UNIT

4

Carbon and its Compounds

GAMQZP

Learning Objectives

After completing this lesson, students will be able to

- explain the special features of carbon.
- know the isomerism of carbon compounds.
- know the three allotropic forms of carbon.
- differentiate between the properties of graphite and diamond.
- recognise the various inorganic carbon compounds with their uses.
- know the few common properties of carbon compounds.
- identify the codes of various plastics.
- understand the effects of plastics on human life and environment.
- know the legal measures to prevent plastic pollution.

Introduction

Carbon is an inseparable chemical entity associated with living things of the earth. The food we eat, the clothes we wear, the cosmetics we use and the fuels by which we run the automobiles all contain carbon compounds. When we burn the materials like cotton, wood, paper, plastics and rubber, they burn with smoky flame and leave some amount of solid or ash at the end. This is nothing but carbon.

Carbon is one of the most important **non-metallic** element. Antoine Lavoisier named Carbon from the Latin word **'Carbo'** meaning coal. This is because carbon is the main constituent of coal. Coal is a fossil fuel developed from prolonged decomposition of buried plants and animals. So it is clear that all the life forms contain carbon. The earth's crust contains only 0.032% of carbon (i.e.320 parts per million by weight) in the form of minerals like carbonates, coal and petroleum and the atmosphere has only 0.03% of carbon dioxide (i.e.300 parts per million by weight). In spite of this availability of small amount of carbon in nature, carbon compounds have an immense importance in everyday life. For example, we ourselves are made of carbon compounds. About 18 % of the weight of human body is carbon.

- ❖ Carbon is present in our muscles, bones, organs, blood and other components of living matter. Carbohydrates (compounds formed primarily of carbon and hydrogen) provide fuel for living organisms, underlie the structure of plants, animals and bacteria and are essential components of DNA and RNA, the molecular blueprints of life.
- ❖ A large number of things which we use in our daily life are made up of carbon compounds.
- ❖ The most vital photochemical reaction of plants involve carbon compounds (CO_2 and Chlorophyll)

So without carbon, there is no possibility for the existence of plants and animals including human. Thus **Carbon Chemistry** is also called as **Living Chemistry**.

4.1 Discovery of Carbon-Milestones

Carbon has been known since ancient times in the form of soot, charcoal, graphite and diamonds. Ancient cultures did not realize, of course, that these substances were different forms of the same element.

In 1772, French scientist **Antoine Lavoisier** pooled resources with other chemists to buy a diamond, which they placed in a closed glass jar. They focused the Sun's rays on the diamond with a remarkable giant magnifying glass and saw the diamond burn and disappear. Lavoisier noted that the overall weight of the jar was unchanged and that when it burned, the diamond had combined with oxygen to form carbon dioxide. He concluded that diamond and charcoal were made of the same element – carbon.

In 1779, Swedish scientist **Carl Scheele** showed that graphite burned to form carbon dioxide and so it must be another form of carbon.

In 1796, English chemist **Smithson Tennant** established that diamond is pure carbon and not a compound of carbon and it burned to form only carbon dioxide. Tennant also proved that when equal weights of charcoal and diamonds were burned, they produced the same amount of carbon dioxide.

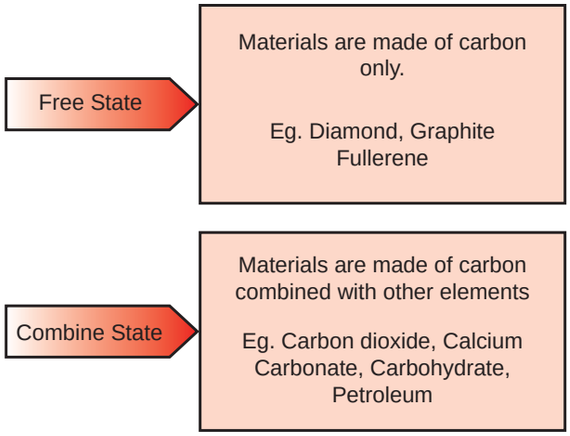
In 1855, English chemist **Benjamin Brodie** produced pure graphite from carbon, proving graphite is a form of carbon.

Although it had been previously attempted without success, in 1955 American scientist **Francis Bundy** and co-workers at 'General Electric' company finally demonstrated that graphite could be transformed into diamond at high temperature and high pressure.

In 1985, **Robert Curl, Harry Kroto and Richard Smalley** discovered fullerenes, a new form of carbon in which the atoms are arranged in soccer-ball shapes. The most recently discovered allotrope of carbon is **graphene**, which consists of a single layer of carbon atoms arranged in hexagons. Graphene's discovery was announced in 2004 by **Kostya Novoselov and Andre Geim**, who used adhesive tape to detach a single layer of atoms from graphite to produce the new allotrope. If these layers were stacked upon one other, graphite would be the result. Graphene has a thickness of just one atom.

4.2 Compounds of Carbon – Classification

Carbon is found both in free state as well as combined state in nature.



In the pre-historic period, ancients used to manufacture charcoal by burning organic materials. They used to obtain carbon compounds both from living things as well as non-living matter. Thus in the early 19th century, Berzelius classified carbon compounds based on their source as follows:

i. **Organic Carbon Compounds:** These are the compounds of carbon obtained from living organisms such as plants and animals. e.g. Ethanol, cellulose, Starch.

ii. **Inorganic Carbon Compounds:** These are the compounds containing carbon but obtained from non-living matter. e.g. Calcium Carbonate, Carbon Monoxide, Carbon dioxide.

4.2.1 Organic Compounds of Carbon

There are millions of organic carbon compounds available in nature and also synthesized manually. Organic carbon compounds contain carbon connected with other elements like hydrogen, oxygen, nitrogen, sulphur etc. Thus depending on the nature of other elements and the way in which they are connected with carbon, there are various classes of organic carbon compounds such as hydrocarbons, alcohols, aldehydes and ketones, carboxylic acids, amino acids, etc. You will study about organic carbon compounds in your higher classes.

