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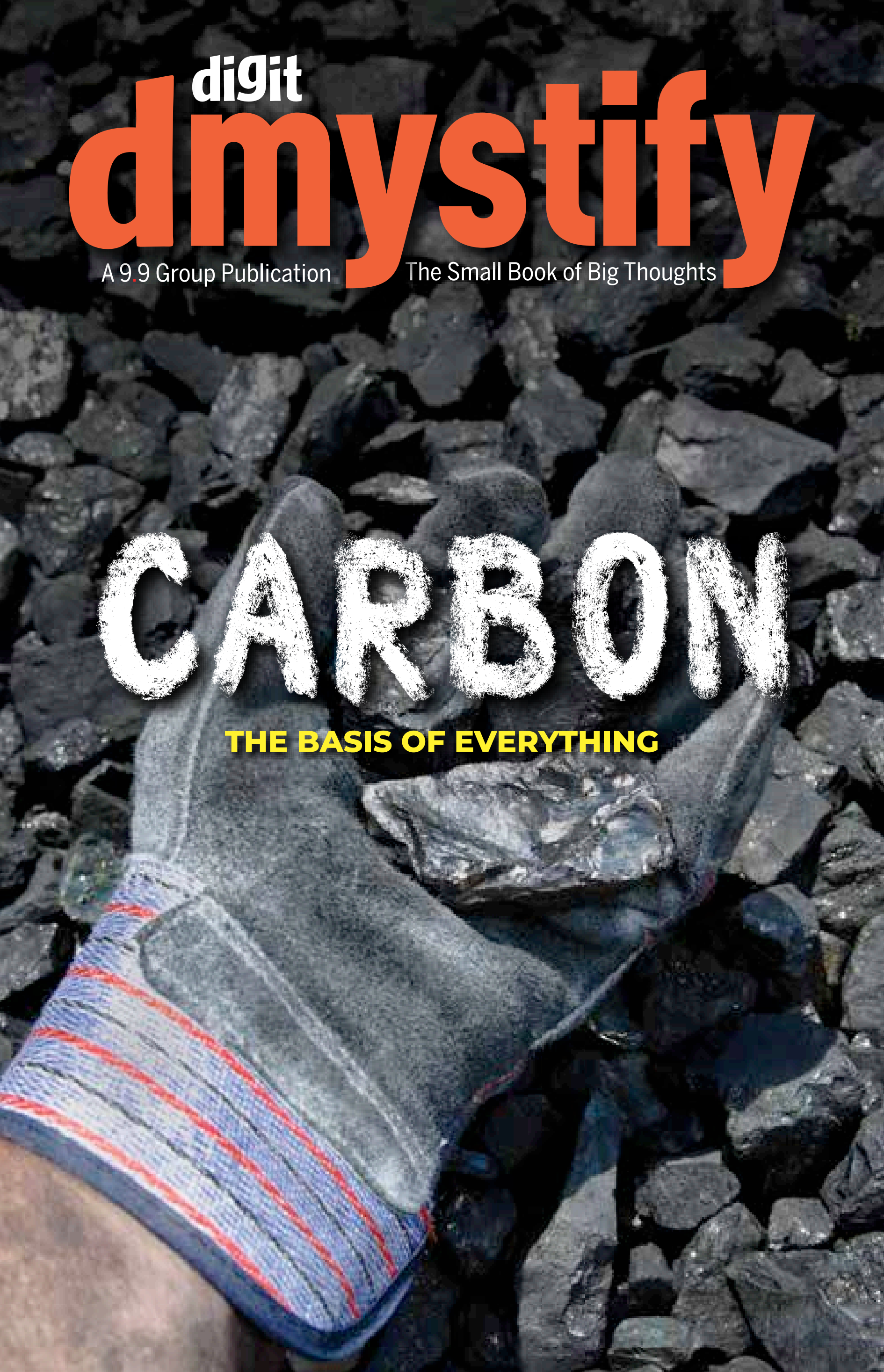
The Small Book of Big Thoughts



CARBON

THE BASIS OF EVERYTHING

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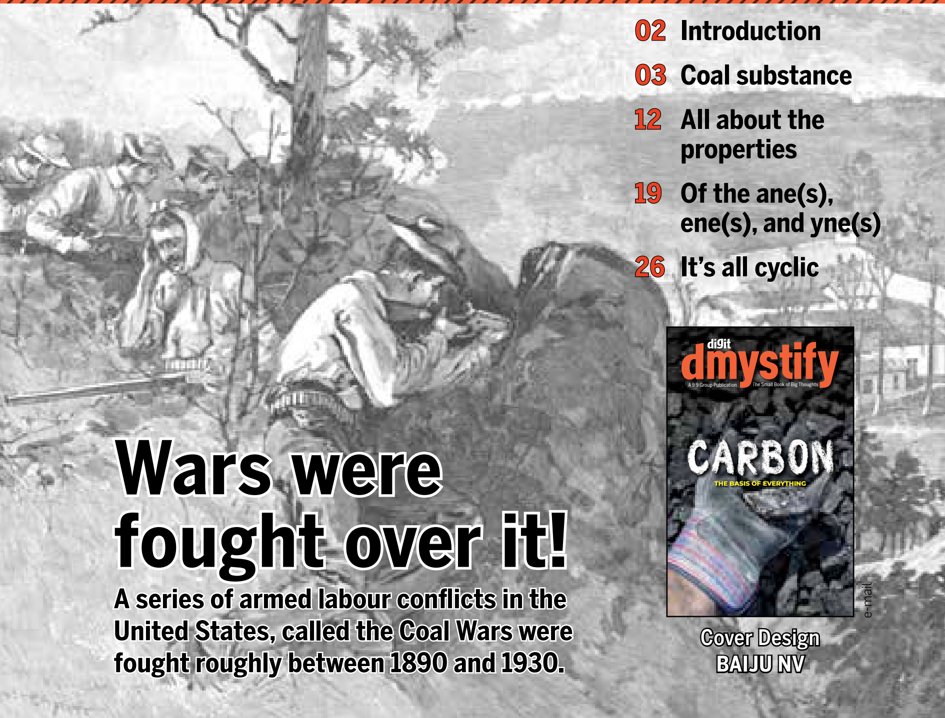
November 2022

INSIDE



Cover Design
BAIJU NV

Wars were fought over it!

A series of armed labour conflicts in the United States, called the Coal Wars were fought roughly between 1890 and 1930.

Credits

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The foundation of everything

Have you ever sat down and given a thought to what you, other life forms, and stuff around you are made of? Well, if you haven't, then take a couple of minutes and do that. We'll wait and count. 120... 119... 118... 117... 116... and time's up!

What came to your mind? If the answer was carbon, then hooray! You are on the right track, and there's a good chance that some stuff in this book may not astonish you. And, if your answer was anything other than carbon, then prepare to be amazed at every step of the way on this journey that we are going to take you on.

Carbon is literally the foundation of almost everything and concept that we have around us on this pale blue dot in the universe that we call Earth. Its presence is what makes us stand apart. So, when we found out that we hadn't covered it yet, we jumped right on to interwebs and started enhancing our knowledge on the subject.

Through the course of this book, we will talk to you about everything carbon. The science, the lore, and the everyday impact and presence of this black coloured chemical that we have almost everywhere around us.

And, as we always say, this book, for the ones who are into the world of science, there's some food for thought, and for the other's there's nothing but four chapters worth of amazing science entertainment. ■

Coal substance

That's what they call it in German, Dutch and Danish!

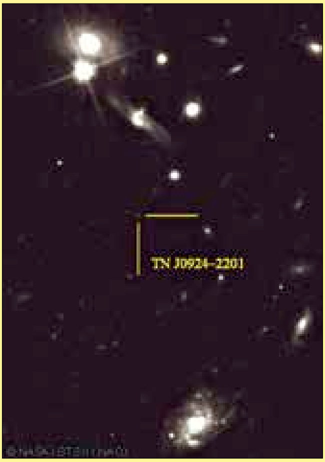
If you are someone who reads dmystify regularly, then you'd know what this chapter will be about. We will start by taking a dive into the history and the scientific origin story of carbon. We will discuss its etymology, atomic data, and other things like basic enthalpy. This will help in building a foundation which will build the pillars of knowledge for you as we progress through the chapters.

