THEME: CARBON IN THE ENVIRONMENT
TOPIC 7: CARBON IN THE ENVIRONMENT
SENIOR: 2 **TERM**: 2 **PERIODS**: 36
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COMPETENCY: **The learner investigates the diversity of carbon compounds in the environment.**

LEARNING OUTCOMES AND SUGGESTED LEARNING ACTIVITIES
From learning outcome A-J: The learner should be able to:

A Understand how and why carbon compounds are used as fuels (k,u)
• Draw on your experience and research to discuss the main uses of common carbon-based fuels in Uganda: charcoal, paraffin, petrol, firewood and diesel.
• Use prior learning to write a word equation to show the reaction when carbon-based fuels burn in oxygen

HOW CARBON-BASED FUELS ARE USED:

1. **Firewood**:
   - Burned directly in fireplaces, stoves, or furnaces to produce heat for warmth, cooking, or water heating.
   - Combustion process: Firewood + Oxygen → Heat + Carbon Dioxide + Water Vapor

2. **Charcoal**:
   - Burned in stoves, grills, or furnaces to produce heat for cooking, warmth, or industrial processes.
   - Combustion process: Charcoal + Oxygen → Heat + Carbon Dioxide

3. **Paraffin (Kerosene):**
   - Burned in lamps, heaters, or stoves to produce light and heat.
   - Combustion process: Paraffin + Oxygen → Heat + Light + Carbon Dioxide + Water Vapor
   - Also used as a fuel for jet engines and rockets.

4. **Petrol (Gasoline):**
   - Burned in internal combustion engines to power vehicles, generators, and machinery.
   - Combustion process: Petrol + Oxygen → Energy (mechanical or electrical) + Carbon Dioxide + Water Vapor

5. **Diesel:**
   - Burned in internal combustion engines to power vehicles, generators, and machinery.
   - Combustion process: Diesel + Oxygen → Energy (mechanical or electrical) + Carbon Dioxide + Water Vapor
   - Diesel engines operate at higher compression ratios than petrol engines, making them more efficient for heavy-duty applications.

In each case, the fuel is combined with oxygen and ignited, releasing energy in the form of heat, light, or mechanical work, and producing carbon dioxide and water vapor as byproducts.

REASONS WHY CARBON-BASED FUELS ARE USED:

1. **Firewood**:
   - Availability and accessibility
   - Low cost
   - Renewable resource (if sustainably harvested)
   - Can be used for cooking, heating, and power generation
   - Does not require complex processing or refining
   - Can be used in traditional and rural settings

2. **Charcoal**:
   - High energy density
   - Portable and easy to store
   - Can be used for cooking, heating, and industrial processes
   - Does not produce smoke or toxic fumes when burned
   - Can be made from waste wood or biomass
   - Has a long shelf life

3. **Paraffin (Kerosene):**
   - High energy density
   - Clean-burning and smokeless
   - Can be used for lighting, cooking, and heating
   - Has a long shelf life
   - Does not require complex infrastructure for transportation and storage
   - Can be used in aviation and rocket fuel

4. **Petrol (Gasoline):**
   - Has high energy density
   - Easy to refine and process
   - Can be used in internal combustion engines for transportation and power generation
   - Has a high octane rating, making it suitable for high-compression engines
   - Can be blended with other fuels to improve performance
   - Has a wide range of applications, from small engines to industrial power generation

5. **Diesel:**
   - High energy density
   - High compression ratio, making it efficient for heavy-duty applications
   - Can be used in internal combustion engines for transportation, power generation, and industrial processes
   - Has a high cetane rating, making it suitable for compression ignition engines
   - Can be used in marine and aviation applications
   - Has a wide range of applications, from small generators to large industrial equipment.

These reasons highlight the advantages and benefits of each fuel, making them suitable for various applications and uses.

B Know and appreciate the difference between renewable and non-renewable fuels and understand that non-renewable fuels are not sustainable (k, u)

• Discuss and report on the meaning of the terms 'renewable' and 'non-renewable' as applied to fuels, and then use data to estimate how long the world's coal, oil and natural gas reserves are likely to last at the current rates of usage.
• Research on the idea of 'sustainability' and write a report on how the use of fuel in your locality can be made more sustainable.

