LESSON 10: CHEMISTRY OF THE ATMOSPHERE
UNIT 1: The Composition of the Atmosphere

Introduction:

Human beings can survive for couple days in the absence of water but this is not the same in the case of air. The air that we breathe is part of the atmosphere. In this lesson, the layers and composition of the atmosphere is revisited.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1) Describe how the different layers of the atmosphere are characterized.
2) Discuss how the change in the lapse rate at the troposphere affect the life on earth.
3) Enumerate the components of the atmosphere.

Course Materials:

Air and the Atmosphere

Air is the term used to describe the homogeneous mixture of gases that makes life on earth sustainable due to its dioxygen molecule component while the ***atmosphere*** refers to the thin air that is made up of a low-density fluid that extends few hundred kilometers from the surface of the earth thus surrounding the planet.

The layers of the atmosphere

The atmosphere is subdivided into different layers in accordance to their temperature profile (Figure 1).

The **troposphere** is the lowest part of the atmosphere. It is where the planet Earth's weather and air pollution takes place. It extends from the ground level to 1- to 15 km. The temperature change within the troposphere with respect to altitude (known as lapse rate) decreases at a rate of 5 to 6 K/km. The troposphere is the occurrence of earth's weather and air pollution.

An unwanted phenomenon may occur in the troposphere, known as thermal inversion. This happens when the lapse rate becomes positive; hence, the reversal of the normal behavior in the troposphere wherein the cold air at the surface of the earth is overlaid by the warmer air. Thermal inversion changes the dynamics of air movement resulting in air pollutants to be trapped near the earth's surface. Prolong occurrence can have several adverse effects on the population's health such as lung inflammation.

The tropopause is the layer of atmosphere of constant temperature found between the troposphere and the stratosphere.

Above the tropopause, is the **stratosphere**. It has a temperature profile that increases with the altitude up to a maximum of about 273K and it reaches at around 50 km from the surface of the earth. The layer's temperature profile is what suppresses air to undergo vertical motions.

The stratopause is the layer of atmosphere of constant temperature found between the stratosphere and the mesosphere.

Above the stratopause is the **mesosphere** with a temperature profile that is similar to the troposphere, that is the temperature increases as the altitude increases until it reaches the mesopause at an altitude of 85 km from the surface of the earth. In this layer, the gases are thick enough to slow down the meteors hurtling to the atmosphere, which when burn up leave fiery tails in the night sky.

The mesopause is the layer of atmosphere of constant temperature found between the mesosphere and the thermosphere.

Above the mesopause is the **thermosphere** with a lapse rate of 5K/km.

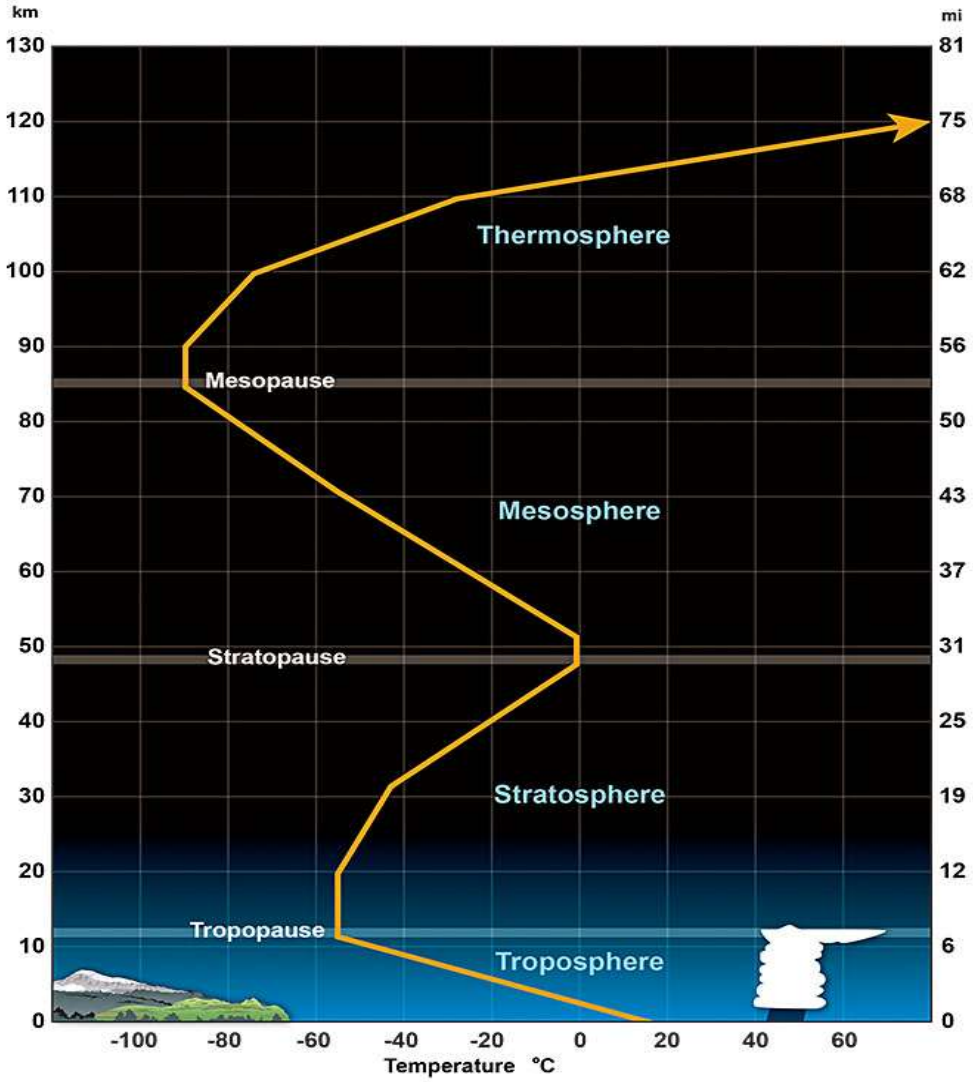


Figure 1: The Temperature Profile of the Atmosphere. Image source: www.weather.gov/jetstream/layers

The thermopause is the layer of atmosphere of constant temperature found between the thermosphere and the exosphere.