So, without wasting much time, let us start by look at the history of carbon.

The first signs

Carbon first appeared on the surface of Earth when the primitive life forms came into being. However, when talking about its presence in the universe, it has been found that the first abundant presence of carbon was first observed in the radio galaxy named – TN J0924-2201. This galaxy, which has been measured to be around 12.5 billion light years away, was first detected by a group of researchers from Ehime University and Kyoto University in Japan.

To detect the presence of carbon in abundant quantities, the team had used a Faint Object Camera and Spectro-



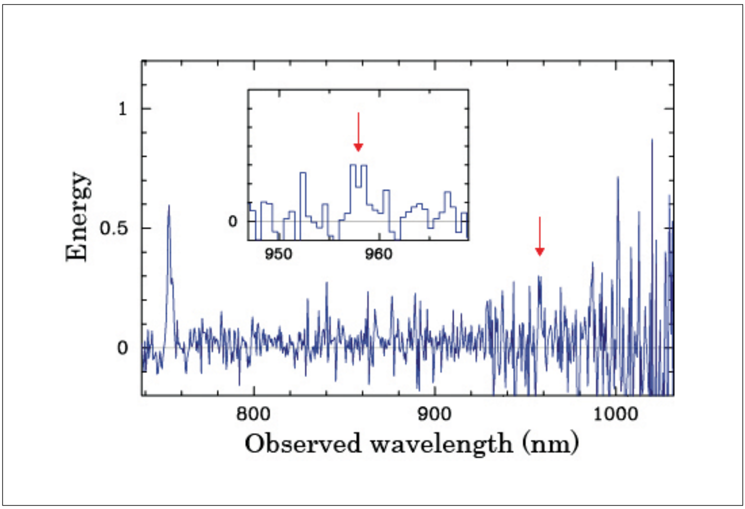
Source: Subaru Telescope

The optical image of TN J0924-2201, a very distant radio galaxy at z = 5.19, obtained by the Hubble Space Telescope

graph (FOCAS) on the Subaru Telescope to track to detect a carbon emission line (CIVλ1549).

We all know that the universe began with a bang that was so large, that we named it the "Big Bang". If you are not that familiar with this enormous explosion that is known to be the origin point of our universe, then we'd recommend you reading the dmystify that we did a few editions ago on the subject. Now, coming back to the bang.

So, when it took place, around 13.7 billion years ago, the only two known elements created were helium and hydrogen. Then as time passed, several nuclear fusion reactions took place in stars, as well as Supernovae phenomenon, contributed to the formation of a lot of elements that we find today. It is safe to assume that at some point during these reactions, carbon was first formed. And, today, its first known abundant presence has been found in the galaxy that is 12.5 billion years away.

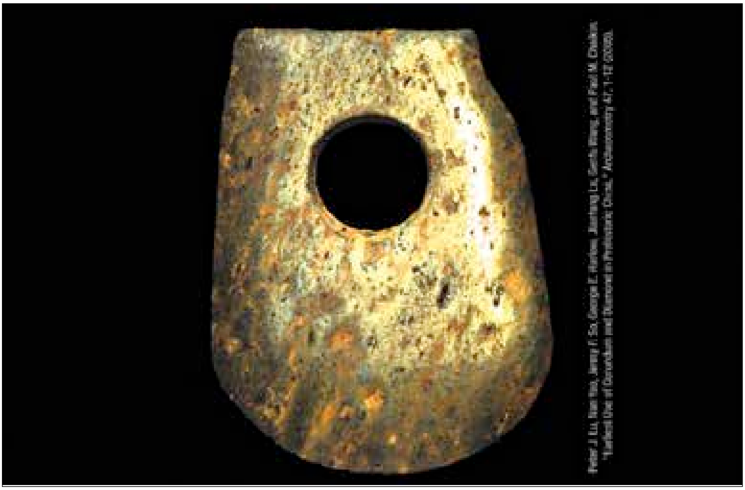


Source: Subaru Telescope

The deep optical spectrum of TN J0924-2201 obtained with FOCAS on the Subaru Telescope. The red arrows point to the carbon emission line (CIVλ1549)

As we know that carbon is the basis of all the life forms on Earth. So, when the first single celled microbes were formed on the planet to now, where we have complex multicellular beings such as us dwelling on the planet, carbon has been present. Most of Earth's carbon, which totals to around 65,500 billion metric tons, is stored in the rocks.

Humans have known about different forms of carbon for many years now. There was dominant use of soot and charcoal in the early human civilisations. In fact, the first formal



use of diamonds, which are also carbon based, dates back to about 2500 BCE in China. In Roman civilisations too, there has been documented proof of charcoal production going on. The most striking thing about that is the fact that they were using the same techniques to make charcoal as we do today. They used to heat wood in a pyramid

A page from the Diamond Sutra

that had been covered with clay to exclude air from the process of its combustion for the most part. The substance that they yielded was charcoal. A carbon-based fuel.

However, it wasn't until the year 1722, when the first use of carbon in the modern society was demonstrated. A French entomologist by the name, René Antoine Ferchault de Réaumur, in a series of experiments proved that common iron could be transformed into steel by the addition of a substance to it. We call that today, carbon. In fact, you will see different types of steel being sold under different code names, which depict the quantity of carbon that is present in it.

About 50 years later, Antonie Lavoisier, a pretty well-known chemist, was successfully able to demonstrate that the hardest substance known to man, diamonds, were made from carbon. During his experiments, he had sample of charcoal and diamond, and found out that neither of these when burnt released water, and most important, released the same amount of carbon dioxide per gram.

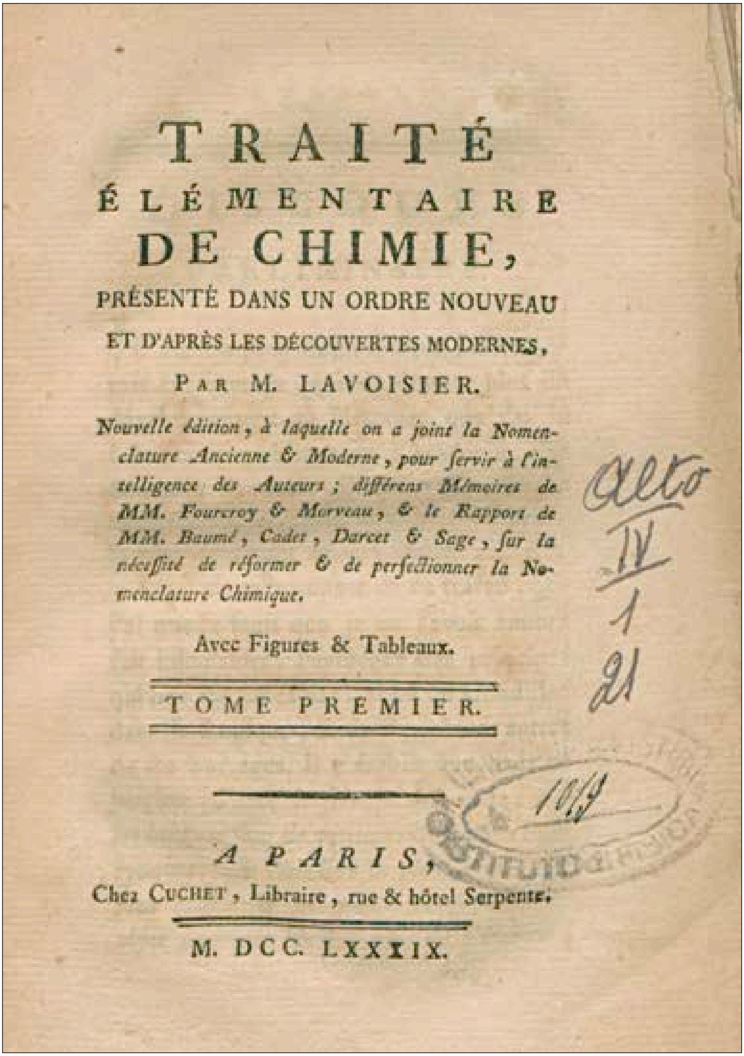
Antonie Lavoisier

As another half a decade passed, we saw another important discovery related to carbon come to life. This time it was from the labs of Carl Wilhelm Scheele, who in 1779 was successful in demonstrating that graphite, which till then had been thought to be related to lead, was in fact a form of carbon. He demonstrated that it was closer to in chemical structure and properties to charcoal, with the presence of a slight bit of iron in it.