RENEWABLE FUEL

A renewable fuel is a fuel that can be replenished naturally over time, typically from natural resources like plants, trees, or waste materials.

Illustration: A tree farm where trees are harvested for firewood or wood pellets. As the trees are harvested, new trees are planted to replace them, making the fuel source renewable.

Example: Biomass fuels like firewood, charcoal (made from sustainable wood sources), biofuels, and biogas.

NON-RENEWABLE FUEL

A non-renewable fuel is a fuel that cannot be replenished naturally over time, typically from finite resources like fossil fuels.

Illustration: An oil well extracting crude oil from the ground. Once the oil is extracted, it cannot be replaced or replenished.

Example: Fossil fuels like petrol, diesel, paraffin, and coal.

FUEL SUSTAINABILITY

Fuel sustainability refers to the ability of a fuel source to meet the energy demands of the present without compromising the ability of future generations to meet their own energy demands.

Illustration: A sustainable fuel cycle where fuel is produced, used, and then replaced or replenished, ensuring a continuous and sustainable supply.
Example: A forest where trees are harvested for firewood, and new trees are planted to replace them, ensuring a sustainable supply of fuel.

In summary, renewable fuels are sustainable and can be replenished naturally, while non-renewable fuels are finite and cannot be replaced once depleted. Fuel sustainability ensures that fuel sources meet present demands without compromising future energy needs.

RENEWABLE AND NON-RENEWABLE CARBON-BASED FUELS

1. **Firewood**: Renewable fuel
   - Reason: Firewood is a biomass fuel that can be sustainably harvested from forests or plantations, and it can be replenished naturally.

2. **Charcoal**: Renewable fuel
   - Reason: Charcoal is made from wood, and if the wood is sourced sustainably,

charcoal can be considered a renewable fuel.

3. **Petrol**: Non-renewable fuel
   - Reason: Petrol is a fossil fuel derived from crude oil, which takes millions of years to form and is finite.

4. **Diesel**: Non-renewable fuel
   - Reason: Diesel is also a fossil fuel derived from crude oil, making it finite and non-renewable.

5. **Paraffin**: Non-renewable fuel
   - Reason: Paraffin, also known as kerosene, is a refined product derived from crude oil, making it a non-renewable fuel source.

WAYS TO MAKE FUEL USE MORE SUSTAINABLE

Major ways can significantly contribute to more sustainable fuel use, reducing environmental impacts and promoting a cleaner energy future as explained below:

Fuel Efficiency and Conservation: Improve vehicle fuel efficiency, use fuel-efficient technologies, and implement fuel-saving measures like turning off engines, using public transport, or carpooling.
Fuel Switching and Blending: Switch from fossil fuels to renewable fuels like biofuels, biogas, or electricity, and blend fossil fuels with renewable fuels to reduce emissions and dependence on fossil fuels.
Sustainable Production and Land Use: Ensure sustainable production and harvesting practices for renewable fuel sources like biomass or biofuels, and promote sustainable land use practices for biofuel crops or biomass production.
Alternative Energy Sources and Technologies: Promote alternative energy sources like solar, wind, or hydro power to reduce dependence on fuels, and continuously research and develop new sustainable fuel technologies and alternatives.
Carbon Capture and Storage: Capture and store carbon emissions from fuel use to reduce greenhouse gas emissions, and utilize waste materials as fuel sources through waste-to-energy technologies.

C Know and appreciate the impact of burning carbon-based fuels on the environment (k, u)

HOW THE BURNING OF CARBON-BASED FUELS IMPACT THE ENVIRONMENT

Air Pollution: Burning carbon-based fuels releases harmful pollutants like particulate matter, nitrogen oxides, sulfur dioxide, and volatile organic compounds, contributing to poor air quality and negative health effects.
Mitigation: Implement emission controls like scrubbers, electrostatic precipitators, and fabric filters; promote cleaner fuels like natural gas or renewable energy.

Climate Change: Burning carbon-based fuels releases carbon dioxide, a greenhouse

gas that contributes to global warming and climate change.
Mitigation: Transition to renewable energy sources like solar, wind, or hydro power; implement carbon capture and storage technologies; increase energy efficiency.

