SACRED HEART COLLEGE SCIENCE DEPARTMENT YEAR 11 SCIENCE

Name _____

INTERNAL ASSESSMENT: CARBON CYCLING

SCIENCE 1.14

Independent research booklet

Resources:

Ultranet page

- **Power points**
- **Animations**
- **Weblinks**
- **Videos**
- **Diagrams**
- **Other info in folders**

Library books

You are advised to do this research thoroughly and not to rush for the sake of completion. Your *in depth* understanding of the Carbon cycle will be tested in this assessment.

Achievement Standard Science 90953: *Demonstrate understanding of carbon cycling*

Credits: 4

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of carbon cycling.	Demonstrate in-depth understanding of carbon cycling.	Demonstrate comprehensive understanding of carbon cycling.

Introduction

Carbon atoms cycle through all parts of Earth. Carbon is constantly entering the atmosphere, mainly in the form of carbon dioxide and methane. At the same time, it is being removed by green plants, the oceans, and even rocks. It is also stored for long or short periods of time. This is the carbon cycle.

This assessment activity requires you to demonstrate your understanding of the carbon cycle. To do this, you will learn about the world-wide carbon cycle and then write an assessment, answering questions to explain, in depth, the links between the addition, removal, and storage of carbon. You will have access to common resource material during the assessment task.

You will study information, images, diagrams, and data from activities such as laboratory experiments, class notes and teaching, and personal research. You will then need to answer questions about the carbon cycle that could be used in a teaching resource for Level 1 students.

Learning about the carbon cycle

Carbon cycling consists of the addition, removal, and storage of carbon.

- Addition is the adding of carbon to the atmosphere as carbon dioxide and methane by:
  - respiration, excretion, decay
  - combustion, e.g. the burning of fossil fuels
  - volcanic activity
- Removal is the removing of carbon from the atmosphere by:
  - photosynthesis, e.g. by phytoplankton, forests
  - dissolving in water e.g. in the surface of oceans
- Storage is the holding of carbon as:
  - short-term storage, e.g. by forests
  - long-term storage by sediments, carbonate rocks (limestone), coal, oil, natural gas, and subduction resulting in carbon rich metamorphic and igneous rocks.

You will do a test in which you will demonstrate:

- what you have learned about the addition, removal, and storage of carbon as a result of your study of the biological and geological carbon cycle including:
- how long carbon remains in some stages of the cycle
- how the key stages of carbon cycling are linked, taking into consideration the addition, removal, and storage of carbon
- explanations as to how the key stages are linked
- how key stages are interconnected, which shows the complexity of the carbon cycle.

You will be given this information in your internal assessment and you will need to be able to define all terms in it and expand on the detail of each process.

READ carefully

IDENTIFY the unfamiliar terms and define them

LOCATE more information on each process

BE ABLE TO EXPLAIN IN YOUR OWN WORDS

The Carbon Cycle

1. What's so Special About Carbon?

- Carbon is one of the most important elements in the earth system.
- The carbon atom has four valence electrons and has the ability to form bonds with as many as four other atoms including other carbon atoms. Carbon can readily bond with almost any element on the periodic table.
- Carbon is unparalleled among elements in its ability to bond with itself almost indefinitely, forming carbon chains, loops and branches.
- What's more, the bonds forged between carbon atoms are very, very strong.

2. Why is Carbon so Important?

- All life, from a whale to a redwood tree, down to a lady bug, to an amoeba, down to our cells, even to the components inside our cells — all of it contains carbon. Carbon is the "duct tape of life," It holds us together.
- Carbon is the main source of food energy. When you eat carbon molecules (plants and animals), the digestive juices in your stomach break the carbon bonds inside and release the energy in the form of calories.
- Hydrocarbon Molecules (coal, oil, natural gas) are the primary sources of energy in our modern society.
- Carbon Molecules (CO_2 and CH_4) in the atmosphere are greenhouse gasses and are play a key role in climate change.

3. The Carbon Cycle

- Carbon atoms continually move through living organisms, the oceans, the atmosphere, and the rocks that make up the earth system. This movement is known as the carbon cycle.
- The paths taken by carbon atoms through this cycle are extremely complex, and may take years to millions of years to come full circle.
- In the cycle there are various stores of carbon and processes by which the various stores exchange carbon on various time scales.