Carl Wilhelm Scheele

This theory was further solidified by the experiments of Claude Louis Berthollet, Gaspard Monge, and C. A. Vandermonde. These scientists had successfully demonstrated that graphite, as correctly theorised by Scheele, was indeed majorly made out of carbon. They had taken notes from the experiments conducted by Lavoisier, and oxidised it in a similar way that he had done to establish the relationship between diamond and carbon.

Later, Lavoisier, in the year 1789, in his textbook "Traité élémentaire de chimie (Elementary Treatise on Chemistry)" for the first time, listed carbon as an element. Robert Boyle had suggested that for anything to be categorised as an element, one should


TRAITÉ
ÉLÉMENTAIRE
DE CHIMIE,
PRÉSENTÉ DANS UN ORDRE NOUVEAU
ET D'APRÈS LES DÉCOUVERTES MODERNES,
PAR M. LAVOISIER.

Nouvelle édition, à laquelle on a joint la Nomenclature Ancienne & Moderne, pour servir à l'intelligence des Auteurs ; différens Mémoires de MM. Fourcroy & Morveau, & le Rapport de MM. Baumé, Cadet, Darcet & Sage, sur la nécessité de réformer & de perfectionner la Nomenclature Chimique.

Avec Figures & Tableaux.

TOME PREMIER.

A PARIS,
Chez CUCHET, Libraire, rue & hôtel Serpente.
M. DCC. LXXXIX.

Traité élémentaire de chimie (Elementary Treatise on Chemistry)

not be able to break it down into simpler substances. So, when Lavoisier published his work, he characterised carbon as “oxidizable and acidifiable nonmetallic element”.

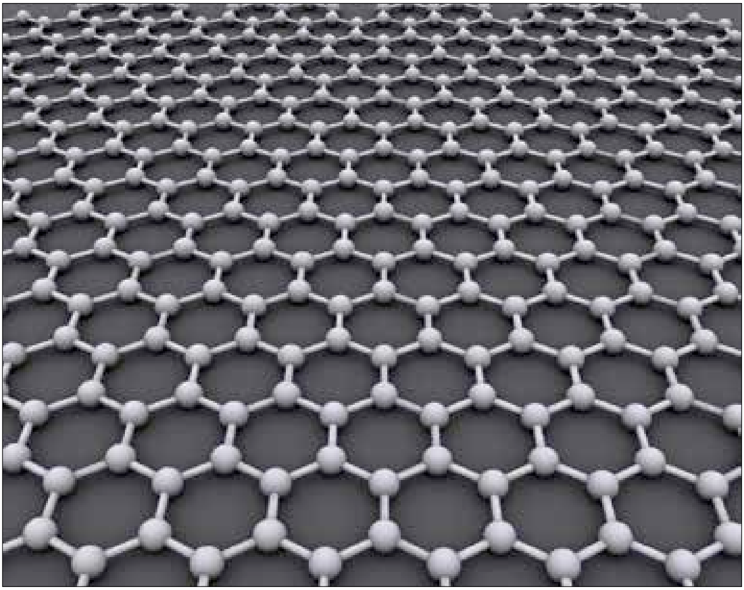
Cut to the 20th century, when science has progressed by leaps and bounds, and flying bird structures, “airplanes” are a thing, and we found a new form of carbon. It

Buckyball – almost like a football

was discovered by Harold Kroto (Sussex University), Robert Curl, Jr. (Rice University), and Richard Smalley (Rice University) in the year 1985. The new form was called "buckminsterfullerene". It was given this name, because its molecules resemble the geodesic domes designed by architect Buckminister Fuller for the 1967 World's fair. For the common folk, the name was "Buckyballs". Buckyballs, due to their characteristic special shape can be found in a lot of lubricants.

That is not it though. To this date, several different carbon structures are being researched on, and we have made major breakthroughs in our quest to expand our understanding and knowledge of carbon. Ever heard about graphene? Well, that's the latest form of carbon that scientists found. As they sweat it out in the labs, we type away.

After reading through this section, you may have realised one thing – there is no one person who can be credited with the discovery of carbon. It is true. It was first



The hexagonal structure of graphene

discovered in prehistoric times. The discoverer might have had a name, let's say Steve. But we can't know for sure. All that we know is that the substance that literally forms the basic structure of our bodies, wasn't recognised as an element until the 18th century.

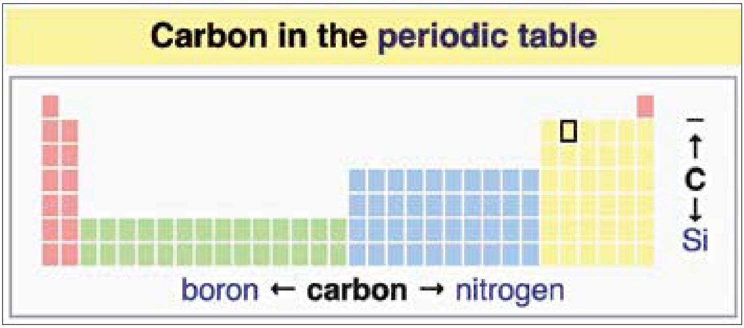
Now that we know that, let's move on and read a bit about some basic chemical facts about carbon before we move to the next chapter and get all sciencey and start throwing definitions around.

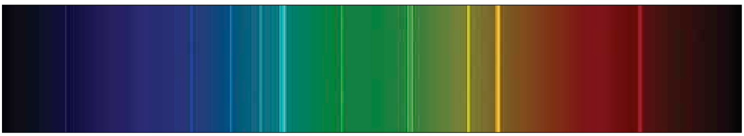
All about the numbers

When coming to the chemistry of any element, the best place to start is by looking at where it has been placed in the periodic table. If you are familiar with the characteristics of elements each group and period, then you'd have no problem in knowing some basic facts about carbon, just by reading the following line –

Carbon is an element that is found in the p block of the periodic table, placed in group 14, and period 2.

Its general state of occurrence is as a solid around the 20-degree Celsius mark, and its atomic number is 6. The melting point of carbon as defined by extensive chemical testing is between 3600 to 3700 degrees Celsius. As for the density, the two of its most common forms of occurrences, diamond and graphite have a





Spectral lines of carbon

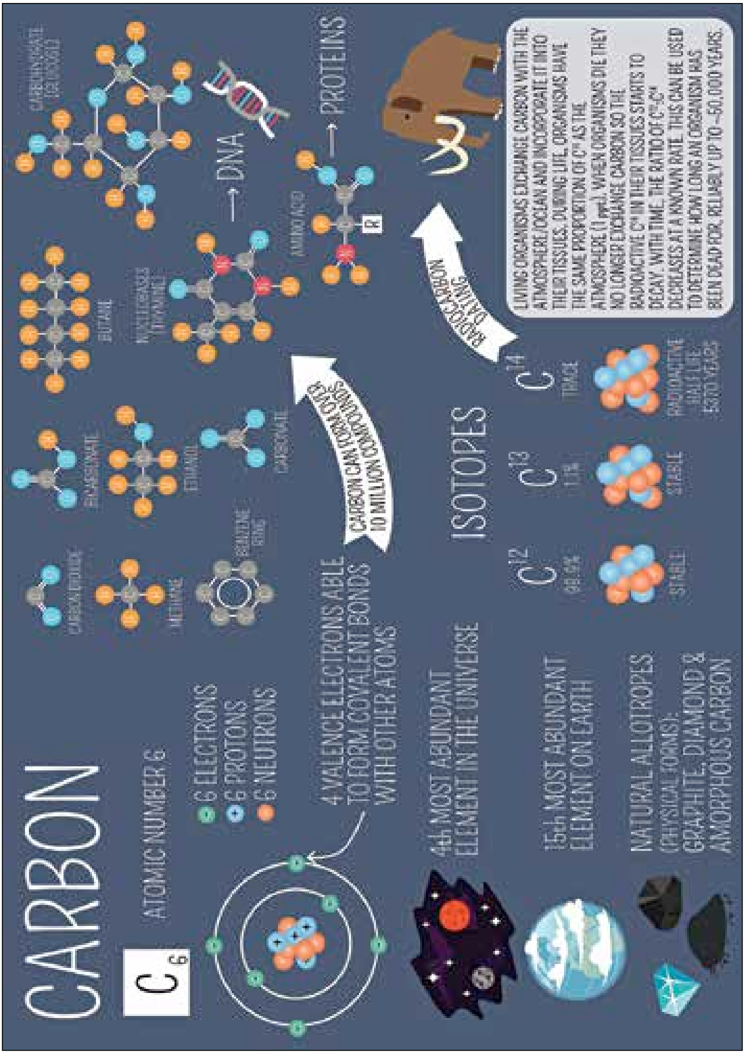
density of 3.513 g cm–3 and 2.2 g cm–3 respectively. Its relative atomic mass is 12.011, and its key isotopes are 12C, 13C, 14C. If all of this sounds like some abstract jargon to you, then fear not. We will explain most of it in the remaining chapters. For now, keep all of this information noted and safe with you. Let's go on to understand the history of the origins of the name.