Acid Rain: Burning carbon-based fuels releases sulfur dioxide and nitrogen oxides, which combine with water and oxygen to form acid rain, damaging ecosystems and infrastructure.
Mitigation: Implement emission controls like scrubbers; switch to cleaner fuels like natural gas or renewable energy; add alkaline substances to neutralize acidity.

Water Pollution: Burning carbon-based fuels can contaminate water sources through wastewater disposal or cooling system discharges.
Mitigation: Implement proper wastewater treatment and disposal; use dry cooling systems or hybrid cooling towers; promote water conservation.

Land Degradation: Extracting, processing, and transporting carbon-based fuels can lead to habitat destruction, soil erosion, and land subsidence.
Mitigation: Implement sustainable extraction practices; restore degraded lands through reclamation and reforestation; promote renewable energy sources.

Health Impacts: Burning carbon-based fuels can cause respiratory problems, cardiovascular disease, and other health issues due to air pollution.
Mitigation: Promote cleaner fuels and energy sources; implement emission controls; increase public awareness and education on air quality and health impacts.

By understanding these environmental impacts and implementing mitigation strategies, we can reduce the harmful effects of burning carbon-based fuels and transition towards a more sustainable energy future.

D Understand the processes of making charcoal, but recognise that the use of charcoal as a fuel is cheap, efficient, and sustainable only if it is made from wood that can be regrown easily (u, s)

• Research on the process of making charcoal from waste organic material, and energy- saving charcoal stoves, and then explain the chemistry of what happens when organic material burns in a limited supply of oxygen.

MAKING CHARCOAL BRIQUETTES FROM WASTE ORGANIC MATERIALS:

Materials Needed:
- Waste organic materials (e.g., sawdust, rice husks, coconut shells)
- Charcoal dust or powder
- A binding agent (e.g., starch, clay)
- Water
- A mixing device (e.g., hammer mill, blender)
- A briquette machine or press
- A drying rack or oven

Procedure:

1. Charcoal Production: Produce charcoal from wood through carbonization.
2. Crushing and Milling: Crush and mill the charcoal into a fine powder.
3. Mixing: Mix the charcoal powder with a binding agent and water to create a uniform blend.
4. Briquetting: Use a briquette machine or press to shape the blend into briquettes.
5. Drying: Dry the briquettes to remove excess moisture.
6. Curing: Allow the briquettes to cure for several hours or days to harden.

Purification Process:

- Sieving: Sieve the briquettes to remove any impurities or irregularly shaped briquettes.

Applications:

- Fuel: Use the charcoal briquettes as a fuel for cooking, heating, or industrial processes.
- Barbecues and Grills: Use the charcoal briquettes as a fuel for barbecues and grills.

Note: The specific steps and purification processes may vary depending on the desired charcoal briquette quality and application. Additionally, proper safety measures should be taken during the process to avoid accidents and ensure a safe working environment.

MAKING CHARCOAL FROM WOOD:

Materials Needed:

- Trees (preferably hardwoods like oak, maple, or beech)
- Axe or chainsaw for felling and cutting
- Kiln or pit for carbonization
- Heat source (e.g., firewood, diesel)
- Ventilation system
- Water for cooling
- Sieves or screens for purification

Procedure:

1. Harvesting: Select and fell trees, then cut them into manageable logs.
2. Splitting: Split logs into smaller pieces to increase surface area.
3. Drying: Dry wood pieces to reduce moisture content.
4. Loading: Load wood pieces into kiln or pit.
5. Carbonization: Heat wood in kiln or pit to high temperatures (200-300°C) in absence of oxygen.
6. Cooling: Allow charcoal to cool before removing from kiln or pit.

Purification Process:

- Sieving: Sieve charcoal through screens or sieves to remove impurities and achieve uniform size.

Applications:

- Fuel: Use charcoal as fuel for cooking, heating, or industrial processes.
- Water Filtration: Use charcoal as filter medium to remove impurities from water.
- Agriculture: Use charcoal as soil amendment to improve soil fertility and structure.

Note: The specific steps and purification processes may vary depending on desired charcoal quality and application. Additionally, proper safety measures should be taken during the process to avoid accidents and ensure a safe working environment.

THE CHEMISTRY BEHIND BURNING ORGANIC MATERIAL BURNS IN A LIMITED SUPPLY OF OXYGEN

When organic material burns in a limited supply of oxygen, it undergoes a process called pyrolysis or carbonization.