More to Know


Friedrich Wohler
(1800 – 1882)

Until the mid – nineteenth century, scientists believed organic compounds came only from live plants and animals. They reasoned that organisms possessed a vital force that enabled them to produce organic compounds. This concept was known as **Vital Force Theory.** In 1829, **Friedrich Wohler** synthesized urea, an organic compound, from inorganic compounds lead cyanate and aqueous ammonia.

$$Pb(OCN)_2 + 2NH_4OH \rightarrow 2\,(NH_2)_2CO + Pb(OH)_2$$

Lead cyanate Aq. Ammonia Urea Lead hydroxide

Wohler was actually attempting to synthesize ammonium cyanate from the foresaid reaction. But he obtained the crystals of urea and thus urea is the first organic compound synthesized in laboratory. This synthesis was a blow to vital force theory. Following Wohler, chemists synthesized many organic compounds like acetic acid, methane, dyes, etc. in laboratory. Hence Friedrich Wohler is called '**Father of Modern Organic Chemistry**'.

4.2.2 Inorganic Compounds of Carbon

As compared to organic compounds, the number of inorganic carbon compounds are limited. Among them oxides, carbides, sulphides, cyanides, carbonates and bicarbonates are the major classes of inorganic carbon compounds. Formation, properties and uses of some of the compounds are given in Table 4.1.

Table 4.1 Inorganic carbon compounds

Compounds	Formation	Properties	Uses
Carbon monoxide (CO)	Not a natural component of air. Mainly added to atmosphere due to incomplete combustion of fuels.	Colourless Odourless Highly toxic Sparingly soluble in water.	Main component of water gas ($CO+H_2$). Reducing agent.
Carbon dioxide (CO_2)	Occurs in nature as free and combined forms. Combined form is found in minerals like limestone, magnesite. Formed by complete combustion of carbon or coke.	Colourless Odourless Tasteless Stable Highly soluble in water Takes part in photosynthesis.	Fire extinguisher Preservative for fruits Making bread To manufacture urea Carbonated water Nitrogenous fertilizers Dry ice in refrigerator
Calcium Carbide (CaC_2)	Prepared by heating CaO and Coke	Greyish black solid	To manufacture graphite and hydrogen To prepare acetylene gas for welding.
Carbon disulphide (CS_2)	Directly prepared from C and S	Colourless Inflammable Highly poisonous gas	Solvent for sulphur To manufacture rayon Fungicide Insecticide
Calcium Carbonate ($CaCo_3$)	Prepared by passing CO_2 into the solution of slaked lime	Crystalline solid Insoluble in water	Antacid
Sodium bicarbonate ($NaHCO_3$)	Formed by NaOH with carbonic acid (H_2CO_3)	White Crystalline substance Sparingly soluble in water	Preparation of sodium carbonate. Backing powder Antacid

Activity 1

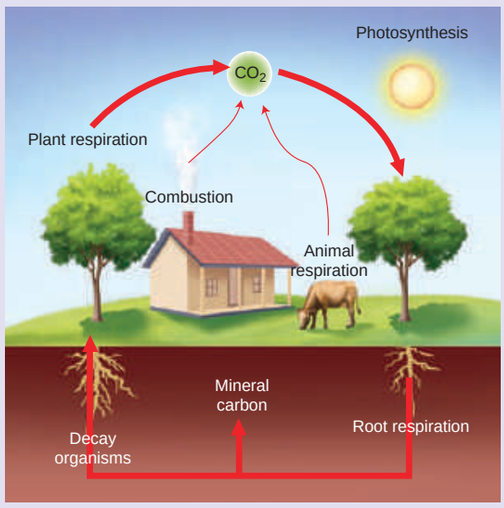
With the help of your teacher, try to classify the following compounds and materials and, fill in the table accordingly.

HCN, CO_2, Propane, PVC, CO, Kerosene, LPG, Coconut oil, Wood, Perfume, Alcohol, Na_2CO_3, $CaCO_3$. MgO, Cotton, Petrol.

Inorganic	Organic

Carbon cycle

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, geosphere, hydrosphere and atmosphere of the Earth. Carbon is the main component of biological compounds as well as a major component of many minerals such as limestone. Along with the nitrogen cycle and the water cycle, the carbon cycle comprises a sequence of events that are key to make Earth capable of sustaining life.



4.3 Special Features of Carbon

The number of carbon compounds known at present is more than 5 million. Many newer carbon compounds are being isolated or prepared every day. Even though the abundance of carbon is less, the number of carbon compounds alone is more than the number of compounds of all the elements taken together. Why is it that this property is seen in carbon and in no other elements? Because carbon has some unique features such as:

- Catenation
- Tetra valency
- Multiple bonds
- Isomerism
- Allotropy

GAHM2C

4.3.1 Catenation

Catenation is **binding of an element to itself or with other elements through covalent bonds** to form open chain or closed chain compounds. Carbon is the most common element which undergoes catenation and forms long chain compounds. Carbon atom links repeatedly to itself through covalent bond to form linear chain, branched chain or ring structure.

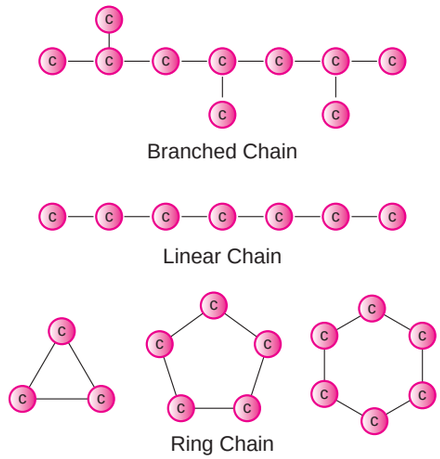


Figure 4.1 Catenation in carbon

This property of carbon itself is the reason for the presence of large number of organic carbon compounds. So organic chemistry essentially deals with catenated carbon compounds.

For example, Starch and Cellulose contain chains of hundreds of carbon atoms. Even plastics what we use in our daily life are macromolecules of catenated carbon compounds.

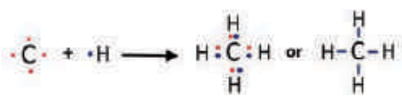
Activity 2

Ask the students to form human chain like catenated carbon compounds of linear, branched and ring structure.