4. Atmospheric Carbon

- Carbon is found in the atmosphere mainly as Carbon Dioxide (CO_2) with a smaller amounts of Methane (CH_4).
- About 750 billion tons (Gigatons - Gt) of carbon is stored in earth's atmosphere. This may seem a lot but carbon is considered a trace gas in the atmosphere because it is much less than 1% and much less abundant than oxygen or nitrogen.
- However, this trace gas plays a vital role in sustaining life on Earth and in controlling the Earth's climate by trapping heat in the atmosphere.
- Atmospheric CO_2 resides in the atmosphere for about 100 years before it interacts with other parts of the earth in four subcycles (parts of the carbon cycle):

    - Rock Subcycle
    - Ocean Subcycle
    - Biological Subcycle
    - Fossil Fuel Subcycle

5. **Carbon Sinks** - Amount of stored carbon in Billions of Metric Tons (Gt)

- Land Plants and ocean Phytoplankton " Biomass" 600 (Gt)
- Fossil Fuels 10,000 (Gt)
- Carbon In Atmosphere 750 Gt
- Carbon In Rocks 100,000,000 (Gt)
- Carbon In Ocean Water 40,000 (Gt)
- Animals, Soil and Marine Sediment " Organic Matter" 1600 Gt

6. Time Scales

- Biological Subcycle Short Term Days - Years
- Ocean Subcycle Short Term 10's - 100's of Years
- Fossil Fuel Subcycle Short Term 10's of Years
- Fossil Fuel Subcycle Long Term Millions of Years
- Rock Subcycle Long Term Millions of Years

7. Rock Subcycle

- Carbon dioxide in the atmosphere reacts with water vapour to form carbonic acid.
- $CO_2 + H_2O \longrightarrow H_2CO_3$ (carbonic acid)
- This chemical weathers (breaks down) rocks ($CaSiO_3$) and the carbon forms calcium carbonate ($CaCO_3$, the mineral calcite) which dissolves in rainwater and is carried to the oceans.
- $CaSiO_3 + H_2CO_3 \longrightarrow H_2O + CaCO_3 + SiO_2$
- Precipitation, warm temperatures and vegetation enhance rates of chemical weathering.
- In the ocean, the carbon, $CaCO_3$ precipitates out of the ocean water, forming layers of sediment on the sea floor.
- As the Earth's plates move, through the processes of plate tectonics, the $CaCO_3$ sediments are subducted underneath the continents.
- Under the great heat and pressure far below the Earth's surface, the sediment melts and reacts with other minerals, releasing carbon dioxide.
- The carbon is then re-emitted into the atmosphere as CO_2 through volcanic eruptions.
- The rock subcycle contains the largest amount of stored carbon and is a long-term cycle (millions of years time scale).
- Earth's greenhouse effect has been regulated by the rock subcycle throughout geologic time.
- Often referred to as Earth's Thermostat .
- During times of extreme heat due to an increase in volcanic eruptions, increased chemical weathering have lowered the earth's temperature.
- Extreme cold periods are interrupted by an increase in volcanism and can be lessened by a decrease in chemical weathering.

8. Ocean Subcycle

- CO_2 from the atmosphere dissolves into cold surface ocean water near the North and South poles (producing carbonic acid).
- $CO_2 + H_2O \longrightarrow H_2CO_3$
- The carbon is carried to the deep ocean by sinking currents, where it stays for hundreds of years.
- Eventually mixing brings the carbon back to the surface near the equator. The carbon in the warm tropical oceans will evaporate back into the atmosphere as CO_2.
- The ocean subcycle contains the second largest amount of stored carbon and is relatively short-term cycle (ten to hundred years time scale).
- Because of the temperature differences, the warm surface ocean contains 2,000 Gt carbon while the cold deep oceans contains 38,000 Gt of carbon.
- As the oceans warm they will be able to store less carbon, thus increasing the amount of CO_2 in the atmosphere.
- During colder climate periods, atmospheric CO_2 dissolves and accumulates in the oceans. Less atmospheric CO_2 makes the climate even colder, thus allowing more CO_2 to dissolve which makes the climate colder and so on…...
- In warmer climates, CO_2 evaporates from the ocean into the atmosphere. More atmospheric CO_2 makes the climate even warmer, thus allowing more evaporation of CO_2 which makes the climate warmer and so on…...

