

STRONG TOWER ACADEMY
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NAME OF TEACHER: FEMI-

CLASS: SSS ONE

SUBJECT: CHEMISTRY

WEEK 6

TOPICS: CARBON AND ITS COMPOUNDS

CONTENT:

1. CARBON, ALLOTROPES AND THEIR STRUCTURES,
2. PROPERTIES, DIFFERENCE BETWEEN DIAMOND AND GRAPHITE
3. CHEMICAL PROPERTIES OF CARBON
4. COAL AND TYPES OF COAL

PERIOD 1: CARBON, ALLOTROPES AND THEIR STRUCTURES

Carbon is a non-metal found in group 4 of the periodic table. It occurs naturally as diamond and graphite. These physically different forms of the same chemical element are known as **allotropes**. Other elements that exist in different forms in their free states include tin, Sulphur and phosphorus. Also, it occurs in an impure form as coal and in the combined state as petroleum, wood and natural gases.

Atomic structure of carbon

Carbon is the sixth element in the periodic table. The nucleus of its atom is composed of six protons and six neutrons and is surrounded by six electrons; 2 in the first energy level (K-shell) and four in the 2nd energy level (L-shell). Its orbital configuration is $1s^2 2s^2 2p^2$. Carbon atom has four valency electrons. Carbon atoms are able to catenate, i.e. join to one another by covalent bonds in a continuous fashion. The phenomenon is

called catenation.

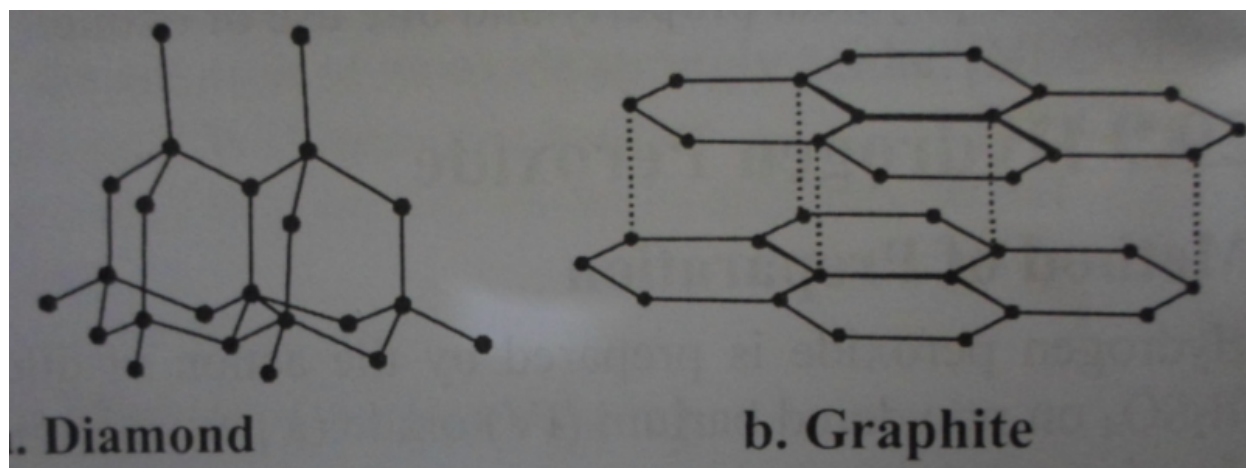
Allotropes of carbon

Allotropy is the existence of an element in the same physical state but in different forms. The various forms are called ***allotropes***. Carbon exhibits allotropy. Other elements that also exhibit allotropy are sulphur, Tin, Oxygen and Phosphorus. The two crystalline allotropes of carbon are: Diamond and graphite. Charcoal is amorphous form of carbon.

Diamond

Structure and Bonding

In diamond, each carbon atom is at the center of a regular tetrahedron and covalently bonded to four other atoms in a strong compact fashion. The covalent linking between the atoms is continuous to produce a single infinite tightly locked 3-dimensional giant (macro) molecule, which has a network octahedral structure see the diagram below:



The rigidity of the structure is responsible for the hardness of diamond; it is the hardest known substance. Since the covalent bonds are strong and the molecule is compact, the melting point of diamond is very high.