Etymology

One of the most fun part for us, whenever we set out to explore the story and chemistry of an element, is its etymology. Knowing the story of how an element's name came to be is fascinating, right?

Coal susbstance for sure

Well, in case of carbon, the story is not that interesting or to say the least, captivating. The English name of carbon, finds its roots in Latin word carbo which stands for coal and charcoal. In other languages, like Danish, German, and Dutch, the name given to carbon, kulstof, Kohlenstoff, and koolstof literally means coal substance. When we move to France, we have the name, charbon which translates to charcoal.



See! We told you it is not captivating. However, you can flex this knowledge at the next barbeque party you attend. We know you'll do. ;-)

Anyway, let's move on to some actual chemistry and look at the isotopes, allotropes of carbon, and other interesting stuff. ■

All about the properties

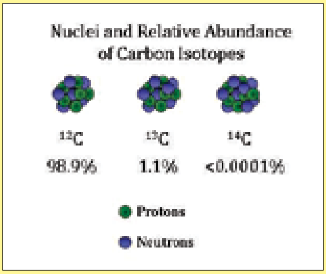
Understand carbon better

So, we have understood the basic chemical properties of carbon. We know its origin story and who characterised it as an element for the first time, and how. The foundation has been laid, and we know enough to continue understanding more interesting theories and information about carbon. Let's start with isotopes.

One of many forms

For the uninitiated, let's begin by understanding what an isotope is. By definition, isotopes are different forms of same chemical element. They have the same number of electrons and protons but have a different number of neutrons. This means that they have different relative atomic mass, but their chemical properties are the same. They can be stable or unstable, depending upon the base nature of the chemical element.

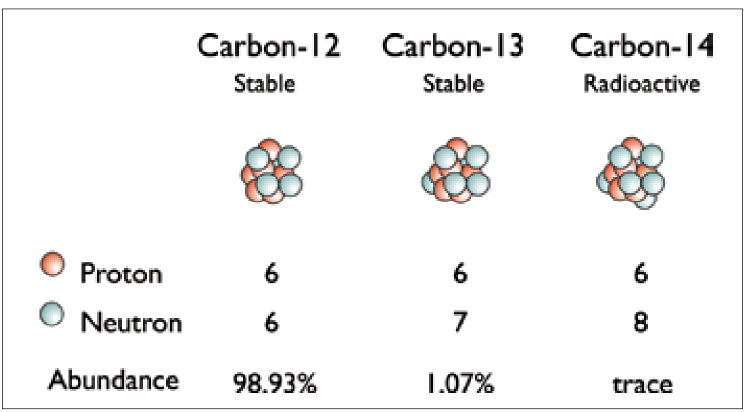
Isotopes are mainly characterised into two categories – stable and unstable isotopes. Isotopes that have an unstable atomic nucleus and undergo atomic decay are called unstable isotopes, while the ones that have extremely long half-lives, are called stable isotopes. Out of the 15 known carbon isotopes, only two are stable, while the remaining 13 are characterised to be unstable.



The isotopes of carbon contain protons, and the number of neutrons in them can vary anywhere between 2 and 16. This means that carbon has 15 known isotopes, from carbon-8 to carbon-22 (8C to 22C). Out of the two stable isotopes of carbon, isotope carbon-12 (12C) is the most abundant one on Earth. It forms about 98.93 per cent of the carbon deposit on the planet.

Due to the nature of certain biochemical reactions, which do not go well with the other stable isotope, carbon-13 (13C), the concentration of carbon-12 in biological materials is much higher than that of carbon-13. The difference is such that in comparison to the carbon-12, carbon-13 isotope forms only 1.07 per cent of the carbon that is present on Earth.

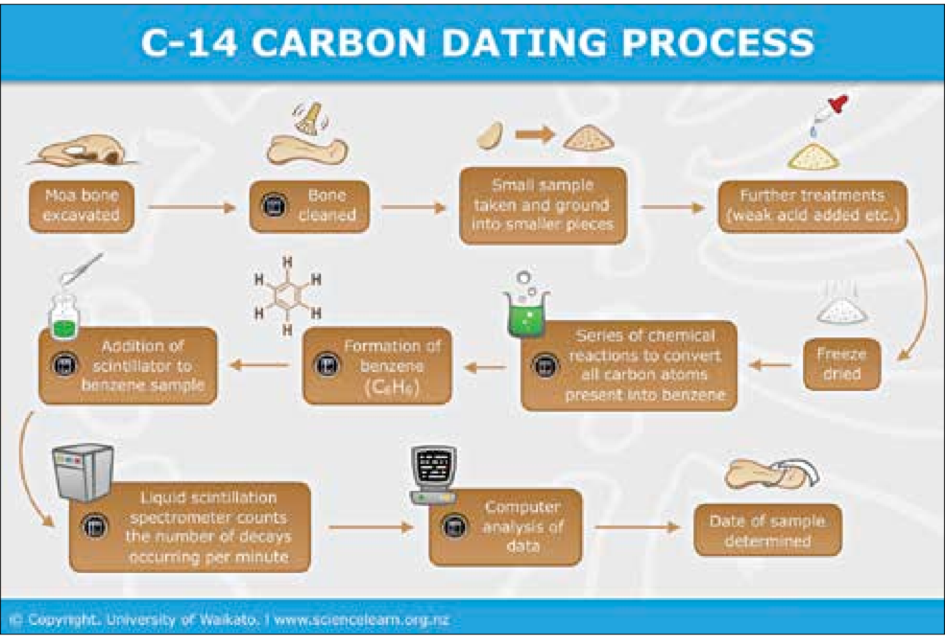
The presence of carbon-12 around us is so common and constant that in the year 1961, the International Union of Pure and Applied Chemistry, or the IUPAC, adopted the isotope to form the basis of atomic weights.



Another important isotope of carbon is carbon-14. While it is present in trace amounts on Earth, its quantity in the atmosphere and in living organisms is almost constant. After the death of living organisms, the amount of carbon-14 decreases at a predictable and pre-defined rate.

This property of carbon-14 was identified in the year 1949, and it gave rise to the science of radiocarbon dating. Since then, radiocarbon dating has seen extensive use in different branches of science and archaeology, with carbonaceous materials, up to 40,000 years old, being identified and dated using the process.

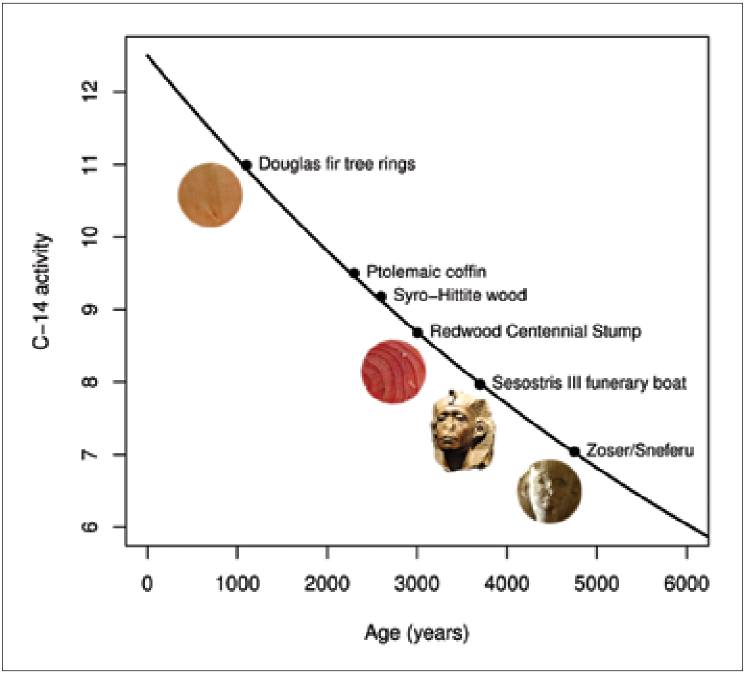
Over the years, there have been changes to the process of radiocarbon dating. In the year 2020, an article published on Nature, there are significant changes are incoming in the technique.