The outermost layer of the atmosphere is the **exosphere** which extends from the thermopause to about 10000 km from the surface of the earth. It is in this layer where satellites orbit the earth.

The components of the atmosphere

The atmosphere is a homogeneous mixture of various gases. Its main composition has remarkably steady for ages with nitrogen and oxygen being the main components. It is the abundance number of oxygen molecules in the atmosphere that makes life possible on earth.

COMPOSITION OF THE ATMOSPHERE

Gas	Percentage
Nitrogen	78%
Oxygen	21%
Argon	0.90000%
Carbon dioxide	0.03000%
Neon	0.00200%
Helium	0.00050%
Methane	0.00020%
Krypton	0.00010%
Hydrogen	0.00005%
Dinitrogen oxide	0.00005%

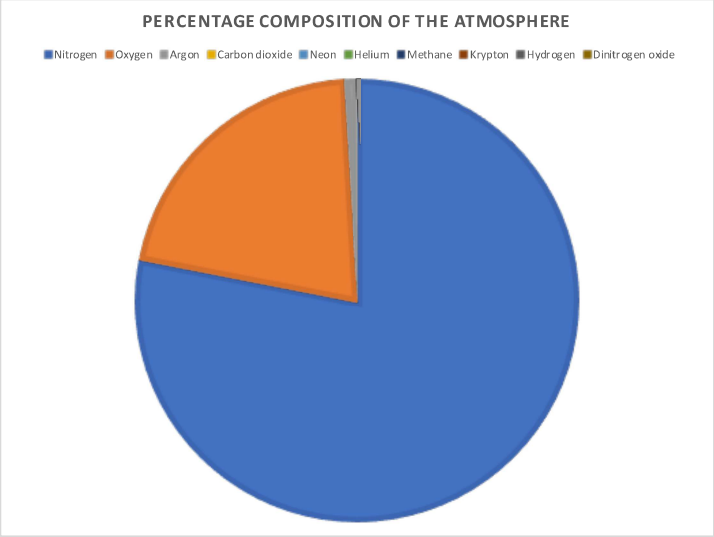


Figure 2: Composition of the Atmosphere

Activities and Assessment:

1. What are the different layers of the atmosphere and how they were characterized from each other?
2. What is thermal inversion and how does it occur? Describe how its occurrence produce adverse effect to humanity.
3. Name the main components of the earth's atmosphere?

LESSON 10: CHEMISTRY OF THE ATMOSPHERE
UNIT 2: Processes in the Atmosphere

Introduction:

Each of the layers of the atmosphere has distinct characteristics and compositions that influence the processes occurring therein. In this lesson, chemical process that are occurring in the troposphere and stratosphere are discussed.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1) Describe the impact of the processes in the troposphere on air quality.
2) Discuss how the stratospheric ozone works.
3) Describe how aerosols affect the earth's temperature and climate.

Course Materials:

Processes occurring at the troposphere

The composition of the stratosphere is dependent on the properties of gases that are present at the troposphere and the processes they undergo. If the trace gases in the troposphere are inert and do not react with the available free radicals, they will be transported to the stratosphere. Examples of these gases are chlorofluorocarbons (CFCs) and methyl chloride. However, there are trace gases that readily react to free radicals and sometimes cause formation of unwanted compounds in the atmosphere.

The presence of these free radicals in the troposphere are crucial to the formation of compounds that are responsible to pollution. According to the work Hiram I.I. Levy entitled "Photochemistry of minor constituents in the troposphere", the reaction of the $^{\bullet}OH$ radical with methane and nitrogen dioxide produces carbon monoxide and nitric acid, respectively.

While dioxygen molecules are abundant in the atmosphere, they are not considered as the principal oxidative species in the troposphere. This is because reactions of dioxygen molecules require higher activation energy compared to that of the free radicals such as the hydroxyl radical, $^{\bullet}OH$. Where are there free radicals come from?

Major sources of $^{\bullet}OH$ is the ozone photolysis with ultraviolet (UV) radiation during daytime, producing excited oxygen atom which rapidly reacts with water vapor.

$$O_3 + hv \rightarrow O_2 + O$$

$$O + H_2O \rightarrow 2 \cdot OH$$

During night time, the nitrite radical $^{\bullet}NO_2$ reacts with ozone (O_3) to produce the nitrate radical $^{\bullet}NO_3$.

$$NO_2 \cdot + O_3 \rightarrow NO_3 \cdot + O_2$$

Moreover, when the compound peroxyacetyl nitrate (PAN, $CH_3COOONO_2$) thermally decomposes in the presence of NO• also produce •OH radicals and convert NO_2•

$$CH_3COONO_2 \rightarrow CH_3CO_3 + NO_2\cdot$$

$$CH_3CO_3 + NO\cdot \rightarrow CH_3CO_2 + NO_2\cdot$$

$$CH_3CO_2 + O_2 \rightarrow CH_3O_2 + CO_2$$

$$CH_3O_2 + NO\cdot \rightarrow CH_3O + NO_2\cdot$$

$$CH_3O + O_2 \rightarrow CH_2O + HOO\cdot$$

$$HOO\cdot + NO\cdot \rightarrow \cdot OH + NO_2\cdot$$

$$CH_2O + \cdot OH \rightarrow CHO + H_2O$$

$$CHO + O_2 \rightarrow CO + HOO\cdot$$

$$HOO\cdot + NO\cdot \rightarrow \cdot OH + NO_2$$

Processes occurring at the stratosphere

The stratosphere is where the ozone layer can be found. Stratospheric ozone protects life in the surface of the earth by screening the harmful ultraviolet rays from the sun through the photodissociation mechanism.

$$O_3 + hv \rightarrow O_2 + O\cdot$$

$$O\cdot + O_2 \rightarrow O_3$$

The ozone in not consumed and the UV radiation is converted into heat. This is the reason behind the positive lapse rate profile of the stratosphere. Because the stratosphere is warmer compared to the troposphere, an inversion between the two layers occur. This traps the molecules found in the troposphere.