4.3.2 Tetravalency

Another versatile nature of carbon is its tetravalency. The shell electronic configuration of carbon is 2,4 (Atomic no: 6). It has four electrons in its outermost orbit. According to Octet Rule, carbon requires four electrons to attain nearest noble gas (Neon) electronic configuration. So carbon has the tendency to share its four electrons with other atoms to complete its octet. This is called its **tetravalency.** Thus carbon can form four covalent bond with other elements.

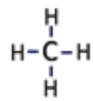
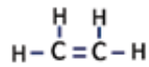
For example, in methane, carbon atom shares its four valence electrons with four hydrogen atoms to form four covalent bonds and hence tetravalent.



4.3.3 Multiple Bonds

As seen above, the tetravalent carbon can form four covalent bonds. With this tetravalency, carbon is able to combine with other elements or with itself through **single bond, double bond and triple bond**. As we know, the nature of bonding in a compound is the primary factor which determines the physical and chemical characteristics of a compound. So the ability of carbon to form multiple bonds is the main reason for the formation of various classes of carbon compounds. Table 4.2 shows one of such classes of compounds called **'hydrocarbons'** and the type of bonding in them.

Table 4.2 Hydrocarbon

Type of bond	Example	Class of the compound
Single Bond	 Methane	**Alkane**
Double Bond	 Ethene	**Alkene**
Triple Bond	H-C ≡ C-H Ethyne	**Alkyne**

When one or more hydrogen in hydrocarbons is replaced by other elements like O, N, S, halogens, etc., a variety of compounds having different functional groups are produced. You will study about them in your higher class.

4.3.4 Isomerism

Isomerism is another special feature of carbon compounds especially found in catenated organic compounds. Let us consider the molecular formula of an organic compound C_2H_6O. Can you name the compound? You can't. Because the molecular formula of an organic compound represents only the number of different atoms present in that compound. It does not tell about the way in which the atoms are arranged and hence its structure. Without knowing the structure, we can't name it.

A given molecular formula may lead to more than one arrangement of atoms. Such compounds are having different physical and chemical

properties. This phenomenon in which the **same molecular formula may exhibit different structural arrangement** is called isomerism. Compounds that have the same molecular formula but different structural formula are called isomers (Greek, isos = equal, meros = parts).

Illustration:

The given formula C_2H_6O is having two kinds of arrangement of atoms as shown below.

(a) CH_3-CH_2-OH (b) CH_3-O-CH_3

Both the compounds have same molecular formula but different kind of arrangements. In compound 'a', the oxygen atom is attached to a hydrogen and a carbon. It is an alcohol. Whereas in compound 'b', the oxygen atom is attached to two carbon atoms and it is an **ether**. These compounds have different physical and chemical properties. You will study about isomerism in detail in higher classes.

4.3.5 Allotropy

Allotropy is a property by which an element can exist in more than one form that are physically different and chemically similar. The different forms of that element are called its allotropes. Look at the materials given below. They are charcoal, graphite and diamond.

Are they equally hard? Are they cost same? Definitely not. Diamond is shiny, costliest and hardest of all. Charcoal and graphite are soft and dark. But chemically they are all similar. Yes. They are made of only carbon. They are called allotropes of carbon.

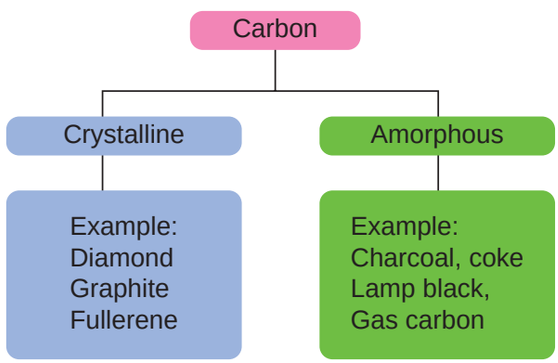
Think yourself:

One gram of diamond costs in thousands where as a kilogram of charcoal costs less than hundred. Even though both are chemically similar, why does diamond cost more?

Why do elements show allotropy?

The main reason for the existence of allotropes of an element is its method of formation or preparation.

Carbon exists in different allotropic forms and based on their physical nature they are classified as below.




Charcoal


Graphite


Diamond

Figure 4.2 Allotropes of carbon

(a) Crystalline forms of Carbon

Diamond:

- In diamond, each carbon atom shares its four valence electrons with four other carbon atoms forming four covalent bonds.
- Here the atoms are arranged in repeated **tetrahedral** fashion which leads to a t**hree dimensional structure accounting** for its hardness and rigidity.

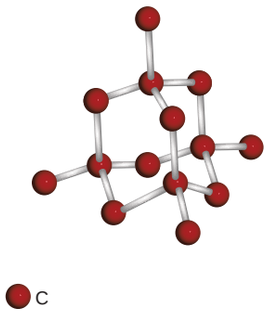


Figure 4.3 Structure of Diamond

Graphite:

- In graphite, each carbon atom is bonded to three other carbon atoms through covalent bonds in the same plane.

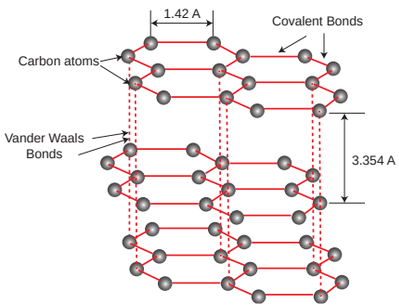


Figure 4.4 Structure of Graphite

- This arrangement forms hexagonal layers which are held together one over other by weak Vander Waals forces.
- Since the layers are held by weak forces, graphite is softer than diamond.

More to Know

Graphene is most recently produced allotrope of carbon which consists of honeycomb shaped hexagonal ring repeatedly arranged in a plane. Graphene is the thinnest compound known to man at one atom thick. It is the lightest material known (with 1 square metre weighing around 0.77 milligrams) and the strongest compound discovered (100-300 times stronger than steel). It is a best conductor of heat at room temperature. Layers of graphene are stacked on top of each other form graphite, with an inter planar spacing of 0.335 nanometres. The separate layers of graphene in graphite are held together by Vander Waals forces.