PHYSICAL PROPERTIES OF DIAMOND

1. Pure diamond is hard, colourless and transparent.
2. Forms octahedral crystals with high refractive index.
3. It is very hard; it has a density of 3.5gcm^{-3} , and melting point of 3600°C .
4. It does not conduct electricity, because all the four valence electrons per carbon atom are used in bonding i.e.no mobile electrons.
5. It is insoluble in any solvent.

USES OF DIAMOND

1. Because of its high refractive index and amazing metallic luster when cut, it is used in jewelries.
2. Because of its hardness, diamond is used in cutting glasses, in drilling rocks; in boring of holes; in making bearings in engines; and as an abrasive, i.e.to smoothen rough surfaces.

GRAPHITE

Structure and Bonding

In graphite, each carbon atom is covalently bonded to three other atoms to produce an infinite two-dimensional flat hexagonal layer structure, which is strong and hard. See the diagram above. The flat hexagonal layers in graphite are held together by the weak van der Waals attractive forces, which allow movement of the planes parallel to each other, and make the graphite to be soft and slippery. The fourth electron in the valence shell of each carbon atom in graphite is mobile, because it is not used in bonding, and account for its electrical conductivity.

EVALUATION

1. Define the term allotropy.
2. What is the structure of? (a) diamond (b) graphite.
3. Give the reason why diamond is hard, while graphite is soft.

PERIOD 2: PROPERTIES, DIFFERENCE BETWEEN DIAMON AND GRAPHITE

Physical properties of graphite

1. Graphite form soft, black and opaque hexagonal crystals, which are greasy to feel.
The softness is due to the ability of the adjacent layers to slide over one another.
2. It is hard. Its density is 2.3gcm^{-3} , and melts at about 3500°C .
3. It is good conductor of heat and electricity-due to the presence of a mobile electron per carbon atom.
4. It is soluble in any solvent. Graphite is an example of a non –metallic conductor.it is a metalloid.

USES OF GRAPHITE

1. Graphite is used as a lubricant, because of its flat hexagonal layer which can slide over one another.
2. Used as inert electrodes during electrolysis and for brushes of electric motors been a good conductor of electric current.
3. When mixed with clay, graphite forms lead, which is used in making lead pencils. The hardness of a pencil depends on the amount of clay in the mixture. Soft pencils contain more of graphite, while hard pencils contain more of clay.

4. Used in making crucible, because of its high melting point.
5. Used in nuclear reactors; being soft and with a high melting point.

DIFFERENCE BETWEEN DIAMOND AND GRAPHITE

DIAMOND PROPERTIES	GRAPHITE PROPERTIES
1. Diamond is a transparent solid that sparkles when cut and polished	Graphite is an opaque solid, with a metallic luster
2. It is octahedral in shape	It is hexagonal in shape
3. Its density is $3.53.5\text{gcm}^{-3}$	Its density is $2.33.5\text{gcm}^{-3}$
4. It is a poor conductor of electricity	It is a good conductor of electricity
5. It is an inert substance but at 900°C , it burns in air to form carbon(iv) oxide and combines with fluorine	It is a more reactive substance burns in air to form carbon (iv) oxide at 7000°C , it also reacts with oxidizing agents to form oxides, it also reacts with fluorine and tetraoxosulphate(vi) acid
6. It is the hardest substance	It is one of the softest minerals known.

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EVALUTION

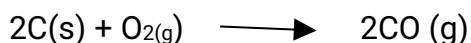
1. List 3 uses of graphite with reasons.
2. Give four differences between diamond and graphite.