The author of the article, Nicola Jones, observed – "Radiocarbon dating — a key tool used for determining the age of prehistoric samples — is about to get a major update. For the first time in seven years, the technique is due to be recalibrated using a slew of new data from around the world. The result could have implications for the estimated ages of many finds — such as Siberia's oldest modern human fossils, which according to the latest calibrations are 1,000 years younger than previously thought.

The work combines thousands of data points from tree rings, lake and ocean sediments, corals and stalagmites, among other features, and extends the time frame for radiocarbon dating back to 55,000 years ago — 5,000 years further than the last calibration update in 2013."

As for the archaeologists, one of the most prominent users of the technique of radiocarbon dating, most of them are excited. Nicholas Sutton, an archaeologist at the University of Otago in New Zealand, commented on this development and Tweeted - "Maybe I've been in lockdown too long but ... I'm really excited about it!"



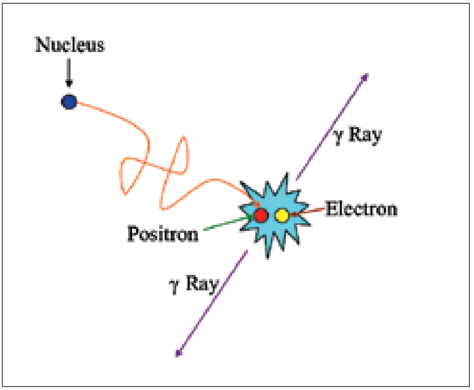
From carbon to boron

Of the many radioactive isotopes of carbon, carbon-11 is the isotope that decays and transforms into boron-11. This change occurs due to the emission of positron emission. Positrons are generally formed when a proton sheds its positive charge and becomes a neutron. A positron is the antimatter equivalent of an electron. It has the mass of an electron, but it has a charge of +1.

The equations for this change are as follows:

$^{11}C \rightarrow {}^{11}B + e^{+} + \nu_{e} + 0.96$ MeV

$^{11}C + e^- \rightarrow {}^{11}B + \nu_e +$ 1.98 MeV



This isotope sees widespread use in the process of radioactive labelling of molecules in the process of positron emission tomography and it has a half-life of 20.3402(53) min.

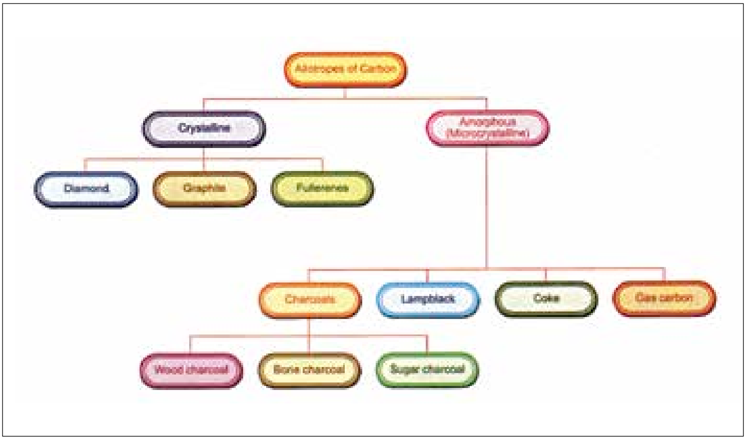
Same in chemistry, but different physically

If we were to ask you the definition of allotrope, you'd guess it using the subheading of this section. If you were not able to guess, then here's how it goes –

Allotropes are variations in the forms of an element which differ in molecular composition or the way in which atoms form different packing arrangements in the solid state.

When talking about carbon, we come across a number of allotropes which often include some very commonly known substances. The allotropes of carbon are mainly divided into two categories – amorphous and crystalline.

The crystalline allotropes include:



- Diamond
- Graphite

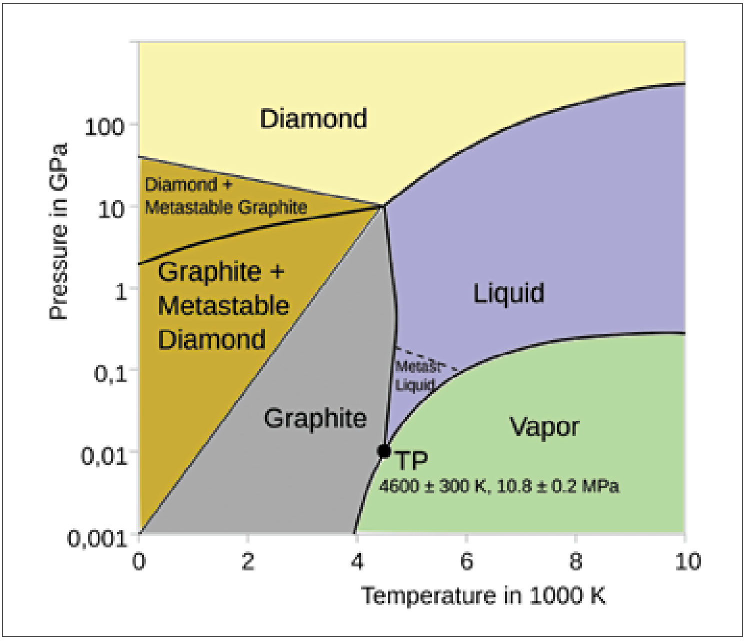
- Fullerenes
- Carbon Nanotubes

The amorphous allotropes include:

- Coal
- Coke
- Wood charcoal
- Animal charcoal
- Sugar charcoal
- Lampblack
- Gas Carbon

The main difference between them is the physical arrangement of carbon atoms in these substances. Now, without wasting this precious real estate, let's get to understanding the composition and structure of three main allotropes.

Diamond: The hardest substance known to humans, diamond has a three dimensional structure in which carbon atoms are held together by strong covalent bonds. Every Carbon iota is in the condition of sp3 hybridisation and connected tetrahedrally



to four adjoining Carbon molecules. Apart from being the hardest known regular substance, diamond is the perfect and densest collection of carbon atoms with a thickness of 3.51 gcm–3.

Graphite: One of the most commonly found and used allotropes of carbon, graphite is characterised by its metallic sheen and dark grey colour. It is one of the very few non metallic conductors. In graphite, the atoms are in the sp2 hybridisation. The atoms are linked to each other via covalent bonds and form planar hexagonal rings.

Buckminsterfullerenes: Also known as Fullerenes, they are the best example of unadulterated type of carbon. Fullerene is an enormous circular particle of arrangement C2n where n□30.

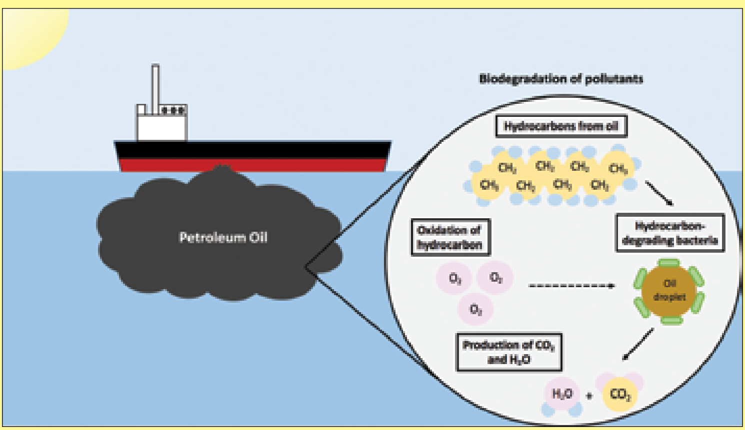
Well... That was it in this chapter. See you in the next one where we will take your knowledge about carbon to the next level by talking about hydrocarbons and other organic compounds. ■

Of ane(s), ene(s), and yne(s)

The story of organic compounds

Now you have read through two chapters, i.e. half of this book and you'd be familiar with the basic chemistry of carbon, and how it exists in multiple different forms after reading about its isotopes and allotropes. With that out of the way, let us go through organic and inorganic compounds that are formed by carbon.