Decomposition: The organic material (e.g., wood) breaks down into simpler molecules, releasing volatile gases and liquids.

Dehydration: Water molecules (H2O) are released, leaving behind a carbon-rich material.

Decarboxylation: Carbon dioxide (CO2) is released, leaving behind a carbon-rich material.

Pyrolysis: The carbon-rich material breaks down into:

a. Volatile compounds (e.g., methane, CH4; hydrogen, H2; and other hydrocarbons)

b. Char (carbon, C): the solid residue, which is the charcoal

c. Tar: a liquid mixture of hydrocarbons

Carbonization: The char (carbon) is the final product, which is the charcoal.

Chemical equations:

$C_6H_{12}O_6$ (wood) → C (char) + H_2O (water) + CO_2 (carbon dioxide) + CH_4 (methane) + other hydrocarbons

Note: The specific chemical equations and reactions may vary depending on the type of organic material and the conditions of the pyrolysis process.

In summary, burning organic material in a limited supply of oxygen leads to pyrolysis, which breaks down the material into simpler molecules, releasing volatile gases and liquids, and leaving behind a carbon-rich solid residue, which is the charcoal.

E Know and appreciate the physical properties and uses of carbon dioxide (k, u)

• From your prior learning of making carbon dioxide by reacting limestone with dilute hydrochloric acid; use apparatus to collect the gas, and then explain the chemical reaction and the property when tested with a lighted splint.

CARBON DIOXIDE GAS

Molecular Formula: CO_2

Elemental Composition: Carbon & Oxygen

Chemical Structure: O=C=O

Molecular Weight: 44.01 g/mol

Category: Covalent compound (Formed by sharing of electrons)

Properties:

Color: Colorless

Odor: Odorless

Taste: Slightly acidic

State: Gas at room temperature and pressure

Density: 1.98 kg/m^3

Test with a lit splint: Extinguishes a lit splint with a "hissing" sound, indicating the presence of CO_2.

Occurrence:

- Found in Earth's atmosphere (0.04%)
- Released through human activities (fossil fuel combustion, deforestation)
- Present in volcanic gases and ocean water

Word Equation Of Carbon Dioxide Production:

Limestone (Calcium Carbonate) + Dilute Hydrochloric Acid → Calcium Chloride + Water + Carbon Dioxide

In chemical symbols:

$CaCO_3$ (limestone) + HCl (dilute hydrochloric acid) → $CaCl_2$ (calcium chloride) + H_2O (water) + CO_2 (carbon dioxide)

USES OF CARBON DIOXIDE

Food and Beverages: CO_2 is used to create the fizz in soft drinks, beer, and sparkling water, making them refreshing and carbonated.

Industrial Applications: CO_2 is used in oil recovery, chemical synthesis, and power generation, helping to extract resources and produce energy.

Cooling and Agriculture: CO_2 is used as a refrigerant in commercial and industrial cooling systems, and in greenhouses to enhance plant growth and photosynthesis.

Safety and Cleaning: CO_2 is used in fire extinguishers to put out electrical fires, and as a solvent for cleaning surfaces and equipment.

Environmental and Energy Applications: CO_2 is used in carbon capture and storage, enhanced oil recovery, and other technologies to reduce greenhouse gas emissions and promote sustainable energy solutions.

F Understand how the increase in carbon dioxide in the air can cause the atmosphere and the oceans to get warmer (u)

• Research and report on how an increase in carbon dioxide in the air can cause the atmosphere and the oceans to get warmer; what does this tells us about the nature of carbon dioxide? Then, explain the effect of carbon dioxide on climate.

ATMOSPHERIC AND OCEAN WARMING

The increase in carbon dioxide in the air leads to atmospheric and oceanic warming through several mechanisms:

Trapping heat: CO_2 absorbs infrared radiation, trapping heat in the atmosphere and preventing it from being released into space.

Greenhouse effect: CO_2 is a greenhouse gas, enhancing the natural greenhouse effect and leading to an increase in global temperatures.

Ocean absorption: The oceans absorb some of the excess CO_2, which increases their acidity and temperature.

Feedback loops: Warmer oceans release more CO_2, amplifying the warming effect.

Therefore this tells us that the nature of carbon dioxide is that of a potent greenhouse gas, capable of altering the Earth's energy balance and leading to significant climate changes.