PERIOD 3: CHEMICAL PROPERTIES OF CARBON AND TYPES OF COAL

CHEMICAL PROPERTIES OF CARBON

1. Combustion reaction

Carbon burns in limited supply of air to form carbon (II) oxide equation for the reaction is given as



In excess air, complete combustion takes place and carbon(IV) oxide is formed. Equation for the reaction is given as.

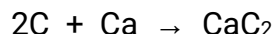
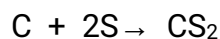


When charcoal is used as fuel, it burns released is used for cooking (exothermic reaction)

NOTE:Carbon occurs most abundantly both naturally as diamond and graphite and in numerous compounds including petroleum coal, natural gas among others.

2. Combination reaction:

Carbon combines directly with certain elements such as Sulphur, hydrogen, calcium and aluminium at a very high temperature.

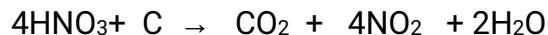


3. As a reducing agent.

Carbon is a strong reducing agent. It reduces the oxides of a less active metals.



4. Reaction with strong oxidizing agent. Trioxonitrate (v) acid oxidizes carbon to carbon (iv) oxide



COAL AND TYPES OF COAL

COAL: This is one the two most principal sources of fuel and energy, the other being petroleum. Coal was found as a result of complex chemical and physical changes when the remains of forest were buried under the earth millions of years ago under great pressure in the absence of air.

Coal is found in great abundance in very many parts of the world including Nigeria. Coal is a complex mixture of hydrocarbons (compounds of carbon and hydrogen) and other organic and inorganic compounds containing small amounts of nitrogen, sulphur and phosphorus as impurities.

Types of Coal

Coal is derived from wood; it naturally contains a lot of carbon. There are four main types of coal, arising from the progressive variation in their carbon content. They are:

1. Peat-like coal: contains about 60% of carbon.
2. Lignite coal: contains about 70% of carbon.
3. Bituminous coal: contains about 85% of carbon. This is the type that is mostly used for our everyday domestic application.

4. Anthracite coal: contains about 94% of carbon.

The carbon content of each type of coal reflects its rank or degree of classification. Based on carbon content, the different types of coals are put into ranks as follows: Peak

→ Lignite → Bituminous → Anthracite

Coal is used mainly as a fuel to generate power for station engines, factories and electric parts. It is also used for making various chemicals.