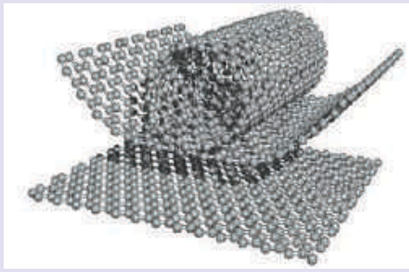


Table 4.3 Difference between Diamond and Graphite

Diamond	Graphite
Each carbon has four covalent bonds.	Each carbon has three covalent bonds.
Hard, heavy and transparent.	Soft , slippery to touch and opaque.
It has tetrahedral units linked in three dimension.	It has planar layers of hexagon units.
It is non-conductor of heat and electricity.	It is conductor of heat and electricity.

Fullerene:

❖ The third crystalline allotrope of carbon is fullerene. The best known fullerene is **Buckminster fullerene,** which consists of 60 carbon atoms joined together in a series of 5- and 6- membered to form spherical molecule resembling a soccer ball. So its formula is C_{60}.

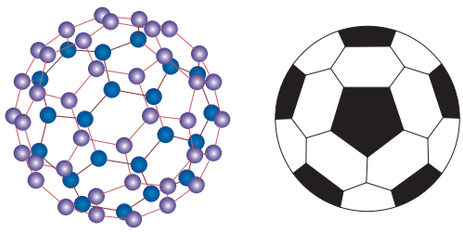


Figure 4.5 Structure of Fullerene

❖ This allotrope was named as **Buckminster fullerene** after the American architect Buckminster **fuller**. Because its structure remembered the framework of **dome shaped halls** designed by Fuller for large international exhibitions, it is called by the pet name **Bucky Ball**. A large family of fullerenes exists, starting at C_{20} and reaching up to C_{540}.

(b) Amorphous forms of carbon

In amorphous form of carbon, carbon atoms are arranged in random manner. These form of carbon are obtained when wood is heated in the absence of air. Table 4.4 enlists some amorphous forms of carbon and their features.

Table 4.4 Preparation, nature and uses of amorphous form of carbon

Amorphous Form	Preparation	Nature	Uses
Charcoal	Prepared from various sources like wood, bone and sugar. Types: wood charcoal bone charcoal, sugar charcoal.	Porous black solid Huge surface area due to porosity	Wood charcoal: Excellent household fuel, as gun powder, reducing agent in metallurgy Bone charcoal: To remove colour in sugarcane juices Sugar charcoal: Extracting metal from oxides
Lamp black	Prepared by burning mustard oil, turpentine oil and petroleum in the absence of oxygen	Greyish black porous solid	Household fuel As reducing agent in the extraction of metals like iron, copper and lead To manufacture graphite and calcium carbide. To manufacture water gas and producer gas.
Coke	Prepared by heating coal in the absence of air at 1300°C. Coal gas is obtained as a biproduct.	Greyish black porous solid.	Household fuel, As reducing agent in the extraction of metals like iron, copper and lead, To manufacture graphite and calcium carbide. To manufacture water gas and producer gas.
Gas Carbon	Prepared by destructive distillation of coal. Thermal vaporization of coal on condensation produces a grey solid.	Dull grey solid. Good conductor of electricity.	Making electrode in dry cell.

Activity 3

- Take a football since it resembles to Buckminster fullerene.
- Count how many hexagonal and pentagonal panels are in it. Every corner is considered as carbon.
- Compare your observation with fullerene and discuss with your friends.

4.4 Physical properties of Carbon and its compounds

- ❖ Carbon is a non-metal found in various allotropic forms from soft powder to hard solid.
- ❖ All the allotropic forms of carbon are solids whereas its compounds exist in solid, liquid and gaseous state.
- ❖ Amorphous forms of carbon and graphite are almost black in colour and opaque. Diamond is transparent and shiny.
- ❖ Its amorphous forms have low melting and boiling point compared to crystalline forms.
- ❖ Carbon is insoluble in water and other common solvents. But some of its compounds are soluble in water and other solvents. e.g., Ethanol, CO_2 are soluble in water.

4.5 Chemical Properties of Carbon and its compounds

Elemental carbon undergoes no reaction at room temperature and limited number of reactions at elevated temperatures. But its compounds undergo large number of reactions even at room temperature.

Oxidation – (Reaction with oxygen)

Carbon combines with oxygen to form its oxides like carbon monoxide (CO) and carbon dioxide (CO_2) with evolution of heat. Organic carbon compounds like hydrocarbon also undergo oxidation to form oxides and steam with evolution of heat and flame. This is otherwise called Burning.

$$2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)} + \text{heat}$$

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + \text{heat}$$

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{heat}$$

Reaction with steam

Carbon reacts with steam to form carbon monoxide and hydrogen. This mixture is called water gas.

$$C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)}$$

DO YOU KNOW?

Carbon monoxide is a toxic oxide gas of carbon. When fuels undergo incomplete combustion (insufficient supply of oxygen), it results in the formation of carbon monoxide. It is released into the atmosphere from various sources like vehicle fuels, domestic fuels, industries, furnaces, etc. Cigarette smoking also is a source of carbon monoxide.

How toxic carbon monoxide is?

It is a colourless, odourless toxic gas. When people exposed to CO, it enters into human body through breathing and affects the function of haemoglobin. CO displaces oxygen from haemoglobin thereby stops its function (supply of oxygen to the parts of body) leading to death.

Reaction with sulphur

With sulphur, carbon forms its disulphide at high temperature.

$$C_{(s)} + S_{(g)} \rightarrow CS_{2(g)}$$

Reaction with metals

At elevated temperatures, carbon reacts with some metals like iron, tungsten, Titanium, etc. to form their carbides.

$$W_{(s)} + C_{(g)} \rightarrow WC_{(s)}$$

4.6 Carbon compounds in everyday life

It is impossible to think of our daily life without carbon compounds. Over time, a large number of carbon compounds have been developed for the improvement of our lifestyle and comfort. They include carbon-based fuels, carbon nanomaterials, plastics, carbon filters, carbon steel, etc.

Even though carbon and its compounds are vital for modern life, some of its compounds like CO, cyanide and certain types of plastics are harmful to humans. In the following segment, let us discuss the role of plastics in our daily life and how we can become aware of the toxic chemicals that some plastics contain.