You may have read it in your chemistry textbooks in school. So we assume that you have a vague idea of what they are. However, since any book about carbon cannot be



Technically it is biodegradable

complete without the mention and explanation about inorganic and organic compounds of carbon, here's a small refresher on the topic, before we move on to the last chapter where we will speak about the different applications of carbon in our daily lives, and the carbon cycle, and the disturbances caused in our environment because of alterations in its normal course.

They're organic!

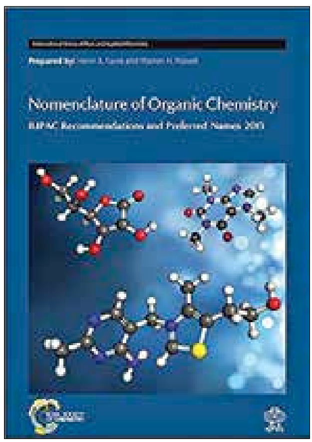
If we were to put it in the simplest of words, then an organic compound is any chemical compound where one or more constituent element is carbon. A more formal definition of the same, as given by the folks at the American Chemical Society is:

"Organic chemistry is the study of the structure, properties, composition, reactions, and preparation of carbon-containing compounds. Most organic compounds contain carbon and hydrogen, but they may also include any number of other elements (e.g., nitrogen, oxygen, halogens, phosphorus, silicon, sulfur). Originally limited to the study of compounds produced by living organisms, organic chemistry has been broadened to include human-made substances (e.g., plastics)."

And, the branch of chemistry that deals with organic compounds is organic chemistry.

Other characteristics of organic compounds include:

1. They are generally soluble in water.
2. They are also soluble in organic solvents like alcohol, benzene, and chloroform.
3. They are characterised by low melting and boiling points and are prone to decomposition on heating.
4. They also tend to catch fire easily.
5. Organic Compounds are non-electrolytes and form covalent bonds.
6. They show the phenomenon of isomerism (remember from the last chapter?)
7. They have a characteristic colour and odour, meaning you can differentiate between any two given organic compounds by smelling or looking at them, or both.
8. Their molecular reactions are slow. This happens due to the presence of linkages. The reactions of organic compounds are never complete.



Very complicated

Around us, the primary sources of organic compounds are:

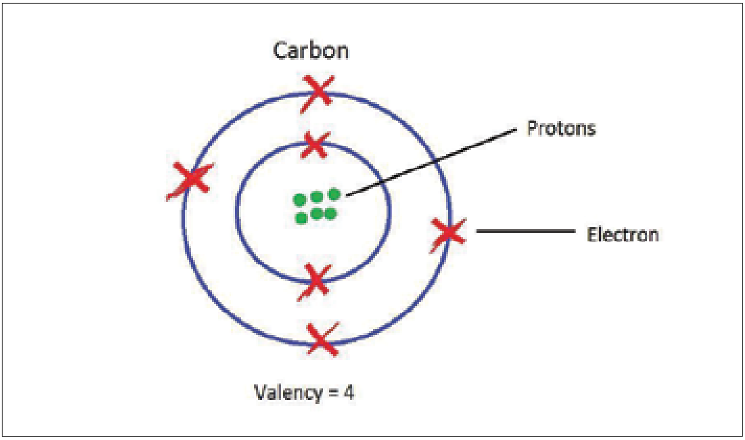
- **Plants:** They provide us with sugar, starch, cellulose, and a host of other drugs, all of which are organic in nature.
- **Animals:** They are a prime source of organic compounds like fats, proteins, urea, etc.
- **Coal:** Destructive distillation of coal helps us obtain compounds like benzene, toluene, naphthalene, dyes, etc.
- **Petroleum:** It is one of the most prevalent sources of organic compounds like gasoline, fuel gases, petrol, etc.

There are other natural sources of organic compounds as well, and there are other methods using which organic compounds can be artificially synthesized in labs as well.

As for the application of organic compounds in our daily lives, we can see them being used extensively in products like powders, perfumes, our food, and other products like natural gas, wood, and insecticides.

The two characteristics

Delving deep into organic chemistry also shows us some interesting characteristics of carbon atoms. The two most important characteristics are – tetravalency of carbon atom, and catenation. Let us take a look at them one by one.



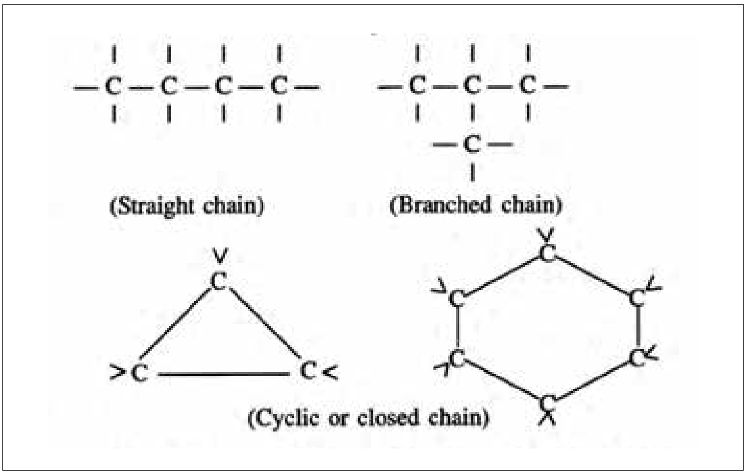
Firstly, let us understand what tetravalency of carbon atom means. As the name suggests, carbon has four valence electrons. This can be identified using the atomic number of carbon is 6, meaning its electronic configuration of carbon is 2,4. Carbon cannot lose or gain electrons to attain octet, it forms covalent bonds by sharing its four electrons with other atoms. Thus, carbon tends to form a total of four covalent bonds. This phenomenon is called tetravalency of carbon.

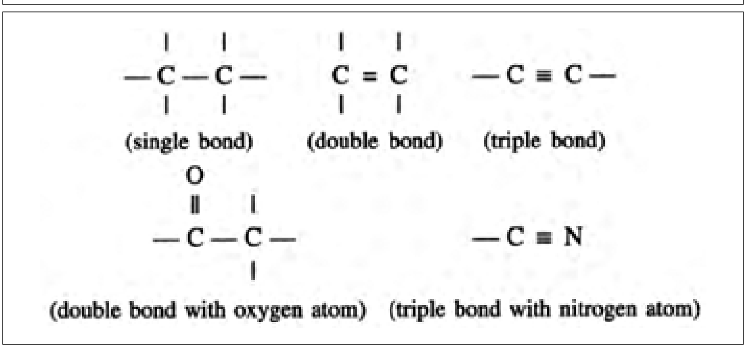
Next, let us look at what catenation is.

Carbon atom has a unique tendency to link together to form very long chains. This property of the carbon atom is called catenation. Formally, catenation can be defined as – The property of self-linking atoms of an element through covalent bonds in order to form straight chains, branched chains, and cyclic chains of different sizes is called catenation.

The formation of chains can involve the formation of three different types of covalent bonds namely, single, double, or triple covalent bonds.

During catenation, carbon atoms can form straight chains, branched chains, or cyclic chains. All the three types of these chains and bonds of carbon are shown below.





We know that the valency of carbon is four. Thus, it has the capability to form bonds with other carbon atoms or other atoms like oxygen and nitrogen too. As a result, we know of more than 5 million organic compounds today, and there are many more being added by the day.

Having understood what catenation and tetravalency of carbon atom is, we will now move on to having a quick look at the different types of organic compounds that are known to us.