IMPACTS OF CARBON DIOXIDE ON CLIMATE

Global Warming: CO_2 traps heat, increasing global temperatures and altering climate patterns. (Example: 2020 was the hottest year on record, with temperatures 1.2°C above pre-industrial levels.)

Extreme Weather Events: CO_2-influenced climate change leads to more frequent and intense heatwaves, droughts, and storms. (Example: Hurricane Harvey in 2017 was intensified by CO_2-driven climate change.) These impacts demonstrate the significant effects of carbon dioxide on the Earth's climate, leading to rising temperatures and extreme weather events.

Understand what greenhouse gases are, where they come from, and how they are affecting climate (u)

•Discuss and produce posters to explain why air pollution is a global problem and why it can only be properly controlled if all the countries of the world agree to collaborate.

GREENHOUSE GASES:

Greenhouse gases (GHGs) are gases that trap heat in the Earth's atmosphere, leading to global warming. Examples:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Ozone (O_3)
- Fluorinated gases (F-gases)

SOURCES OF GREENHOUSE GASES

- Human activities: burning fossil fuels, deforestation, agriculture, industrial processes
- Natural sources: volcanic eruptions, wildfires, ocean releases

WAYS GREENHOUSE GASES ARE AFFECTING THE CLIMATE

Major ways Greenhouse Gases are affecting the climate include:

Rising Global Temperatures: The average global temperature has risen by about 1°C since the late 1800s, leading to:

- Increased heatwaves, droughts, and water scarcity
- Melting of polar ice caps, glaciers, and sea-level rise
- Changes in seasonal patterns and weather extremes.

Extreme Weather Events: Greenhouse gases intensify weather events, leading to:

- More frequent and intense storms, hurricanes, and typhoons
- Severe droughts, wildfires, and heatwaves
- Unpredictable and dangerous weather patterns

Sea-Level Rise: Melting ice caps and glaciers cause sea levels to rise, resulting in:

- Coastal erosion, flooding, and saltwater intrusion
- Loss of coastal ecosystems, habitats, and biodiversity

- Displacement of coastal communities and cities

Changes in Precipitation Patterns: Greenhouse gases alter global precipitation patterns, leading to:
- Droughts, water scarcity, and impacts on agriculture
- Floods, landslides, and infrastructure damage
- Changes in ecosystems, biodiversity, and food chains.

Loss of Biodiversity: Climate change affects ecosystems, leading to:
- Extinctions, habitat loss, and species migrations
- Disruptions to food chains, fisheries, and agriculture
- Decreased ecosystem resilience and adaptabilitYy

CONTROLLING THE NEGATIVE EFFECTS OF GREENHOUSE GASES

- Transition to renewable energy sources
- Increase energy efficiency and conservation
- Electrify transportation and industry
- Carbon capture and storage technologies
- International cooperation and climate policies (e.g., Paris Agreement)

All countries can control GHG emissions by:
- Implementing policies and regulations
- Investing in clean energy and technology
- Promoting sustainable land use and forestry practices
- Encouraging individual actions and behavior change
- Collaborating globally to address this shared challenge

H Understand the origin of hard water in limestone areas and investigate how it can be softened (u, s)
- Research on how rainwater becomes hard as it soaks through limestone.
- Describe how hard water affects soap.
- Discuss, research and explain how adding washing soda (sodium carbonate) results in reducing the water 'hardness'.

WATER HARDNESS

Hard water is water that contains high levels of dissolved minerals, specifically calcium (Ca) and magnesium (Mg) ions. These minerals make water "hard" because they react with soap and other cleaning agents, making it difficult to lather or foam. Hard water can also lead to scaling, which is the deposition of mineral deposits in pipes and appliances.

HOW RAINWATER BECOMES 'HARD'

In limestone areas, hard water originates from the dissolution of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) from limestone rocks in the ways below;

1. **Limestone formation:** Limestone is formed from the accumulation of calcium carbonate ($CaCO_3$) from ancient marine organisms, such as coral, shells, and skeletons.
2. **Rainwater absorption:** Rainwater absorbs CO_2 from the atmosphere, forming a weak carbonic acid (H_2CO_3).
3. **Reaction with limestone:** The acidic rainwater reacts with limestone, dissolving

the calcium carbonate ($CaCO_3$) and releasing calcium (Ca) and bicarbonate (HCO_3^-) ions.