EVALUATION 1. Carbon occurs most abundantly both naturally as _____ and _____

2. With two equations only, describe the combustion of carbon allotropes.

3. Mention four types of coal

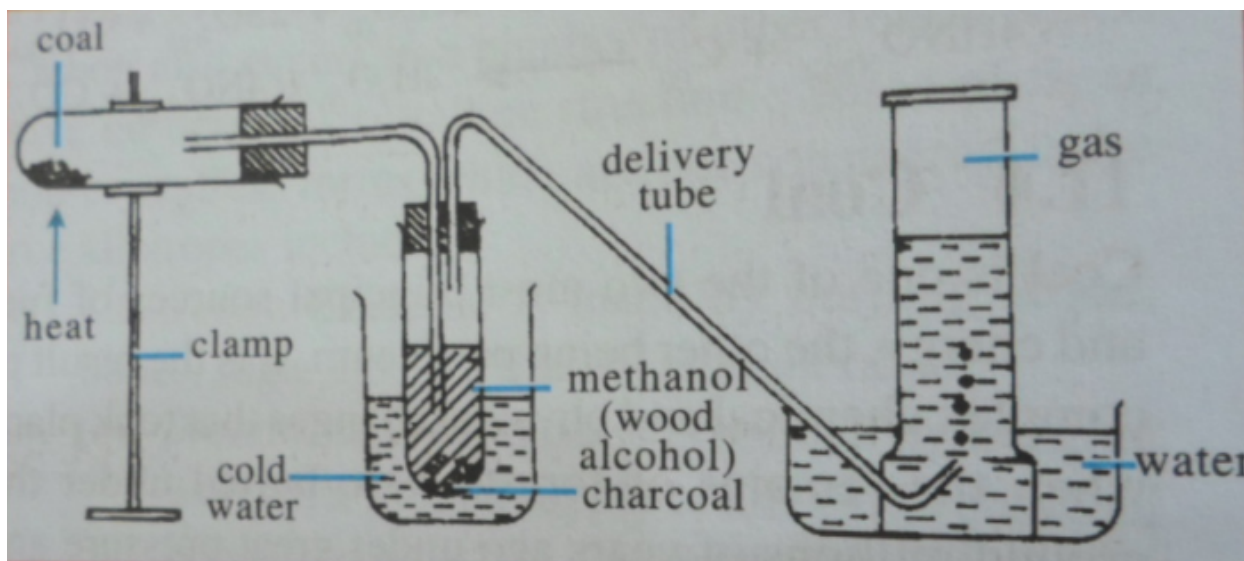
PERIOD 4: DESTRUCTIVE DISTILLATION OF COAL AND GASIFICATION OF COAL

DESTRUCTIVE DISTILLATION OF COAL

Destructive distillation of coal involves heating of coal to a very high temperature (600---1200° C) in the absence of air. During the process, coal decomposes to give coal gas, coal tar, ammoniacal liquor and coke as the main products.

Coal + *heat* → coal gas + coal tar + ammoniacal liquor + coke

The process is also known as industrial distillation of coal. The destructive distillation of coal can be carried in the laboratory using the set up below.



Uses of product of destructive distillation of coal

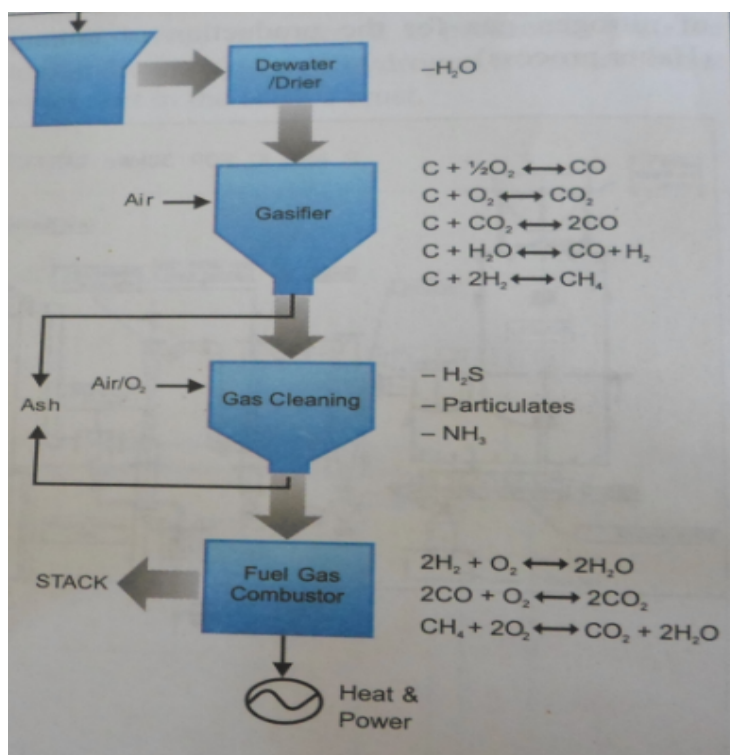
1. Coal gas: Coal gas is a gaseous mixture of hydrogen, methane, carbon (ii) oxide and small amount of ethane, hydrogen sulphide and Sulphur(iv)oxide. The main use of coal gas is as fuel. It is cleaner and more efficient than coal and solid or liquid fuel.
2. Coal tar: Coal tar, a thick brownish-black liquid, is a mixture of many organic chemicals including benzene, toluene, phenol, naphthalene and anthracene. The components can be separated by fractional distillation and are used for the manufacture of commercial products including drugs, dye, paints, insecticides, explosives, etc.
3. Ammoniacal liquor: This an aqueous solution containing mainly ammonia and is used in the manufacture of ammonium tetraoxosulphate(iv), $(\text{NH}_4)_2\text{SO}_4$.
4. Coke: Coke is non-volatile residue which contains about 90% of amorphous carbon and is chemically similar to hard coal. Coke is used in the manufacture of carbide, as a fuel and as a reducing agent in the extracting of metals. Coke is used to make producer gas and water gas through a process called gasification.