On the other hand, O_2 can be consumed if O• collides with O_3, the process known as the recombination reactions. This process is very slow and if it is the only means by which O_3 is consumed, then the ozone layer will be thicker than it really is.

$$O_3 + O\cdot \rightarrow 2O_2$$

Another way by which O_3 is consumed is catalysis of the recombination reactions by available free radicals such as NO•, NO_2•, H•, •OH, HO_2•, Cl•, ClO• and ClO_2•.

The thickness of the ozone layer is therefore due to the competition among these three reactions.

Aerosols

It is not only the gaseous compounds that have impact to the atmospheric conditions. Solid and liquid particulates, known as aerosols, also have consequences in atmospheric temperature and climate because they have the ability to alter the radiative processes of the Earth. An example of which is the soot as a product from the burning of fossil fuels.

Activities and Assessment:

1. The free radicals that are found in the troposphere have a significant role in air pollution. Discuss the mechanisms by which they were produced.
2. Elaborate the meaning of the statement: “The thickness of the ozone layer is therefore due to the competition among these three reactions”.
3. How do aerosols affect the earth’s atmospheric conditions?

LESSON 10: CHEMISTRY OF THE ATMOSPHERE
UNIT 3: Air Pollution, Sources and Effects

Introduction:

The atmosphere has its own ways of recreating the balance to make life sustainable for all its habitats. However, changes occur due the presence of pollutants in the atmosphere. In this lesson, we are to discuss the common compounds that pollute the air and how they do it.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1) Enumerate the ten groups of air pollutants and discuss their respective sources and effects.
2) Discuss how the incomplete internal engine combustion adds to air pollution.
3) Describe how greenhouse gases enhance the greenhouse effect.
4) Discuss the chemical reactions behind photochemical smog formation, stratospheric ozone destruction and acid rain formation.

Course Materials:

Air Pollutants

Air pollutants are products and by-products of different process such as combustion, industrial activities, natural resource processing and commercial services. They can be classified as ***primary pollutants*** (those that are directly emitted to the atmosphere) and ***secondary pollutants*** (those that are products of various chemical reactions in the atmosphere). There are ten groups of air pollutants according to the US EPA (Environment Protection Agency) official Hazardous Air Pollutants (HAPs) list:

1. Carbon dioxide (CO_2) and Carbon monoxide (CO)

   Carbon dioxide is produced from complete combustion of fuels and metabolic processes while carbon monoxide is derived from the incomplete combustions processes and from the photochemical transformation of volatile organic compounds (VOCs) by the free hydroxyl radical (•OH) generated in the atmosphere such as methane.

$$CH_4 + \cdot OH \rightarrow CH_3 \cdot + H_2O$$

$$CH_3 \cdot + O_2 + hv \rightarrow CO + H_2 + \cdot OH$$

   Carbon dioxide is considered toxic because it can replace oxygen uptake by hemoglobin.

2. NO_x: Nitrogen oxide (NO), nitrogen dioxide(NO_2) and dinitrogen oxide (N_2O)

   Nitrogen oxide is a product of combustion through the oxidation of air nitrogen at high temperature and can also be produced by lightning. It can also oxidize into nitrogen dioxide which is a precursor of acid rain and smog formation. Meanwhile, the dinitrogen

oxide is released by soil bacteria and can be converted as nitrogen oxide into the atmosphere.

3. SO_x: Sulfur dioxide (SO_2) and sulfur trioxide (SO_3)

   Sox are produced from the oxidation of sulfur-containing fuels and dihydrogen sulfide, H_2S. H_2S is a toxic gas that is produced from biological decay of organic matter and various human activities such as geothermal and industrial processes.

$$H_2S + O_3 \rightarrow H_2O + SO_2$$

$$2SO_2 + O_2 \rightarrow 2SO_3$$

4. Photochemical oxidants

   Photochemical oxidants are considered as secondary pollutants as they are products of chemical reactions from other pollutants. The common photochemical oxidants are ozone (which can be produced through lightning or photochemical reactions), peroxybenzonyl nitrate (PBzN), peroxyacyl nitrate (PAN), hydroxyl radicals ($^{\bullet}OH$) and nitrogen oxide derivatives. In was seen from the previous lesson on how free radicals react with other compounds in the atmosphere.

5. Particulates and aerosols

   Particulates and aerosols are complex mixture of extremely small particles and liquid droplets. They are existing in different forms such as ocean salt crystals, soil particles, minerals and metallic compounds. These small particles may come from wild fires, volcanic eruptions, incomplete combustion, mineral processing, industrial processing among others. The two most common particulates are the PM2.5 and PM10. PM2.5 are those that has an average diameter od $\leq 2.5\mu$ and is considered dangerous because they are often carcinogenic yet the body is not able to release them. Moreover, they are also active in smog formation and other photocatalytic activities. PM10, on the other hand, are those that have diameters within the range of $2.5\mu m \leq d \leq 10\mu m$.

6. Metal and metalloid compounds and vapors

   These may consist of hazardous particulate matter or vapors of metals such as Pb, Hg, As, Ni, Be, and Cu that are generated by combustion and incineration processes, engine wear, lubricating oil components, lamp wastes, and mineralization of geologic formations.

7. Polycyclic aromatic hydrocarbons and derivatives (PAHs)

   These are aromatic compounds of at least three fused aromatic rings and are hazardous. They are products of incomplete combustion of fossil fuels and vegetable matters, petroleum products and petroleum refineries.

8. Volatile organic compounds (VOCs)

   These are light hydrocarbons and unsaturated hydrocarbons and are precursors to smog formation and organic aerosols. They usually come from incomplete combustion

processes, fugitive sources, industrial processes, petroleum processing and solvent intensive processes such as painting.

9. Halogenated hydrocarbons and polychlorinated organic compounds

   Hazardous compounds volatile chlorinated hydrocarbons and polychlorinated dibenzo compounds dioxins and furans belong to this category. They usually come from incineration processes and car emission. The ozone layer destructing chlorofluorocarbons (CFCs) are also included in this category.

10. *Radionuclides*

    Their presence is due to natural gas or particulate emissions from natural deposits of uranium where radon is liberated, as well as emissions from uranium processing, nuclear reactors, and fuel-reprocessing wastes.