4. **Groundwater flow:** The water, now rich in calcium and bicarbonate ions, flows through the ground and into aquifers.

5. **Magnesium contribution:** Magnesium, present in smaller amounts in limestone, also dissolves and contributes to the hardness of the water.

6. **Hard water emergence:** The water, now containing high levels of calcium and magnesium ions, emerges as hard water in wells, springs, or surface water sources.

In summary, hard water in limestone areas originates from the dissolution of calcium and magnesium carbonates in limestone rocks, which are then carried into the water supply by rainwater and groundwater flow.

TYPES OF WATER HARDNESS

Two types exists i.e:

1. Temporary Hardness (Carbonate Hardness)

- *Caused* by calcium (Ca) and bicarbonate (HCO_3) ions
- *Sources*:
    - Surface water (rivers, lakes, reservoirs)
    - Groundwater (wells, springs) in limestone or dolomite aquifers
    - Municipal water supplies that use surface or groundwater sources
    - Rainwater that has passed through carbonate-rich soils or rocks

2. Permanent Hardness (Non-Carbonate Hardness)

- *Caused* by calcium (Ca) and magnesium (Mg) sulfates, chlorides, and nitrates
- *Sources*:
    - Groundwater (wells, springs) in aquifers with high sulfate or chloride concentrations
    - Seawater or brackish water
    - Municipal water supplies that use desalination or wastewater treatment
    - Industrial processes that use water with high levels of dissolved minerals.

Note that some water sources may exhibit both temporary and permanent hardness, depending on the specific geology and water chemistry.

SOFTENING WATER HARDNESS

Temporary Hardness:

Boiling:
- Simply boil the water to precipitate calcium carbonate ($CaCO_3$) out of solution.
- Effective for small quantities of water.

Lime Softening:
- Add lime (calcium oxide, CaO) to the water to remove calcium and bicarbonate ions.
- Forms calcium carbonate precipitate, which can be removed.

Precipitation with Washing Soda:
- Add washing soda (sodium carbonate, Na_2CO_3) to the water to precipitate calcium carbonate.

Permanent Hardness

Distillation:

- Vaporize the water and then condense it, leaving minerals behind.
- Effective, but energy-intensive.

Chemical Softening:

- Add chemicals like sodium carbonate (Na_2CO_3) or sodium hydroxide (NaOH) to remove calcium and magnesium ions.
- Forms precipitates or complexes with the minerals, making the water softer.

Ion Exchange (IX):

- Use a resin to exchange calcium and magnesium ions for sodium or potassium ions.
- Regenerate the resin with salt (sodium chloride) periodically.

Reverse Osmosis (RO):

- Use a semipermeable membrane to remove calcium and magnesium ions from the water.
- Produce a permeate stream (soft water) and a concentrate stream (hard water).

Electrodialysis (ED):

- Use an electric field to remove calcium and magnesium ions from the water.
- Produce a dilute stream (soft water) and a concentrate stream (hard water).

HOW WATER HARDNESS AFFECTS SOAP

Reduced Lather Formation:

- Hard water ions (Ca2+ and Mg2+) react with soap to form a sticky scum, reducing lather.
- Illustration: Soap + Hard Water = Scum + Less Lather

Soap Scum Formation

- Hard water ions combine with soap to form a white, sticky scum.
- Example: Soap scum buildup on skin, hair, and surfaces.

Increased Soap Consumption

- Hard water requires more soap to produce a lather.
- Illustration: Hard Water + Soap = More Soap Needed

J Understand how the properties and uses of the allotropes of carbon relate to their structures (u)

• Research and make models to explain the structures of diamonds and graphite, and explain how their properties determine the uses of carbon structures such as carbon fibres and grapheme.