9. Biological Subcycle

- Producers are organisms that produce their own organic compounds using carbon dioxide from the atmosphere.
- The most important producer for the carbon cycle are plants on land and phytoplankton in the Earth's oceans.
- Carbon in the form of CO_2 is removed from the atmosphere and stored in producers thorough the process of photosynthesis.
- $CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$
- This requires energy from the sun.
- $C_6H_{12}O_6$ (glucose) is a simple carbohydrate (a "sugar" or "carb") which stored by the organism for energy.
- A consumer is an organism that consumes producers and uses their stored carbon for growth.
- Carbon from plants can be consumed and digested by animals (Consumers) or become part of the organic matter component of soil.
- Phytoplankton is consumed by marine life and accumulates on the ocean bottom sediments after the death of the consumers.
- The biomass (carbohydrates) from the producers after consumption or death is called "organic matter."
- Carbon is released back into the atmosphere from organic matter by on a short term time scale (from days to years) through the processes of Respiration and Decomposition
- Burning of biomass and/or organic matter can also transfer substantial amounts of carbon to the atmosphere
- Respiration
    - $C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$
    - Aerobic Reaction (Requires Oxygen)
    - Occurs in consumers of plants (animals and bacteria) when stored energy in organic carbon molecule is used.
- Decomposition
    - $C_6H_{12}O_6 \longrightarrow CO_2 + CH_4$
    - Anaerobic Reaction (No Oxygen)
    - Occurs in low oxygen and oxygen-free environments (soils, ocean floor, mammal intestines, landfills) where anaerobic bacteria and fungi ferment the organic material.
- Carbon returns to the atmosphere as carbon dioxide and methane (CH_4).
- Methane will react with oxygen in the atmosphere to produce carbon dioxide and water.
- $CH_4 + O_2 \longrightarrow CO_2 + H_2O$
- CH_4 last only 10 years in the atmosphere before becoming CO_2

10. What are Fossil Fuels?

- Fossil = Preserved remains of past life
- Fuel = Substance combusted to produce energy (mainly thermal)

11. The Importance of Fossil Fuels

- Fossil Fuels deliver lots of energy (Joules) in a small volume
  - Gasoline: 364,000 kilojoules per kilogram
  - Coal: 7,193 kilojoules per kilogram
  - Compare to:
  - Wood: 3,600 kilojoules per kilogram
  - A “horse” (working 1 hour) uses 2,500 kilojoules
  - A human (working 1 hour) uses 200 kilojoules
  - Our Modern Civilization has been built upon abundant, cheap, high energy fossil fuels!!!

12. Fossil Fuel Subcycle

- On longer time scales (millions of years), the organic material buried in sediments eventually becomes rock.
- Fossil Fuels form rocks only if:
  - the concentrations of organic matter are very high in the sediment
  - the sediment is deposited in an anaerobic (low to no oxygen) environment.
- Large tropical swamps and the deep ocean floor are anaerobic environments where large amount of organic material may accumulate.
- Over the course of millions of years, the organic matter is converted to fossil fuels due to the higher temperatures and pressures associated with forming rocks.
- Chemically the organic molecules become hydrocarbons
- Fossil Fuels derived from Phytoplankton forms petroleum (tar, oil and natural gas).
- Fossil Fuels derived from plants forms coal.
- Combustion of Fossil Fuels release CO_2 back into the atmosphere.
- The example below is the combustion of the simplest hydrocarbon molecule, methane (CH_4).
- $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$
- Until recently, the flow of carbon stored in fossil fuels to the atmosphere was tiny—nearly zero. The fossil fuel storage represented a “dead-end” for the carbon cycle.
- Since the 1800’s, humans have been burning the 10,000 Gt of carbon that had been stored in fossil fuels for millions of years.
- This is releasing carbon back into the atmosphere as CO_2 at an alarmingly fast rate.

http://www.slideshare.net/edstermer/carbon-cycle-3440224

Refer to the resources on your ultranet page to find the relevant information.

The basics

Carbon comes in many forms and compounds:

Graphite – draw and describe its structure and properties

Diamond – draw and describe its structure and properties

Carbon dioxide – draw and describe its structure and properties

Carbonates – draw and describe its structure and properties

(calcium carbonate in particular)

Methane – draw and describe its structure and properties

Glucose – draw and describe its structure and properties

Complete the table

Carbon form	Formula	Properties	Found in	Uses
Graphite				
Diamond				
Carbon dioxide				
Calcium carbonate				
Methane				
Glucose				

Carbon cycling

Define the following terms:

Respiration (include equation)

Photosynthesis (include equation)

Storage

Addition

Removal

Long term storage

Short term storage

Atmosphere

Biosphere

Geosphere

Decay

Phytoplankton

Limestone

Excretion

Combustion

Dissolving

Sediments

Fossil fuels:

How is each of the following formed?

Where is it stored?

How is it accessed – naturally/human activity?

How is the carbon released?

Coal

Oil

Natural gas

There are cycles within the carbon cycle – briefly describe each one –they are located in the:

Atmosphere	Geosphere
Oceans	Biosphere

Describe the Green house effect

What are the gases involved in the Greenhouse Effect?

How does Human Activity influence the levels of these gases?

Use a diagram to explain how the Greenhouse effect works.

Describe the effects of the Greenhouse effect – now and if it gets worse

What planet in our solar system has a Greenhouse effect? – Describe the conditions and effects of this.