Internal Engine Combustion Process

Combustion of fossil fuel leads to the production of main primary pollutant CO, NOx, VOCs and SO_2.

The combustion equation of an internal engine that is ideally operating is given by the equation below:

$$C_nH_m + \left(n + \frac{m}{4}\right) O_2 \rightarrow nCO_2 + \left(\frac{m}{2}\right) H_2O$$

If the hydrocarbon (C_nH_m) to oxygen ratio is not adequate, unreacted hydrocarbons and partially oxidized carbon will be emitted to the atmosphere. Moreover, with an excess O_2, NO production is favored as it reacts with a sufficient amount of nitrogen in the atmosphere:

$$N_2 + O_2 \leftrightarrow 2\,NO$$

$$2NO + O_2 \leftrightarrow 2NO_2$$

In addition, the sulfur content of the fuels generated sulfur dioxide upon burning:

$$S + O_2 \rightarrow SO_2$$

The Greenhouse Effect

The greenhouse effect (Figure 1) is a natural process by which earth maintains the heat on its surface to make life sustainable. Solar radiation passes through the clear atmosphere wherein most of the radiation are absorbed by the earth's surface which keeps its warmth. Some of the heat from the earth radiates towards space but some of it is trapped by the greenhouse gases in the atmosphere. This keeps the planet warm enough to sustain life. However, the concentration of greenhouse gases in the atmosphere is gradually increased. This is trapping more heat from earth resulting for the earth's temperature to rise. The phenomenon known as the ***global warming***. Climate change, on the other hand, refers to the effect of global warming to the winds and ocean currents in ways that can cool some areas and warm others.

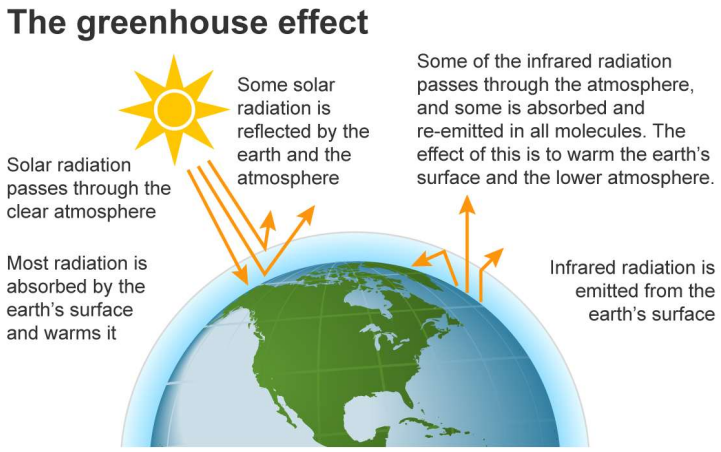


Figure 14: The Greenhouse Effect Image source: www.eia.gov

The greenhouse effect is primarily due to the augmented emissions of CO_2, NO_x, water vapor and other greenhouse gases into the atmosphere. Water vapor is the largest contributor to greenhouse effect because it absorbs infrared radiation. It helps in the maintenance of atmospheric temperature during night time when the earth's surface is emitting radiation into space. The second major contributor is the carbon dioxide due to the increase in energy production. Although carbon dioxide is being absorbed by the oceans and is being used by plants during photosynthesis, its generation is much faster than being absorbed or used. Another main contributor is the methane production due to the increasing demand on rice production (methane is produced in rice pads) and the intensive livestock breeding. Other greenhouse gases include chlorinated alkyl compounds (such as CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs).

Photochemical Smog Formation

Photochemical smog is a consequence of photochemical reactions based on primary pollutants discharged into the atmosphere. Smog has many deleterious effects on human health as well as on plants and materials. Nitrogen oxides and hydrocarbons emitted from vehicles with sunlight and oxygen produce pungent nitrogen dioxide and toxic ozone.

$$N_2 + O_2 \rightarrow 2NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 + h\nu \rightarrow NO + O\cdot$$

$$O\cdot + O_2 \rightarrow O_3$$

$$O_3 + NO\cdot \leftrightarrow NO_2 + O_2$$

NO and NO2 can also react with other free radicals that come from hydrocarbon emission after reacting with strong oxidizers.

The Stratospheric Ozone Destruction

Stratospheric ozone protects life on the surface of the Earth by screening harmful UV radiation coming from the sun through a photodissociation mechanism.

$$O_3 + hv \rightarrow O_2 + O\cdot$$

$$O\cdot + O_2 \rightarrow O_3$$

However, anthropogenic generated chlorine and bromine compounds in the atmosphere are responsible in the decrease in the ozone concentration in the stratosphere. Chlorine and bromine compounds are converted into it more active forms – free radicals.

$$Cl_2 + hv \rightarrow 2Cl\cdot$$

$$ClO\cdot + BrO\cdot \rightarrow Br\cdot + Cl\cdot + O_2$$

$$Cl\cdot + O_3 \rightarrow ClO\cdot + O_2$$

$$Br\cdot + O_3 \rightarrow BrO\cdot + O_2$$

$$2O_3 \rightarrow 3O_2$$

With this, Montreal Protocol was established with numerous signatories around the world. It has an objective of saving the ozone layer from destruction by abandoning the use of ozone depleting substances.

The Acid Rain

Under normal conditions, the pH of rain is slightly acidic at 5.7 due to the dissociation of dissolved carbon dioxide in water:

$$CO_2 + H_2O \rightarrow HCO_3^- + H^+$$

However, in polluted environments, oxides of sulfur and nitrogen are also present which when dissolved in rain droplets, its pH goes below 5.7. This is how the formation of acid rain occurs.