ALLOTROPY

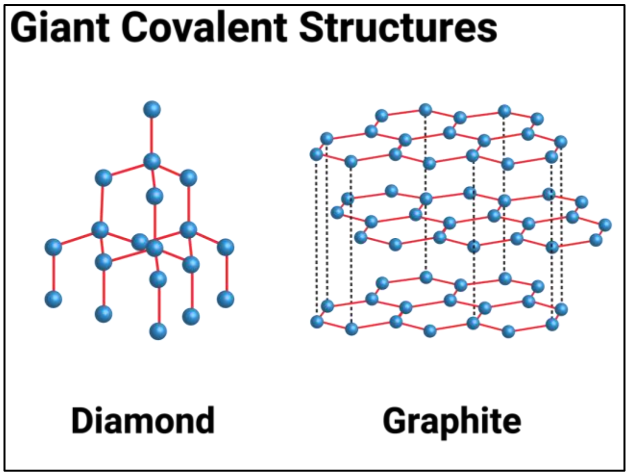
Allotropy refers to the existence of two or more different physical forms of the same element with the same atomic number but differ in their atomic arrangement, crystal structure, or molecular configuration. These different forms are called allotropes. Allotropes are different physical forms of the same element, which can exhibit varying physical and chemical properties.

Examples:

- **Carbon** allotropes includes:
  - Diamonds
  - Graphite (used in pencils)
  - Fullerenes (hollow spheres)
  - Nanotubes (tiny tubes)

-**Phosphorus** allotropes includes:
- White phosphorus (toxic and waxy)
- Red phosphorus (less reactive and more stable)
- Black phosphorus (graphite-like structure)

THE STRUCTURE OF DIAMONDS AND GRAPHITE AS ALLOTROPES OF CARBON:



Diamonds:
- Crystal structure: Face-centered cubic (FCC)
- Each carbon atom is bonded to four neighboring atoms in a strong, three-dimensional lattice
- Extremely hard and rigid, with high thermal conductivity

Graphite:
- Crystal structure: Hexagonal or layer lattice
- Each carbon atom is bonded to three neighboring atoms in a planar, hexagonal arrangement
- Weak van der Waals forces hold layers together, making graphite soft and slippery.

These different structures result in distinct properties, making diamonds ideal for industrial cutting tools and graphite perfect for pencil lead and lubricants.

THE PROPERTIES OF DIAMONDS AND GRAPHITE THAT DETERMINE THEIR USES:

The following properties make diamonds and graphite versatile materials with various industrial, technological, and artistic applications.

Diamonds:

Hardness: Diamond is the hardest substance known, making it ideal for:
- Cutting and drilling tools (e.g., diamond-tipped saw blades)

Thermal Conductivity: Diamond is an excellent heat conductor, making it suitable for:
- Electronic heat sinks and thermal management

Optical Transparency: Diamond is highly transparent, making it perfect for:
- High-pressure windows and optical components

Chemical Inertness: Diamond is resistant to chemicals, making it ideal for:
- Chemical reaction vessels and containers

High Dispersion: Diamond has a high dispersion coefficient, making it suitable for brilliant gemstones and jewelry

Graphite:

Softness: Graphite is soft and slippery, making it perfect for:

- Pencil lead and lubricants (e.g., graphite powder in locks)

Conductivity: Graphite is a good electrical conductor, making it suitable for:

- Electrodes in batteries and electrolysis

Thermal Resistance: Graphite has low thermal conductivity, making it ideal for:

- Heat shields and thermal insulation

Chemical Inertness: Graphite is resistant to chemicals, making it suitable for:

- Crucibles and reaction vessels

Lubricity: Graphite is highly lubricating, making it perfect for:

- Bearings and gears in machinery

APPLICABLE SCENARIOS

Scenario 1:

Kampala International University wants to reduce its carbon footprint by 20% within the next year. The university's current carbon footprint is 10,000 metric tons of CO_2 equivalent ($MTCO_2$ e).

Task: As a chemistry learner, make a written advice to achieve this goal.

Scenario 2:

A coastal community dependent on shellfish farming is experiencing declines in production due to ocean acidification caused by excess carbon dioxide absorption. The dependants are angry of the consequences. Their leader has consulted you for advice he can use in the workshop already organized.

Task: As a chemistry learner, develop a plan to be used.

Scenario 3:

Part of Kampala town wants to increase its urban forest cover to sequester more carbon dioxide and mitigate the urban heat island effect. Currently, the town has 10% tree cover, and the goal is to increase it to 20% within the next two years. The town mayor responsible for the task has approached you for more details from what he knows.

Task: As a chemistry learner, make a detailed write up to satisfy the town mayor

END