4.7 Plastics – Catenated long chain carbon compounds

Plastics are a major class of catenated organic carbon compounds. They are made from long chain organic compounds called 'polymer resins' with chemical additives that give them different properties. Different kinds of polymers are used to make different types of plastics. Plastics are everywhere. They are convenient, cheap and are used in our everyday life. Plastics have changed the way we live. They have helped improve health care, transport and food safety. Plastics have allowed many breakthroughs in technology such as smartphones, computers and the internet. It is clear that plastic has given our society many benefits. But these benefits have come at a cost.

4.7.1 Drawbacks of plastics

- Plastics take a very long time to fully break down in nature.
- The microbes that break down plastic are too few in nature to deal with the quantity of plastics we produce.
- A lot of plastic does not get recycled and ends up polluting the environment.
- Some types of plastics contain harmful chemical additives that are not good for human health.
- Burning of plastics releases toxic gases that are harmful to our health and contribute to climate change.
- One-time use and throwaway plastics end up littering and polluting the environment.

In order to know which plastics are harmful, you will need to learn the secret 'language' of plastics (resin codes).

Plastics in the environment break down into pieces that are smaller than 5mm in diameter. Dangerous pollution in the ocean sticks to microplastics making them harmful to marine life (fish and shrimp) who mistake them as their food.

4.7.2 Identifying different types of plastics

(a) The resin codes

Look at the following pictures.

Figure 4.6 Plastic items used in daily life

One is a plastic sachet in which milk is distributed to consumers and the other is a plastic food container. Observe the code shown on it (circled). Do you know what this code means? It is called a '**resin code**'. The resin code represents the type of polymer used to make the plastic.

(b) Need for resin codes

Plastics should be recycled or disposed of safely. Certain types of plastics should be avoided so that they do not end up polluting the environment or harming our health. Each plastic is composed of a different polymer or set of molecules. Different molecules do not mix when plastics are recycled, it is like trying to recycle paper and glass together. For this reason, they need to be separated. The resin codes of plastics were designed in 1988 and are a uniform way of classifying the different types of plastic which help recyclers in the sorting process.

(c) How to find the resin code on plastic items

The secret resin codes are shown as **three chasing arrows in a triangle**. There is a **number in the middle or letters under the triangle** (an acronym of that plastic type). This is usually difficult to find. It can be found on the label or bottom of a plastic item.

Figure 4.7 Resin codes

The resin codes are numbered from 1 to 7. Resin codes #1 to #6 each identify a certain type of plastic that is often used in products. Resin code #7 is a category which is used for every other plastic (since 1988) that does not fit into the categories #1 to #6. The resin codes look very similar to the recycling symbol, but this does not mean all plastics with a code can be recycled. The Table 4.5 shows information of various resin codes.

Activity 4

- Collect various plastic materials we use in our day-to-day life and try to find the resin code.
- Once you have found an everyday plastic item with a resin code – ask yourself the following questions.

What plastic resin codes did you find?
Is this plastic item used to store or serve food or drinks?
Do these types of plastics contain harmful chemicals?
To find out these answers, please refer Table 4.5, Plastic Resin Code Chart. Prepare a report of your observations.

Table 4.5 Plastic Resin Code Chart

PLASTIC RESIN CODE CHART

Plastic resin codes can be found on the label or bottom of most plastic items.
It is a number or acronym found in the middle of a chasing arrow triangle.
There may be other numbers or letters on the plastic items, but these are not resin codes.

RESIN CODE	OTHER NAMES	COMMON ITEMS	ABOUT
01 PET	PETE, Polyester	Mineral water or soft drink bottles and plastic jars.	This plastic is designed to be used only ONCE. Reusing PET plastic can release a chemical additive called antimony which is not good for your health.
02 HDPE	PEHD	Bottles (shampoo, detergent, etc.), toys, plastic bags and waste bins.	Considered one of the safer plastics. It is light, very strong and widely recycled.
03 PVC	V, Vinyl	Raincoats, ring binders, shoes, floating pool toys and shiny prints on backpacks.	The most toxic plastic. Do the smell test: some PVC has a new shoe or new car smell. Avoid this type of plastic where possible.
04 LDPE	PELD, LLDPE	Food packaging, plastic bags, food storage containers and plastic coating on the inside of paper cups.	Considered one of the safer plastics. It is very flexible and soft but strong.
05 PP		Bottle caps, straws, food containers, hard pencil cases and plastic chairs.	Considered one of the safer plastics. It feels waxy or greasy. It is light and hard but scratches easily.
06 PS	Thermocol, EPS, XPS and HIPS	Pens, rulers, foam, packaging, toys, disposable cups, plates and cutlery.	One of the unsafe plastics as it has harmful chemicals. Thermocol is very light weight (95% air) and often ends up polluting the oceans.
07 OTHER	Polycarbonate (PC), Acrylonitrile Butadiene Styrene (ABS), acrylic (AC), bioplastics, nylon, polyurethane (PU), etc.	PC: baby bottles, water bottles and food containers. ABS: Lego, helmets, and kitchen appliances. Acrylic: phone screens and paints. Bioplastics: plastic bags and tableware. Nylon: clothes and toothbrush bristles. PU: mattress foam and shoe soles.	This code includes all plastic types that do not fit into the resin codes 1-6. PC and ABS are two of the unsafe plastics and are considered toxic. When you see a #7 plastic try to know more before buying and using it.
NO CODE	Does not have a resin code or an acronym	Can be any plastic item.	The company did not follow the rules and mark what type of plastic was used. It could be harmful but you do not have the information to know for sure. Avoid using plastic without a resin code.

(d) Where will the resin code be shown on plastic items?

Flip a plastic item to find the resin code on the bottom.

Sometimes the bottom of plastic item will only have an acronym or the full name of that plastic type.

If you do not find it on the bottom, search for the code on the label.

Some plastics do not have a code. The company did not follow the rules and you do not know if it is safe to use.

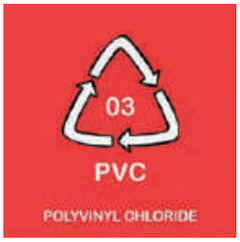
4.7.3 Harmful effects of plastics

Plastics in our everyday life can be harmful for two reasons. The first reason is that some types of plastic contain chemicals that are harmful to our health. The second reason is that a lot of plastics are designed to be used just one time. This use and throwaway plastic causes pollution to our environment.