Sulfur dioxide (SO_2) come from the combustion of sulfur-containing fossil fuels. It is oxidized in the atmosphere to form sulfur trioxide (SO_3) which reacts with water to form sulfuric acid:

$$SO_2 + O\cdot \rightarrow SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$H_2SO_4 \rightarrow SO_4^- + 2H^+$$

On the other hand, nitrogen oxides form due to the presence of nitrogen and oxygen gases in air. These two goes on a series of chemical reactions to produce nitric acid, another component of acid rain.

$$N_2 + O_2 \rightarrow 2NO\cdot$$

$$2NO\cdot + O_2 \rightarrow 2NO_2\cdot$$

$$3NO_2\cdot + H_2O \rightarrow 2HNO_3 + NO\cdot$$

$$HNO_3 \rightarrow NO_3^- + H^+$$

Acid rain oxidizes materials such as copper and iron. They also cause deterioration of marble and other carbonate materials due to the decomposition reaction:

$$CaCO_3 + 2H^+ \rightarrow CO_2 + H_2O + Ca^{2+}$$

Volcanic eruptions are natural sources of SOx, while lightnings are natural sources of NOx and ozone. Combustion processes remain as the top anthropogenic sources of SOx and NOx.

Activities and Assessment:

1) Enumerate the ten groups of air pollutants and discuss their respective sources and effects.
2) How does the incomplete internal engine combustion add to air pollution?
3) Differentiate greenhouse effect, global warming and climate change. How are the three related to each other?
4) How does human activities contribute to photochemical smog formation, stratospheric ozone destruction and acid rain formation?
5) Suggest ways of how are you going to contribute to climate change, minimization of photochemical smog formation, destruction of ozone layer and acid rain occurrences. Cite one for each.

LESSON 11: CHEMISTRY OF THE HYDROSPHERE
UNIT 1: The Composition of the Hydrosphere

Introduction:

The hydrosphere is one of the geological spheres that makes up the earth. It is composed of the different water bodies that are found on the surface and deep below the earth, including the water that is found in the atmosphere. In this lesson, the major composition of the hydrosphere – water - is explored. An overview on the importance of water and the interrelationship between its composition, structure and properties are presented. Also, a deeper discussion on the water cycle and global water distribution are also included.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1) Describe the importance of water.
2) Explain the properties of water with respect to its composition and structure.
3) Discuss the different processes within the hydrological cycle.
4) Label the different water bodies with their approximate global distribution.

Course Materials:

The Water Molecule

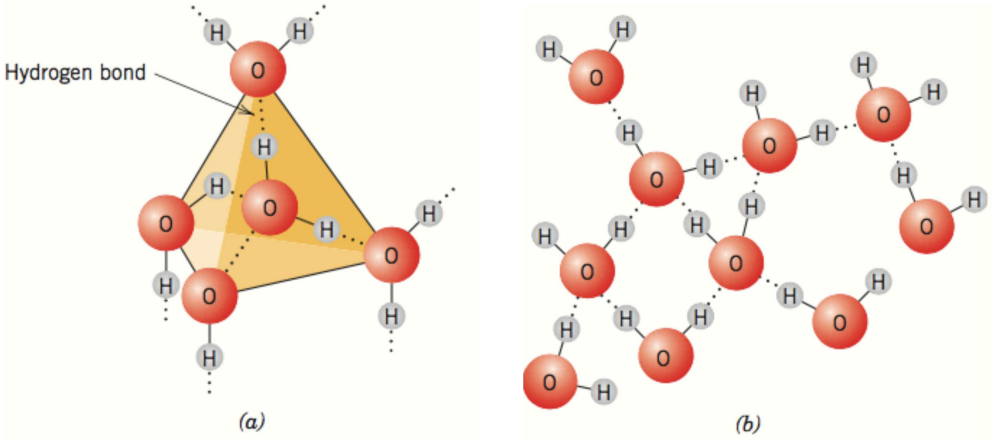


Figure 15: Water molecules in (a) solid form and (b) in liquid form. Image source: *Callister Jr., W. (2007) Material Science and Engineering An Introduction, John Wiley & Sons, Inc., USA*

Water serves as the home to many aquatic organisms. It boosts growth of plants. It also provides nutrients and minerals for the sustenance of physical life. With this, it is considered as an essential nutrient that we cannot live without.
The importance of water is due to it renowned properties. It is an excellent solvent, has a high surface tension and exists in wide range of temperature in its liquid form. These properties is due to its composition and structure.
Water molecules is made up of one hydrogen and two oxygen atoms forming two O-H bonds leaving two unpaired electrons on the oxygen. The distribution of forces among the elements

results to its bent molecular structure. In addition, the oxygen atoms in the water molecule have high electronegativity which makes them attract the O-H bond creating strong dipoles that attract each other and form new bonds known as the hydrogen bond. The hydrogen bonds among the water molecules is what maintain a strong adhesion among the molecules.

The Hydrological Cycle

The hydrological cycle involves the physical changes water undergoes as it continuously move above, on and below the surface of the earth. It is also known as the water cycle. As it goes through the cycle, it serves as a reagent in the chemical transformations of matter and as a transport medium for compounds to the different parts of the earth.

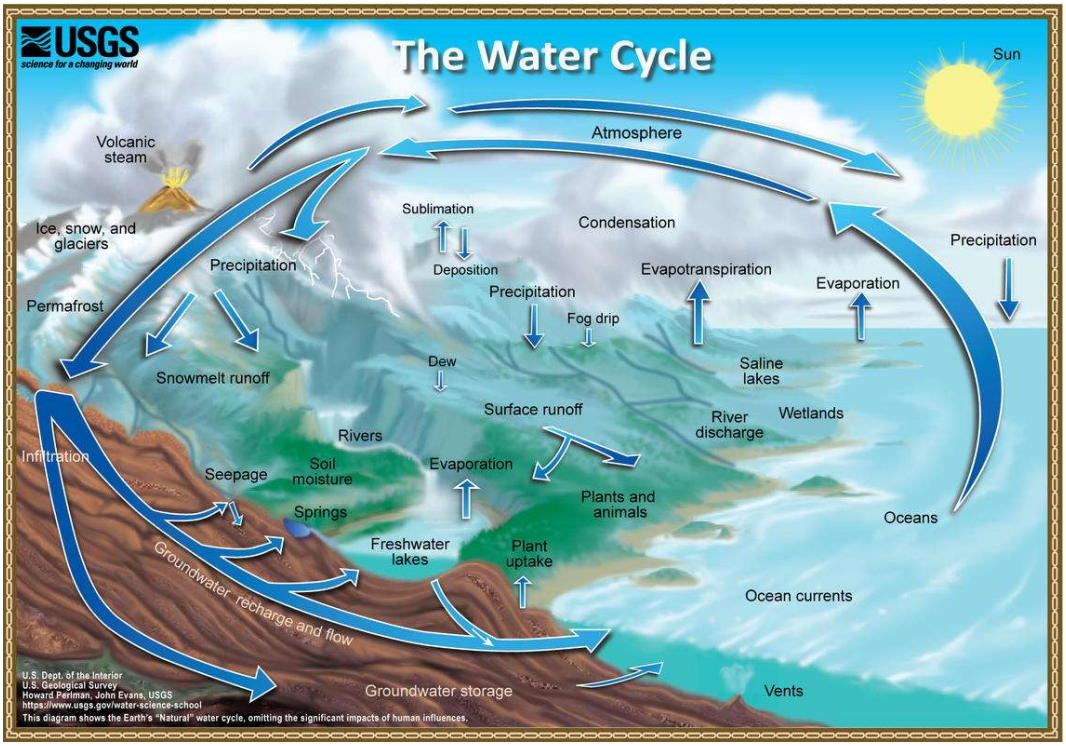


Figure 16: The Hydrological Cycle. Image source www.usgs.gov.

a) Evaporation

Evaporation is the process wherein the liquid water changes into gas at ambient temperature. The heating of bodies of water and of lands by the sun causes evaporation of some of its waters into the air.

b) Sublimation

Evaporation is not the only source of water vapor in air. Some of the water components of ice and snow sublimes to water vapor. Sublimation is the process wherein the solid water changes into gas.

c) Evapotranspiration

Apart from evaporation and sublimation, evapotranspiration also contributes to the amount of water vapor that enters the atmosphere. Evapotranspiration is a combination of evaporation and transpiration. Transpiration is the process by which plants takes water from the soil through its roots and later released through its leaves. The water that is released is further evaporated into the air.

d) Condensation

The water vapor resulting from the processes of evaporation from the oceans, sublimations from ice and snows and transpiration from plants are carried up into the atmosphere by rising air currents. When the vapor reaches the air of cooler temperature, it transforms into clouds through the condensation which is the process wherein water vapor changes into liquid.

e) Precipitation

The clouds are moved by air currents, collide, grow and fall out as precipitation which is the process wherein liquid or frozen water in the atmosphere goes back to earth in the form of rain, snow or sleet. Most precipitation falls back to the land, oceans and other bodies of water.

f) Runoff

Runoff is the process when water runs over the surface of the earth. The snow precipitates are accumulated as ice caps and glaciers but some of them melts wherein the melted water flows as a snowmelt over lands as snowmelt runoff. Some of the precipitation flows over the ground as surface runoff. Portions of the runoffs goes to the rivers and oceans. Some of the precipitate go through groundwater seepage and later stored as freshwater in lakes.

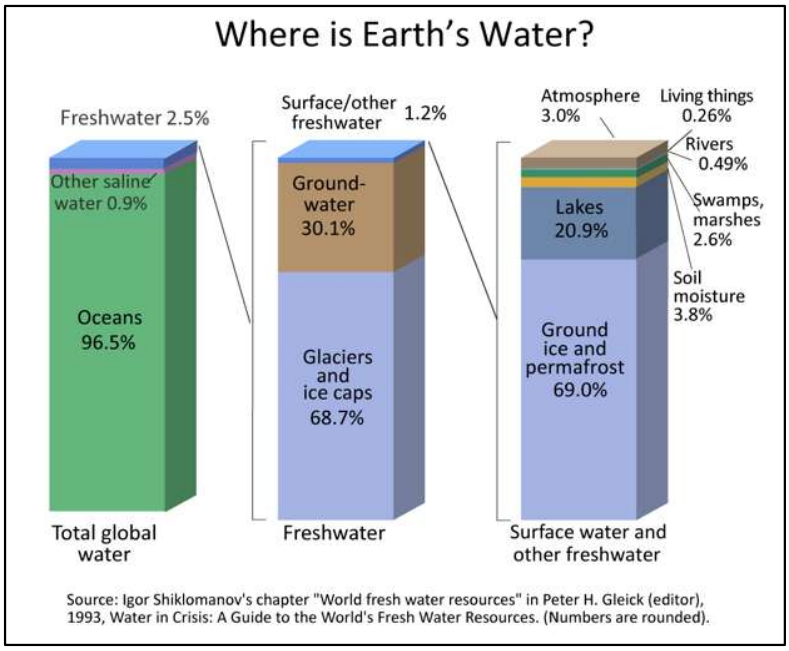
g) Infiltration

Not all runoffs goes back to the hydrosphere, absorbed by plant or get evaporated because much of the water soaks deep into the soil through the process of infiltration. Some of the water infiltrates deep into the ground to replenish the ground water table and aquifers. Some stays close to the land surface and seeps back into the surface as groundwater discharge and freshwater springs.

Global Water Distribution

Estimate of Global Water Distribution	Volume (1000 km3)	Percent of Total Water
Oceans, Seas, and Bays	1,338,000	96.5
Ice Caps, Glaciers, and Permanent Snow	24,064	1.74
Groundwater	23,400	1.7
Fresh	(10,530)	(0.76)
Saline	(12,870)	(0.94)
Soil Moisture	16.5	0.001
Ground Ice and Permafrost	300	0.022
Lakes	176.4	0.013
Fresh	(91.00)	(0.01)
Saline	(85.40)	(0.01)
Atmosphere	12.9	0.001
Swamp Water	11.47	0.0008
Rivers	2.12	0.0002
Biological Water	1.12	0.0001
Total	**1,385,984**	**100**

Source: Gleick, P. H., 1996: Water resources. In *Encyclopedia of Climate and Weather,* ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.



Activities and Assessment:

1) Why is water important?
2) How are the properties of water related to its composition of having two atoms of hydrogen and one atom of oxygen?
3) How does the hydrological cycle work?

LESSON 11: CHEMISTRY OF THE HYDROSPHERE
UNIT 2: The Chemistry of Natural Waters

Introduction:

In the previous section, the relationship of the structure and composition of water to its function were discussed. A more extensive discussion on how the global water maintains its existence through the global water cycle was also undertaken. In this section, the different classifications of natural water are examined including the processes on how they were formed and the different factors that affect their quality.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1. Differentiate the classifications of natural waters according to their sources.
2. Describe how the different natural waters are formed.
3. Discuss how the different factors affect the water quality.