Uses of Coke

1. It is used as fuel both industrially and domestically
2. It is used to manufacture carbide used in production of ethyne.
3. It is a reducing agent in the extraction of metals from their ores.
4. It is used in the production of graphite.

GASIFICATION OF COKE:

Gasification of gas is the conversion of coke to combustible gases by incomplete oxidation with steam and air at 1000°C . Partial oxidation of coke with air and steam gives producer gas and water gas respectively.



GASIFICATION OF COKE

Producer gas: This is a mixture of one-third of carbon(II)oxide and two-thirds nitrogen by volume. It is obtained by heating coke in a furnace in a limited. This is achieved by passing air through red hot coke. During the process, coke is oxidized to carbon (IV)

oxide which is subsequently reduced by the hot coke to carbon (II) oxide, a combustible gas. The process can be represented by the following equations.

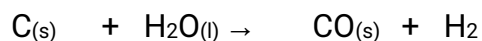


Uses of producer gas

1. Producer gas is used as fuel in furnaces, retorts and limekilns.
2. It is used as a source of nitrogen for the manufacture of ammonia.

Water gas

Water gas is produced by passing steam through hot coke at 1000°C . This results in reduction of the steam; carbon (II) oxide and hydrogen are formed. Water gas is mixture containing hydrogen and carbon (II) oxide in equal volume.



Water gas has a high calorific value because both carbon (II) oxide and hydrogen are combustible, whereas the calorific value of producer gas is low because nitrogen which is one of its constituents is not combustible

Uses

1. Water gas is used as a fuel.
2. It is used as a source of hydrogen and other organic compounds.

EVALUATION

1. Differentiate between water gas and producer gas.
2. What is gasification of coke?
3. Highlight 4 main products of destructive distillation of coal. State their uses.

4. Explain briefly, how destructive distillation of coal is obtained.

GENERAL EVALUATION

OBJECTIVE TEST:

1. Carbon is often deposited in the exhaust pipes of cars because of the (a) Presence of carbon (b) Incomplete combustion of petrol (c) excessive use of petrol. (d) use of impure fuel.

2. Destructive distillation of coal means ----- (a) heating coal in plentiful supply of air (b) heating coal in the absence of air. (c) conversion of coal to gas (d) destroying coal to produce gas.

3. An aqueous sodium trioxocarbonate(vi) solution is alkaline because the salt is _____ (a) soluble in water (b) a basic salt (c) fully ionized in water (d) hydrolyzed in water

4. The following statements about graphite are correct except that it _____. (a) has octahedral structure (b) is soft (c) is used as a lubricant (d) has a network structure

5. The following can be obtained directly from the destructive distillation of coal except. (a) ammoniacal liquor (b) producer gas (c) coal gas (d) tar

6. Water gas is a mixture of A. CO_2 and H_2 B. CO_2 and H_2O C. CO_2 D. CO and H_2

7. The liquid product from the destructive distillation of coal is A. ammoniacal liquor B. Coal fume C. Dyestuff D. coal plasma

8. Producer gas is with a low heating power because it contains more A. CO_2 than O_2 B. nitrogen than carbon (II) oxide C. CO_2 than nitrogen D. nitrogen than CO

ESSAY QUESTIONS

1. What do you understand by the term allotropy?
2. Mention two main types of allotropes of carbon.
3. Differentiate the two main types of allotropes of carbon with their diagrams only
4. In a tabular form, differentiate between the two main types of allotropes of carbon.
5. Mention three amorphous or non-crystalline forms of carbon
6. What do you understand by the term gasification of coke?
7. Give the products of gasification of coke..