(a) Harmful plastics

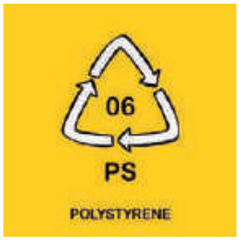
There are three types of plastic that use toxic and harmful chemicals. These chemicals are added to plastics to give them certain qualities such as flexibility, strength, colour or fire and UV resistance. The three unsafe plastics are PVC (resin code #3), PS (resin code #6 also commonly called Thermocol) and PC/ABS (resin code #7).

PVC – Polyvinyl Chloride plastics



- Heavy metals (cadmium & lead) are added to PVC.
- Phthalates (chemical additive) copy our hormones.
- Burning PVC releases dioxins (one of the most toxic chemicals known to humans).

PS **– Polystyrene plastics**



- Styrene is a building block of this plastic and may cause cancer.
- It takes very long time to break-down (100- 1 million years).
- Higher amounts of toxic styrene leak into our food and drinks when they are hot or oily.

PC – Polycarbonate plastics

- PC plastic contains Bisphenol A (BPA).
- BPA leaks out of PC products used for food and drinks.
- BPA increases or decreases certain hormones and changes the way our bodies work.

ABS – Acrylonitrile Butadiene Styrene

- Styrene causes problems for our eyes, skin, digestive system and lungs.
- Brominated Flame Retardants (BFRs) are often added.
- Studies show toxic chemicals leak from this plastic.

(b) One-time use plastic

Use and throwaway plastics cause short and long-term environmental damage. Half of all the plastic made today is used for throwaway plastic items. These block drains and pollute water bodies. One-time use plastic causes health problems for humans, plants and animals. Some examples are plastic carry bags, cups, plates, straws, water pouches, cutlery and plastic sheets used for food wrapping.

Figure 4.8 One-time use plastic items

These items take a few seconds to be made in a factory. You will use them for a very short time. Once you throw them away, they can stay in our environment for over a 1,000 years causing plastic pollution for future generations.

We need rules and laws to protect people and the environment from plastic pollution.

More to Know

The impacts of one-time use and throwaway plastics on animals

One-time use and throwaway plastics can cause harm to animals. In the past, restaurants and teashops used banana leaves as a plate and for takeaway food. This was a good source of food for cows that would eat the leftover food and banana leaves, making them the perfect recyclers. They recycled this waste and in return provided us with nutritious milk and valuable cow dung as a fertiliser. Since plastics have been introduced, the banana leaf has been replaced by a plastic sheet (commonly called a 'cut-piece') on top of plates for food. When these are thrown away animals such as cows smell the leftover food. When they try to eat it, they eat the plastic by accident. The chemical composition of plastic does not allow it to be broken down by the cow's digestive system. Instead the plastic gets stuck in the rumen (stomach) of a cow, occupying precious space and reducing the ability of a cow to digest nutrients and provide nutritious milk and valuable cow dung for society.

- How can you make sure that cows do not eat your leftover food in plastic packaging?
- How will the ban on one-time use and throwaway plastics as of 1st January 2019 in Tamil Nadu help animals such as cows?
- What can you do in your day-to-day life to protect animals from the dangers of plastics?

4.8 New rules to make Tamil Nadu plastic free

As we know, the Government of India is progressively taking various legal initiatives to stop plastic pollution by making some provisions and amendments in the Environment (Protection) Act 1988. With reference to this act, Government of Tamil Nadu has taken a step forward to ban the usage of some kind of plastic items (Environment and Forests Department, T.N. G.O. No: 84, dated 25/06/2018).

As per the government order cited above, the Tamil Nadu Government has banned the usage of one-time use and throwaway plastics from 1st January 2019. This excellent legislation is designed to protect Tamil Nadu from plastic pollution.

Rules which ban the production, storage, supply, transport, sale and distribution of one-time use plastics are extremely effective. They are successful because they target all sections of society– manufacturer, supplier, shopkeeper and customer. This progressive initiative taken by the State of Tamil Nadu leads by example for the rest of the nation.

Please find below some key aspects of the new rules along with science-based facts why these items have been banned in Tamil Nadu.

If we do not change our habits, one study estimates that our oceans will have more plastic than fish (in weight) by 2050.

4.8.1 Banned items

Plastic carry bags

- Globally we use 2 million plastic bags each minute.
- 97% of plastic bags do not get recycled.
- Animals eat plastic bags by accident as they contain food. A cow was found with over 70 kilos of plastic in its stomach.

Plastic plates

- Dirty plastics (like a used plate) are difficult to recycle.
- Most one-time use plates are made from Polystyrene (resin code # 6) which is harmful to your health.
- Plates will be used for just 20 minutes but stay in the environment for over a 1,000 years.

Water pouches

- Water pouches are often littered, increasing plastic pollution.
- The blue print (ink) on the clear plastic pouch decreases the recycling value.
- Once a water pouch is used, it is difficult to recycle as it contains leftover water and gets covered in dirt.

Plastic straws

- Plastic straws are too lightweight and small to be recycled.
- Straws are one of the top 10 items which are found in the plastic pollution in oceans.
- 90% of seabirds have ingested plastics such as straws.

Plastic sheets

- Plastic sheets used on top of plates get dirty and cannot be recycled.
- More chemicals leak from plastic into food when it is hot, spicy or oily.
- Animals such as cows, goats, and dogs eat plastic by accident because it smells like food.

DO YOU KNOW?

A study found that one-time use and throwaway plastic items such as cups, plates, spoons and straws were among the top 10 plastic items found in garbage washed up from the ocean.

4.9 Role of students in the prevention of plastic pollution

Plastics affect all of us. Change starts with you and your family. The first step to change something is to know why you need to change. Equipped with the right knowledge, you can start to take small steps to protect yourself, your family and beautiful Tamil Nadu.

You play a very important role and have the power to minimise plastic pollution. You can start today by reflecting on the plastic you use in your everyday life.

Ask yourself, is this plastic safe or harmful plastic? If it is not a harmful plastic type, is it a one-time use plastic item? These questions and the science-based knowledge will help you to reduce unnecessary plastic pollution.

4.9.1 What can you do to prevent plastic pollution?

- As a student, you can share your scientific knowledge on plastics and their effects with your parents, relatives and friends to make them aware of plastic pollution.
- You can help by teaching them how to avoid harmful plastics by searching for the resin codes.
- You can educate them about the new rules and how important it is to stop one-time use plastics.

4.9.2 Practice in your daily life

- Do not litter the environment by throwing plastic items.
- Do not use Thermocol (resin code #6 PS) for your school projects.
- Do not use one-time use or throwaway plastics like plastics bags, tea cups, Thermocol plates and cups, and plastic straws.
- Do not burn plastics since they release toxic gases that are harmful to our health and contribute to climate change.
- Burning PVC plastic releases dioxins which are one of the most dangerous chemicals known to humans.
- Do not eat hot or spicy food items in plastic containers.
- Segregate your plastic waste and hand this over to the municipal authorities so that it can be recycled.
- Educate at least one person per day about how to identify the resin codes and avoid unsafe plastics (resin code #3 PVC, #6 PS and #7 ABS/PC).

Let us join together to make our nation pollution free.

Points to Remember

- Carbon is an inseparable chemical entity associated with living things.
- Carbon chemistry is also called as living chemistry.
- Carbon is found both in free state as well as combined state in nature.
- Friedrich Wohler is called Father of Modern Organic Chemistry.
- Catenation, tetra valency, multiple bonds, isomerism and allotropy are the unique features of carbon.
- Carbon atom links repeatedly to itself through covalent bond to form linear chain, branched chain or ring structure.
- Carbon combines with other elements or with itself through single bond, double bond and triple bond.
- Charcoal, graphite and diamond are the allotropes of carbon.
- In diamond atoms are arranged in repeated tetrahedral fashion.
- In graphite, each carbon atom is bonded to three other carbon atoms through covalent bonds in hexagonal fashion.
- Buckminster fullerene consists of 60 carbon atoms joined together in series of 5- and 6- membered to form spherical molecule resembling a soccer ball.
- Buckminster fullerene is named after the American architect Buckminster fuller.
- All the allotropic forms of carbon are solids whereas its compounds exist in solid, liquid and gaseous state.
- Carbon monoxide is a toxic oxide gas of carbon. When fuels undergo incomplete combustion (insufficient supply of oxygen), it results in the formation of carbon monoxide.
- The resin code represents the polymer used in making of plastics. The resin codes are numbered from 1 to 7.
- The three unsafe plastics are PVC (Polyvinyl chloride), PS (Polystyrene) and PC (Polycarbonate) / ABS (Acrylonitrile Butadiene Styrene).
- One-time use plastic causes health problems for humans, plants and animals.
- Government of Tamil Nadu has taken a step forward to ban the usage of some kind of plastics items (Environment and Forests Department, T.N. G.O. No: 84, dated 25/06/2018).
- Plastic carry bags, cups, plates, straws, water pouches, cutlery and plastic sheets used for food wrapping are one – time use plastics.

A-Z GLOSSARY

Allotropes	Different forms of an element.
Allotropy	Property by which an element can exist in more than one form that are physically different and chemically similar.
Carbon cycle	It is the biogeochemical cycle by which carbon is exchanged among the biosphere, geosphere, hydrosphere and atmosphere of the Earth.

Catenation	It is binding of an element to itself or with other elements through covalent bonds to form open chain or closed chain compounds.
Harmful plastics	Plastic that use toxic and harmful chemicals.
Inorganic carbon compounds	Compounds of carbon obtained from non-living matter.
Isomerism	Phenomenon in which the same molecular formula may exhibit different structural arrangement.
Isomers	Compounds that have the same molecular formula but different structural formula.
One-time use plastic	Use and throwaway plastics.
Organic carbon compounds	Compounds of carbon obtained from living organisms.
Plastics	Major class of catenated organic carbon compounds made from liquid polymers called 'resins' added with some additives.
Tetravalency	Tendency of carbon to share its four electrons with that of other atoms to complete its octet.

TEXTBOOK EVALUATION

GB6I3Z

I. Choose the correct answer.

1 A phenomenon in which an element exists in different modification in same physical state is called

(a) Isomerism (b) Allotropy
(c) Catenation (d) Crystallinity

2 Number of free electron(s) in each carbon of graphite is

(a) one (b) Two
(c) Three (d) Four

3 The carbon atoms in fullerene are arranged in mixed

(a) Tetragon and Pentagon
(b) Pentagon and Hexagon
(c) Hexagon and Heptagon
(d) Heptagon and Octagon

4 Carbon forms large number of organic compounds due to

(a) Allotropy (b) Isomerism
(c) Tetravalency (d) Catenation

5 Diamond is not a good conductor of electricity because

(a) it is very hard
(b) it has no free electron
(c) its structure is uniform
(d) it is insoluble in water

6 Which of the following does not contain double bond

(a) CO_2 (b) C_2H_4
(c) HCl (d) O_2

7 Which of the following is highly toxic?

(a) Carbon dioxide
(b) Carbon monoxide
(c) Calcium carbonate
(d) Sodium bicarbonate

8 Raagav brings his lunch every day to school in a plastic container which has resin code number 5. The container is made of

(a) Polystyrene (b) PVC
(c) Polypropylene (d) LDPE

9 Plastics made of Polycarbonate (PC) and Acrylonitrile Butadiene Styrene (ABS) are made of resin code _____

(a) 2 (b) 5 (c) 6 (d) 7

10 Which of the following plastic items are banned by the Government of Tamil Nadu as of 1st January 2019?

(a) Plastic sheets
(b) Plastic tea cups
(c) Plastic water packets
(d) All the above

11 Graphite is used as lubricant in machines because

(a) it is good conductor of electricity
(b) it is made of slippery layers and has high melting point
(c) it has high density
(d) it is strong and soft

12 The lead pencil contains

(a) Graphite (b) Diamond
(c) Lead (d) Charcoal

13 Graphene is one atom thick layer of carbon obtained from

(a) Diamond (b) Fullerene
(c) Graphite (d) Gas Carbon

14 Plastic resin codes are shown as three chasing arrows in a_____ with a number in the middle or letters (an acronym of that plastic type).

(a) Logo (b) Recycling symbol
(c) Square (d) Triangle

15 The legal measures to prevent plastic pollution come under the _____ Protection Act 1988.

(a) Forest (b) Wildlife
(c) Environment (d) Human Rights

II. Fill in the blanks.

1. _____ named carbon.
2. Buckminster Fullerene contains _____ carbon atoms.
3. Compounds with same molecular formula and different structural formula are knows as _____.
4. Different methods of formation of carbon is the main reason for its _____.
5. There are _____ plastic resin codes.

III Match the following

Alkyne	-	Bucky Ball
Andre Geim	-	Oxidation
C_{60}	-	Graphene
Thermocol	-	Triple bond
Burning	-	Polystyrene

IV Answer very briefly.

1. How many valence electrons are there in carbon?
2. Who is called 'Father of Modern Organic Chemistry'?
3. Which three resin codes are unsafe?

IV. Answer in brief.

1. Differentiate graphite and diamond
2. What are saturated and unsaturated compounds called?

3. Carbon do not form ionic compounds. Why?
4. What is the valency of carbon in carbon monoxide?
5. Why are one-time use and throwaway plastics harmful?

V. Answer in detail.

1. What is catenation? How does carbon form catenated compounds?
2. What are the chemical reactions of carbon?
3. Name the three safer resin codes of plastics and describe their features.

VI. HOTS

1. Why do carbon exist mostly in combined state?
2. When a carbon fuel burns in less aerated room, it is dangerous to stay there. Why?
3. Explain how dioxins are formed, which plastic type they are linked to and why they are harmful to humans.
4. Yugaa wants to buy a plastic water bottle. She goes to the shop and sees four different kinds of plastic bottles with resin codes 1, 3, 5 and 7. Which one should she buy? Why?

VII. Answer the following by rearranging the jumbled letters.

1. It is the hardest allotrope of carbon. mnodaid Ans:_____
2. Organic compounds having double bond between carbon atoms are
   knelaes Ans: _____
3. Reaction of carbon with oxygen gives
   osdiexs Ans: _____
4. In this molecule, carbon is attached with four hydrogen atoms.
   emathen Ans: _____
5. Carbon combines with other elements through _____ bond.
   lnaocvet Ans: _____
6. It is used as gun powder.
   ocahrcla Ans: _____
7. Plastics made of _____ are represented by resin code #6.
   sytlopynere Ans: _____
8. One-time use plastics are also known as _____ plastics.
   awyrhotwa Ans: _____
9. One-time use plastics cause _____ damage.
   trnvomenialne Ans: _____
10. Expanded polystyrene is commercially known as
    mthreolco Ans: _____

REFERENCE BOOKS

1. Modern Inorganic Chemistry by R.D Madan
2. Fundamentals of Organic Chemistry by B.S.Bahl et.al
3. Organic Chemistry by Paula Bruise, 6th Edition

INTERNET RESOURCES

http://www.chemicool.com/elements/carbon.html

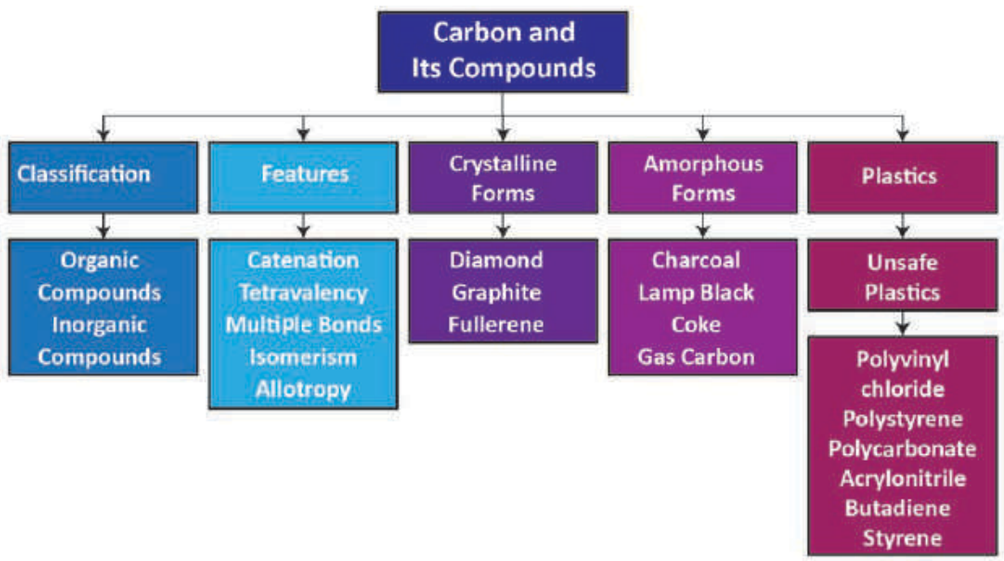
https://en.wikipedia.org/wiki/Carbon

https://courses.lumenlearning.com/introchem/chapter/allotropes-of-carbon/

https://plastics.americanchemistry.com/Plastic-Resin-Codes-PDF/

https://www.youtube.com/watch?v=8Obb982Sg84

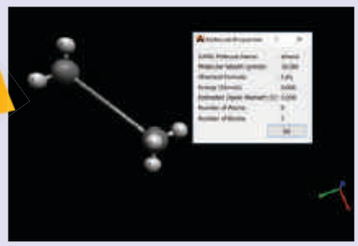
Concept Map



ICT CORNER

Experiment carbon bonding with an intuitive molecular editor and visualization tool

Carbon



Steps

- Reach the given URL to download and install the "Avogadro" cross platform application in your computer.
- Open the Avogadro application and select carbon from "Element" tab and select the available bond type "Single" or "Double" or "Triple".
- Place the mouse pointer on the black screen and click and drag the mouse to draw the carbon structure. Extend the bonding by dragging repeatedly. Build the structure of Ethane, Methane etc.
- Select "Auto Rotation" from the tools and rotate the molecular structure by dragging the mouse on the bond. To view various properties of the drawn bonding go to menu View -> Properties.


Step1


Step2


Step3


Step4

Avogadro

URL: https://avogadro.cc/ or Scan the QR Code.

*Pictures are indicative only

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