Course Materials:

Natural waters are comprised of rainwater, surface water, groundwater, sweater and saline water.

1) Rainwater

Rainwater comes from the evaporation, condensation and precipitation processes in the water cycle. It takes 8 – 10 days for the water in the atmosphere before it precipitates as rain. The rainwater composition depends on the zone of the origin of the clouds that carried it, the composition of the winds that carried them to the precipitation cite and on the composition of the atmosphere at the precipitation zone.

The pH of the rainwater depends on the compounds found in the atmosphere. The presence of carbon dioxide (CO_2) makes it slightly acidic. The sulfate concentration also lowers the pH of rainwater. Compounds such as SO_2 and NO_2 undergoes oxidation and dissolution to produce sulfuric and nitric acid, respectively. This is the cause of acid deposition such as ***acid rain***. Moreover, the sulfuric and nitric acids formed can further react to ammonium ions from the dissolution of ammonia to produce ammonium salts.

The salinity content of rainwater depends on the amount of salt particles that are suspended in air when the rain falls. These salt particles are results of evaporated marine-generated aerosols and gases that were released from the sea surface.

2) Surface water

Surface water is formed when the precipitation rate exceeds the infiltration rate. The excess water flows as runoff and gets to streams, rivers, ponds, lakes, swamps, marshes and springs. The composition of surface waters depends on the processes that takes place in the geographic zone such as weathering, precipitation and eutrophication.

In zones where soil weathering prevails over rainfall, the surface waters has a moderate ionic strength brought by the presence of calcium ions, bicarbonate ions and silicates which are the common minerals resulting from weathering. If vegetation and animal excretes are abundant in an area, the presence of organic and inorganic matters are dominant as particulate solids and dissolved organic matter. Places with surface waters having rich organic compounds are also abundant with ammonia, nitrates and orthophosphates due to the rich aquatic fauna and flora in the area.

In places where rainfall predominates over soil weathering, the lower concentration of total dissolved salts in the surface waters has a low ionic strength. However, the concentration of ions in surface waters is also affected by the amount of ions present in the atmosphere that are washed by rainwater such as sodium ions, magnesium ions, chloride ions and sulfate ions.

Another important process that affects the composition of surface water specifically rivers and lakes is ***eutrophication***. It is a condition when a body of water is enriched with excessive nutrients from surface runoff and stimulates growth of plants. This results to a decrease in the concentration of dissolved oxygen in the body of water causing death to the aquatic species living in it.

3) Groundwater

Groundwater is the accumulated water that fills the water table and the aquifers that came from precipitation and was infiltrated through the soil. The water table is below the surface of the ground where water can be found. The aquifers, on the other hand, is made up of permeable rocks that holds a large reservoir of water that can easily be transmitted into springs are wells. Groundwater is also the water in voids and spaces between soil, sand, gravel, clay silt and rocks.

The quality of ground water is good enough for human use and consumption as it contains minerals and nutrients that are essential for body functions. The nutrients and minerals that the groundwater contains is dependent on the composition of the soil and rocks that it penetrates on its way to the water table and aquifers. The most common ions that are naturally occurring in groundwaters are magnesium ions, calcium ions, potassium ions, sodium ions, ferric ions, ferrous ions, chloride ions and percarbonate ions. Normally, the groundwater has a pH level of 6.5 to 8.

4) Seawater

The seawater is composed of all waters that are leading to the seas and the oceans and it comprises 97% of the waters in the whole planet Earth. It is the home of thousands of aquatic species whose lives depend on the composition of the saltwater. Aerobic biological processes is supported in seawaters due to the presence of high amounts of dissolved oxygen resulting from gas transfer and dissolution promoted by strong mixing process. On the other hand, anaerobic biological processes are supported in the deeper parts of the ocean where lower dissolved oxygen levels are available.

Most of all minerals and nutrients that are found in seawater comes from different sources that were carried by the waters leading to its place. Seawater has high in salinity (mainly

as NaCl) and in dissolved solids contents. ***Salinity*** is defined as the amount of dissolved solids per gram of seawater. Studies show that the major ions present in seawater are sodium, potassium, calcium, magnesium and the chloride ion. These minerals along with the intense surface and current movements of the seawater affects the different process occurring therein including the removal of the minerals.

5) **Brackish/Saline Water**

When the salt content of the water is greater than the fresh water but lower than that of the seawater, it is categorized as brackish or saline water. It has an average salt content of 0.5 to 30 g/L. Saline waters are usually classified according to their salinity to check their possibility of being used in irrigation systems. This is because high salt concentration may be toxic to plants or accumulate in plants and later place their consumers at risk.

Activities and Assessment:

1. What makes rainwater acidic?
2. How does weathering, precipitation and eutrophication affect the quality of surface waters?
3. What makes groundwater suitable for human consumption?

LESSON 11 : CHEMISTRY OF THE HYDROSPHERE
UNIT 3: Water Pollution, Sources and Effects

Introduction:

The hydrosphere is one of the important spheres of the earth that we need to take care of. We have known how important it is for our survival; therefore, it is important for us to understand how it will get destroyed so that we know how to prevent it. This part of the lesson discusses the effects of the different pollutants in the hydrosphere.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1) Describe the different sources of water pollutants.
2) Discuss the impacts of each of the pollutants to the bodies of water and the organisms living in them.

Course Materials:

The common water pollutants and their corresponding effects are as follows:

1) Oxygen-Demanding Materials

   Oxygen-demanding materials are compounds in water bodies that consume dissolved molecular oxygen. They can either be biodegradable organic or inorganic compounds. These materials are can come from human wastes and food residues that are dumped into water bodies.

   The amount of oxygen-demanding compounds present in water can be measured in two (2) ways: Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD).

   COD measures of the amount of the amount of molecular oxygen required to achieve a complete chemical oxidation of a sewage sample using a strong oxidizing agent mixed with a water sample and then heated to 150°C for two hours. The difference on the amount of oxidizing agent before and after the oxidation process is recorded as COD in mg/ L.