Notes

Go to ‘animation 5’ on the ultranet page and copy the basic diagram onto this page:

From the animation copy the information down under each title:

ATMOSPHERE

BIOMASS

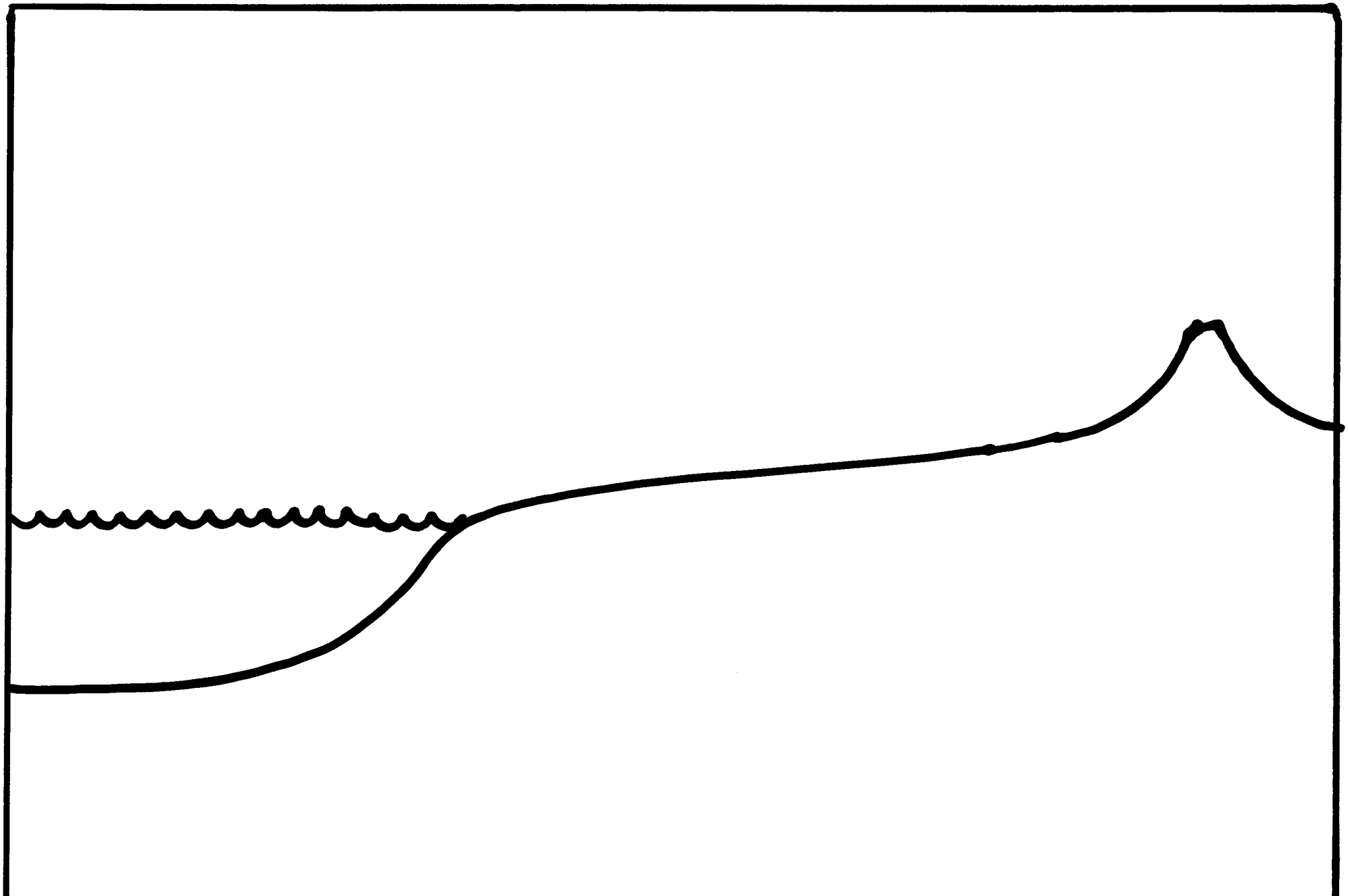
OCEANS

CARBONATES

SOIL

FOSSIL FUELS

The Carbon Cycle - draw onto this template a carbon cycle diagram



<u>Addition, removal and storage of carbon</u> Explain the terms above and indicate how long carbon atoms are involved in the different storage states:

Process involving carbon	Happens in	Processes involved	Length of time
Addition			
Removal			
Storage			

Print off at least 4 different carbon cycle diagrams and glue them in here:

Compare and contrast your diagrams – which parts of the carbon cycle do the show well/not so well. How could they be improved to show all of the aspects that we need to consider – see info page at the front of this booklet.

Make your own diagram using the information for all of the diagrams that you printed on the next page.

My carbon cycle diagram: