithium batteries are commonly used as power sources for portable electronics and implanted medical **devices**. Though more expensive than ordinary alkaline batteries, lithium batteries have a significantly longer lifespan.

What Are Lithium Batteries Used For?

- Pacemakers

Pacemakers and other implantable medical **devices** use specially designed lithium-iodide batteries that can last 15 years or longer before replacement is necessary.

- Digital Cameras

Many digital cameras are able to use lithium batteries, dramatically increasing the number of photographs that can be taken between battery changes. The manufacturer's recommendations regarding lithium battery use should be strictly followed, as overload can result in damage to the device.

- Personal Digital Assistants (PDAs) and Smartphones

Small lithium batteries are used to power many standalone PDAs, as well as so-called smartphones that incorporate cell phone, PDA, music and camera features.

- Watches

With long life being an attractive and convenient feature, many watch manufacturers are now producing wristwatches that run on 3-volt lithium batteries.

- Miscellaneous Devices

Lithium batteries are used to power an increasing number of devices, such as thermometers, remote car locks, laser pointers, MP3 players, hearing aids, calculators and battery backup systems in computers. Remote control toys also use lithium batteries, with the batteries frequently outliving the toys themselves.

GREEN CHEMISTRY

INTRODUCTION TO GREEN CHEMISTRY

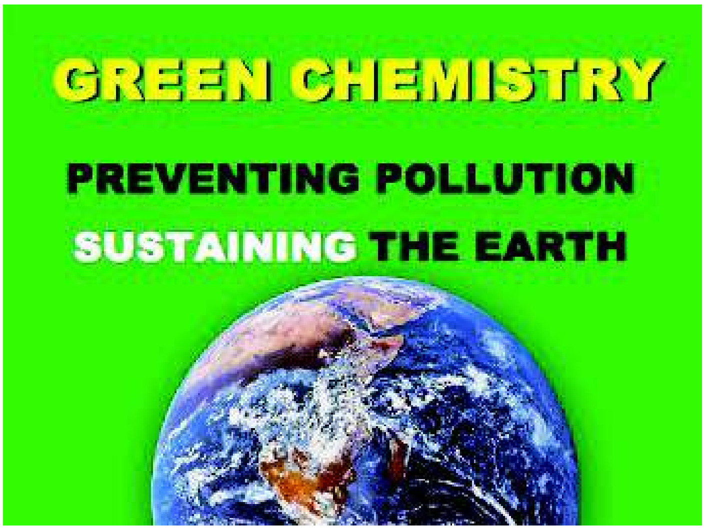
Green chemistry, also called sustainable chemistry, is an area of chemistry and chemical engineering focused on the designing of products and processes that minimize the use and generation of hazardous substances .Whereas environmental chemistry focuses on the effects of polluting chemicals on nature, green chemistry focuses on technological approaches to preventing pollution and reducing consumption of nonrenewable resources.

The overarching goals of green chemistry—namely, more resource-efficient and inherently safer design of molecules, materials, products, and processes—can be pursued in a wide range of contexts.

There is increasing pressure from both society and governments for chemistry-based industries to become more sustainable through development of eco-friendly products and processes that both reduce waste and prevent toxic substances from entering the environment.

The chemical industry is vitally important to the world economy; however the success of the industry has led to some environmental damage and a low public perception of the industry. In order to prevent further environmental damage and to encourage more young people into the industry, the public acceptability needs to be raised by adoption of greener and cleaner processes and green product design.

Industry is making progress, but it is frequently commented that new graduates are not adequately equipped with the tools, techniques, and culture to ensure that they can rapidly make a positive impact on industry's increasing requirement for green chemistry and sustainable technology.



Globally there is a growing requirement for cleaner processes and products, with many 'third-world' countries now insisting that licensed technology is the cleanest available while the EU is leading the world in its requirements for greener products. In order to ensure the future success of chemistry-based industries, it is vital to equip students with the requisite tools, knowledge and experience.

The Green Chemistry Centre of Excellence (GCCE) aspires to maintain and enhance the high quality of provision of green and sustainable chemistry to enable a strategic step change to a low carbon, bio-based economy, based on core values of high quality pure and translational research, education, training, networking and partnerships embedded within a framework of sustainable development.

12 Principles of Green Chemistry

1. 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 Syntheses

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.

APPLICATIONS OF GREEN CHEMISTRY

I. **Antibacterial Products**
II. **Laundry**
III. **Water Pollution**
IV. **Industrial Cleaning**

ANTIBACTERIAL PRODUCTS

- Environmentally benign antibacterial agents.
- Alternatives to traditional chlorine or tin containing antibacterial agents
- Bandages, sutures, hospital gowns, acne medication, toothpastes, air filters, antiviral agents.

Magnesium hydroperoxyacetate

OH-O-Mg-OAc

Magnesium dihydroperoxide

OH-O-Mg-O-OH

CLEANING CLOTHES

- TAML catalysts active hydrogen peroxide
  - Inhibit dye transfer
  - Potential for washing machines that use less water

- Total Impact Program (TIP)
  - Chemistry +Application Knowledge +Product stewardship
  - Laundry formulation incorporates neutral pH detergent, enzymes, surfactants, oxygen bleach and biological softeners.
- Benefits
  - Avoids high pH detergents, chlorine bleach, acid neutralisation, poorly degradable surfactants
- Dry cleaning with liquid Carbon dioxide
  - Current processes use (perchloroethylene), a suspected carcinogen and groundwater contaminant.
  - New processes uses liquid carbon dioxide, a nonflammable, nontoxic, and renewable substance.

CLEANING WATER

- Chlorine disinfection
  - Important for preventing disease
  - Toxic to aquatic life
  - Sulphur based compounds used to neutralise chlorine
- Vitamin C (Ascorbic Acid)
  - Safer, Effective neutralisation alternative
  - Boosts immune system of aquatic life

- Ultimer Polymer Technology
    - Manufacture of high molecular weight, water soluble polymers in aqueous salt solution
    - Eliminate use of oils and surfactants in manufacture and use
    - Uses aluminium sulfate, a waste by-product from the manufacture of Caprolactam
    - Eliminates need for expensive mixing equipment required for water-in-oil emulsions

INDUSTRIAL CLEANING

- Crystal Simple Green
    - Water based industrial cleaner
    - Non-toxic, biodegradable surfactants
    - Replaces traditional organic solvents
    - Eliminates hazardous waste sludge production and VOC pollution
- Isomet
    - Mixture of isoparaffinic hydrocarbon, propylene glycol, monomethyl ether, and isopropyl alcohol
    - Replaces Typewash(mixture of methylene chloride, toluene, and acetone)
    - Excellent performance in postage stamp and overprinting presses
    - Acceptable properties (cleaning ability, solvent evaporation rate, odour, environmental compliance, and cost)
- Printed circuit boards assembled using Surface Mount Technology (SMT)
    - Lead/ Tin solder paste stenciled onto substrate
    - Stencils cleaned before reuse
        - CFC Solvents
        - Aqueous solvents (high temperature, high pH)
- 440-R SMT Detergent
    - Aqueous-based, contains no VOCs
    - Ultrasonic Technology

ADVANTAGES

1. Clean, non-toxic, biocompatible and eco-friendly method for synthesis of nanoparticles.

2. Cost effective, safe and sustainable.

3. Bacteria are easy to handle and can be easily manipulated.

DISADVANTAGES

1. Culturing of micro-organisms is time-consuming.

2. Difficult to have control over size, shape and crystallinity.

3. Particles are not mono-dispersed and rate of production is slow.

SYNTHESIS USING PLANT EXTRACTS

ADVANTAGES:

- Environmental friendly
- Easily scaled up for large synthesis of nanoparticles
- No need of high temperature, pressure, energy and toxic chemicals
- More advantageous over use of micro-organisms by less elaborate process of maintaining cultures
- Reduces cost of micro-organism isolation and their culture media

DISADVANTAGES:

- Plants cannot be manipulated as the choice of nanoparticles through optimized synthesis through genetic engineering
- Plant produce low yield of secreted proteins which decreases the synthesis rate

SYNTHESIS USING WASTE

ADVANTAGES:

- Easily available and does not require rigorous processing
- Directly used for NP synthesis
- Option for waste management
- Leads to fast and cost effective approach
- Does not induce toxic NP

-