Types of compound	*Identified by the presence of*	*Example*
1. Hydrocarbon		
(a) alkane	—C—C— bond	Ethane $H_3C—CH_3$
(b) alkene	—C = C— bond	Ethene $H_2C = CH_2$
(c) alkyne	—C ≡ C— bond	Ethyne $HC \equiv CH$
2. Alcohol	—OH group	Methanol CH_3OH
3. Aldehyde	—CHO group	Ethanal CH_3CHO
4. Ketone	>C = 0	Propanone CH_3COCH_3
5. Carboxylic acid	—COOH group	Ethanoic acid CH_3COOH
6. Ether	C—O—C group	Dimethyl ether $H_3C—O—CH_3$
7. Halide	—X (F, Cl, Br, I)	Chloroethane C_2H_5Cl

Hydrocarbons

Hydrocarbons are one of the most important part of organic chemistry, so much so that they are almost synonymous with this branch of chemistry. They are the compounds that contain only hydrogen and carbon atoms. Hence the name.

Just like other compounds that we have studied about so far in this chapter, hydrocarbons also have certain categorisations of the compounds. The two main types are aliphatic or open chain compounds and cyclic or closed chain compounds. Open chain compounds, as the name suggests, have a long open chain of bonded atoms, while the cyclic closed chain compounds have rings and other similar closed structures made by chemically bonded atoms.

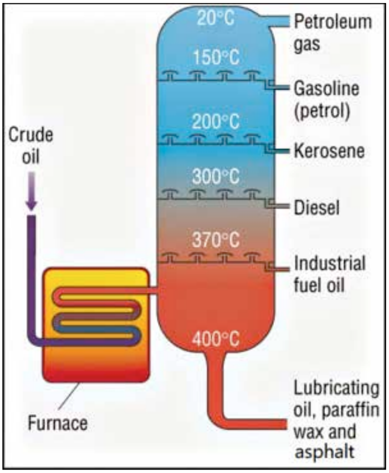
Open chain compounds are further divided into two categories – saturated alkanes (paraffins), and unsaturated compounds, which in turn see division into two categories. We will talk about that later. Let's first look at the division of paraffins.

Paraffins or Saturated alkanes are the simplest form of hydrocarbons. They are represented by the following formula –

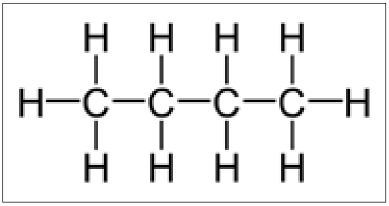
$$C_nH2_{n+2}$$

(n is the number of atoms)

This means that if we have a saturated hydrocarbon with five atoms of carbon, the number of hydrogen atoms in that compound would be (5x2) + 2, which would equate to 12. Thus, the formula of the resultant hydrocarbon would be C5H12.



Petroleum hydrocarbons



Aliphatic compound

In the world of saturated compounds, things are relatively simple, as all the four valencies of carbon are satisfied by a single covalent bond. However, when we come unsaturated compounds, things get very interesting.

In unsaturated organic compounds, the valencies of at least two carbon atoms are not fully satisfied by the attached hydrogen atoms. This means that the atoms (carbon and hydrogen) are joined by double covalent or triple covalent bonds. As a result, these compounds are generally more reactive due to the presence of electrons in the double and triple covalent bonds.

Number of covalent bonds	Name
1 (one)	Alkanes
2 (two)	Alkenes
3 (three)	Alkynes

Closed chain hydrocarbons that contain three or more carbon atoms in their molecules, and have properties similar to open chain hydrocarbons are called carbocyclic compounds.

Now, we are sure that the thought that might be lingering in your curious minds would be what would happen if we play around with the composition of these compounds. Well, that would be a very valid question. And, that is what we will answer in the next section which covers alkyl group.

If we were to go all sciency and dive straight into the definition, then alkyl group is obtained by removing one atom of hydrogen from an alkane molecule. The reaction for this process goes as follows:

The general formula of alkyl is –

$$C_nH_{2n+1}$$

(n is the number of atoms)

When it comes to naming, we the name of the alkane from which it is being derived from, and just replace the -ane suffix with the -ayl suffix.

Now if we would go any further into the explanation of hydrocarbons, we would end up writing a whole book about it. So, let us put to this, and move on to the next chapter where we will look into the uses and origins of certain carbon compounds, and also take a dive into the concept of carbon cycle, and understand why is it so important for us. ■

It's all cyclic

Well... the very reason for our existence is what poses a threat to it

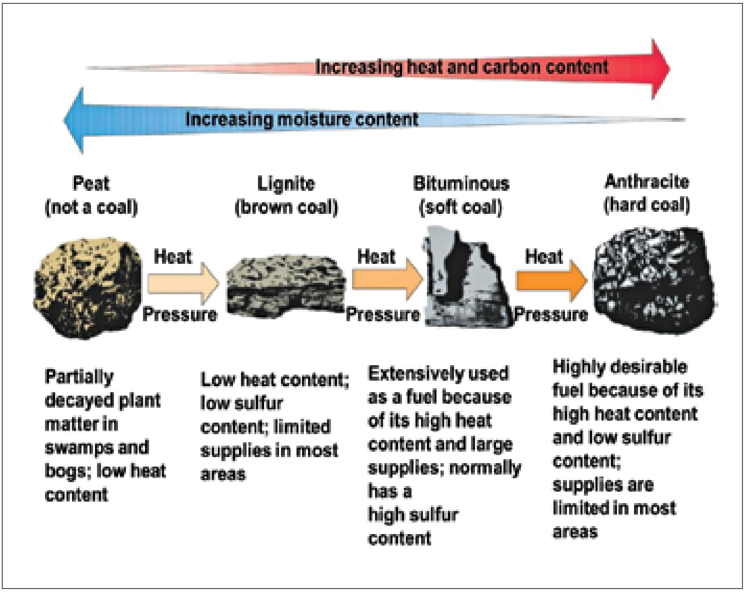
If you made it so far in this book then congratulations! You are well equipped with information about carbon that not many would know about. But, the lesson is not done just yet. We have told you about organic compounds and explained almost all the other jargon that comes along when reading about carbon.

However, what use would be that knowledge if you'd find no practical use of it. Or to better put it, have conversations about it! So, in this chapter we will be touching upon the different applications of carbon and related substances. We will also discuss the carbon cycle, whose imbalance has been a topic of discussion for quite some time now.

The fuel of the industrial revolution

Well, if the heading of this section wasn't hint enough, then let us tell you that we are talking about coal here. Yes, the black lump of carbon and other elements that powered our way into the machine and technology rich world that we live in. The natural coal that is extracted from beneath the surface of Earth takes a fairly long time to develop fully, millions of years to say the least.

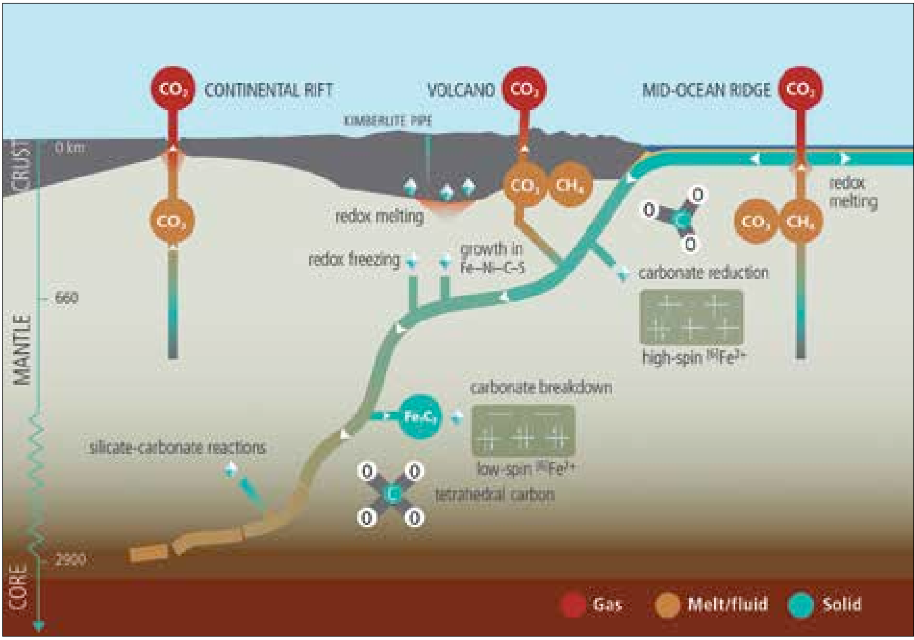
The base material of natural coal are the ancient vegetation and other organic matter that was covered with layers upon layers of soil, to be compressed under an immense weight for a long time. If we take a timeline and decide to plot the development of coal, then it would be as follows:



The process of the deposition of layers of coal one over other, leading to an increased percentage of carbon, and a decrease in the amount of impurities is called carbonisation. As the records state, the most active episode of carbonisation took place in the carboniferous era, which is about 270 million years ago.

Depending upon their age, and the resulting carbon content, coal is divided into the following four categories:

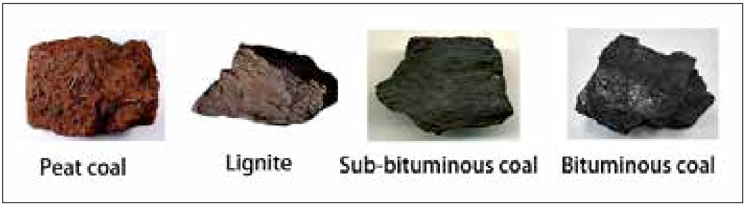
1. **Peat** – It is the first stage in the process of coal formation. Peat is characterised by its light brown colour, and is known to contain a fairly lower percentage of carbon content. It varies around 50 to 60 per cent.
2. **Lignite** – It is the second stage, where the carbon content gradually increases to rise over the 60 per cent mark. In terms of the colour, it carries over the brown shade from Peat, but is harder than its predecessor.
3. **Bituminous** – It is the third stage, where we find three varieties of coal. All of these are yet again classified and identified using the percentage of carbon content present in them. The high variety is known to have close to 90 per cent carbon content, while the medium and low varieties have 80 and 70-75 per cent carbon content respectively. It is one of the most commonly found varieties of coal and is often used in household applications. So, you know what to tell your peers and friends at the next barbeque party that you throw. As you might already know, this



variety of coal generally tends to be black and hard, which yields both volatile and non-volatile materials when heated.

4. **Anthracite** – The oldest variety of coal, Anthracite is formed in the last stage of coal formation. Since it is the oldest variety, the carbon content in this form of coal tends to be between the 92-98 per cent mark. Anthracite is difficult to ignite. However, once it catches fire, it burns with a lot of heat for a fairly long period of time. Given its age, it is also very rare and is found in selected regions of the world.

Now, you'd expect that we'll move on to explain the uses of coal. But, that is not the case. We are sure that that particular piece of info for you is just a search away. Here, we will focus on dmystifying science for you all. So, let's move on and



understand the process which coal is put through, and that yields products like coke (not the drink), coal-tar, etc.

The process is called destructive distillation of coke. In general terms, destructive distillation of coal is the process where a substance is heated in the absence of air. This leads to the decomposition of the substance, leaving behind a residue that is rich in carbon.

It can be summed up using the following chemical equation:

$$\text{Coal} \xrightarrow[\text{distillation}]{\text{destructive}} \text{Coke} + \text{Coal-tar} + \text{Coal-gas} + \text{Ammonical Solution}$$

Here, the carbon rich residue that is being left behind is coke, coal-tar, coal-gas, and ammonia solution. Now, with that out of the way, let's look at the carbon cycle, and understand its importance and significance before we head to the conclusion of the book.

The Cycle of Carbon

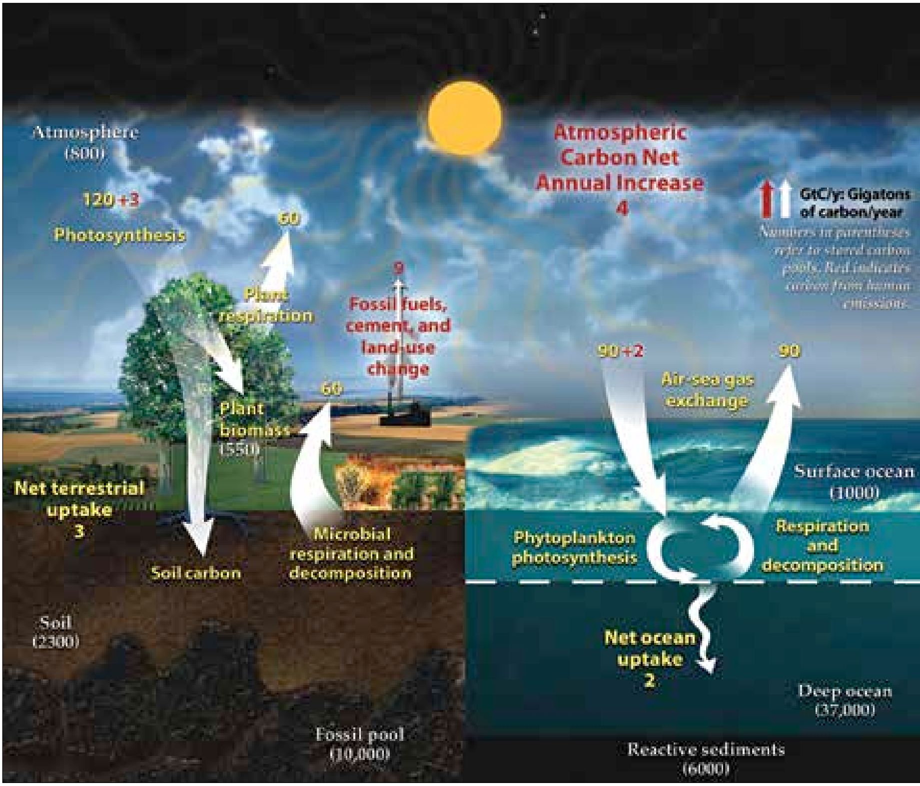
The Carbon Cycle is one of the most important phenomenon occurring on the planet that we live on. It is responsible for the circulation of one of the most important element across ecosystems. Carbon gets converted into different forms and moves across several ecosystems that co-exist on Earth.

Commenting on the importance of the Carbon Cycle, the blog run by the Earth Observatory of NASA noted:

"Carbon flows between each reservoir in an exchange called the carbon cycle, which has slow and fast components. Any change in the cycle that shifts carbon out of one reservoir puts more carbon in the other reservoirs. Changes that put carbon gases into the atmosphere result in warmer temperatures on Earth.

Over the long term, the carbon cycle seems to maintain a balance that prevents all of Earth's carbon from entering the atmosphere (as is the case on Venus) or from being stored entirely in rocks. This balance helps keep Earth's temperature relatively stable, like a thermostat.

This thermostat works over a few hundred thousand years, as part of the slow carbon cycle. This means that for shorter time periods—tens to a hundred thousand years—the temperature of Earth can vary. And, in fact, Earth swings between ice ages and warmer interglacial periods on these time scales. Parts of the carbon cycle may even amplify these short-term temperature changes.



The carbon cycle

On very long time scales (millions to tens of millions of years), the movement of tectonic plates and changes in the rate at which carbon seeps from the Earth's interior may change the temperature on the thermostat. Earth has undergone such a change over the last 50 million years, from the extremely warm climates of the Cretaceous (roughly 145 to 65 million years ago) to the glacial climates of the Pleistocene (roughly 1.8 million to 11,500 years ago)."

When there are disturbances and changes in the carbon cycle, everything from the atmospheric balance to the ocean, and even land based ecosystems are affected. We have stressed across the editions of this book, how important the delicate balance of everything that sustains life on planet Earth is. We know that there has been a substantial increase in the CO_2 deposit, and subsequently, an increase in the overall temperature of the planet. And that is actively messing up more things than one! So,

become more aware and proactively take part in preserving the balance that sustains life on this beautiful pale blue dot in the universe.

It may seem that we have explored this phenomenon thoroughly, there is still a lot that needs to be uncovered. The atmosphere contains more carbon than ever, which means there have been systemic changes that are yet to be thoroughly explored. Some questions such as – What will those changes look like? What will happen to plants as temperatures increase and climate changes? Will they remove more carbon from the atmosphere than they put back? Will ocean life become less productive? How much will the ocean acidify, and what effects will that have? - still remain unanswered. If you think that you might have an answer to some, do let us know by writing to us at *editor@digit.in*. ■