   BOD, on the other hand, is used when the oxidation process is carried by microorganisms instead of strong oxidizing agent. In a BOD_5 test, microorganisms are introduced to a water sample where they oxidize the organic and inorganic compounds in the dark at 20°C over a period of 5 days.

   High COD and BOD values mean high organic content of the water sample. Discharging water with high COD and BOD values results to a reduction of dissolved oxygen in water and may pose threat to the aquatic organisms that require it for respiration.

2) Nutrients

Of all the nutrients available, phosphorous and nitrogen are of primary concern with respect to the water quality because they are essential to the growth of living organism. Their presence in waters supports the natural food chain; however, when excessive, some of the organisms proliferate at the expense of others.

Moreover, due to excessive nutrient concentrations, bodies of water becomes shallower and more productive. A process called ***eutrophication***. This may promote algal growth that eventually result in higher supply of food for higher organisms. With higher fish population, water quality will suffer due to algal death and decomposition.

Sources of nutrients are phosphorous-based detergents, fertilizers and food-processing wastes.

3) Pathogenic Organisms

Pathogens are disease-causing bacteria, viruses and other parasitic organisms that are present in waters usually from untreated sewage. They can contaminate drinking, swimming and bathing waters and food. These medium can be used by the pathogens to access individuals and cause the diseases such as typhoid fever, cholera, diarrhea and dysentery.

4) Suspended Solids

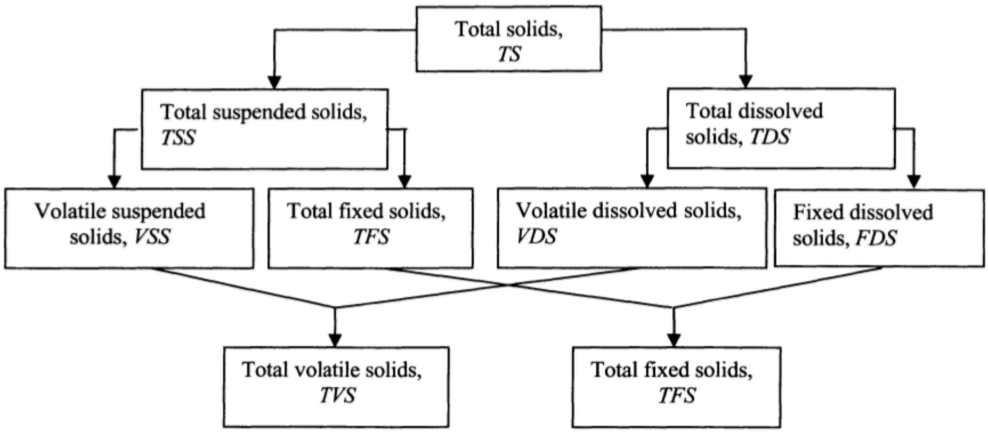


Figure 17: Classifications of Solids in Water. Image Source Ibanez, J.G., et. al. (2007) ***Environmental Chemistry Fundamentals***, Springer Science+Business Media, LLC, New York, USA

Total solids (TS) are those that are obtained by evaporating a sample wastewater to dryness at 103 to 105°C. These TS undergo filtration: the filtered ones are called as *Total Suspended Solids (TSS)* and those that were dissolved and became part of the filtrate are the *Total Dissolved Solids (TDS)*. When the TS are subjected to ignition at 500°C: the residue is known as the *Total Fixed Solids (TFS)*, while those that were volatilized are the Total *Volatile Solids (TVS)*.

Some of the pathogenic organisms may be encased in the solids which serves as their protection against disinfection. With this, the amount of suspended solids present in water became a measure of a waste treatment facility's efficiency. It can be determined by means of turbidity - the measure of the light scattering properties of water. The higher the content of suspended solids, the more polluted the water is.

5) Oil and Grease Spills

Oil and grease spills are products of accidents, lack of maintenance and neglectfulness from machineries. In addition to being displeasing to the eye, oil and grease spills has negative impact on the environment and on the living species in the area because oil and grease are toxic and carcinogenic. Moreover, oil emulsions block the entrance of light into the bodies of water resulting in a decrease of biological activities.

6) Metallic and Metalloid Compounds

The presence of metallic and metalloid compounds can be attributed to widespread human activities such as mining ang smelting. These compounds can damage deep-rooted plants and contaminate groundwater. They are in some of their forms are toxic and hazardous both to humans and other organisms. In addition, they also increase the water turbidity and coloration, stain materials in contact to it and gives the water a bad taste.

7) Radionuclides

Mishandled radionuclides are toxic to human health. Most of them came from nuclear facilities and improper disposal of medical applications.

8) Detergent and Nutrient Enrichment

As discussed earlier, nutrients can cause eutrophication which results in death of algae, microbial degradation and decrease in dissolve oxygen thereby lowers the life-sustaining ability of the water. In addition, algae impedes the access of light into the water affecting the natural photosynthesis of organisms therein.

9) Salts

Salt coming from industries may affect the quality of water such that it is no longer useful for public water supply and irrigation. High salt concentration damages crops and causes soil poisoning.

10) Heat

Heat is not considered as pollutant but it produces problems at their disposal to bodies of waters. High water temperature kills some of the water species and it also increase the rate of dissolved oxygen depletion.

11) Others

Large plastics resemble food of larder organisms in the bodies of water. On the other hand, plastic debris may be broken down into smaller fragments which may threat the lives of the organisms that happen to ingest them.

Activities and Assessments:

1) What is the difference between COD and BOD?
2) How does high values of COD and BOD affect the lives of aquatic organisms?
3) How does eutrophication takes place? How does it affect water quality?
4) What are the impacts of oil and grease spills in bodies of water?
5) Explain how plastics of various sizes affect organisms living in bodies of waters.

LESSON 12: CHEMISTRY OF THE LITHOSPHERE
UNIT 1: The Structure and Composition of the Earth

Introduction:

The field of chemistry discusses the structures and compositions of different substances including the changes that they undergo as a result of the various interactions among the elements they are composed of.

In this particular lesson, the overview on the structure and composition of the huge spherical land structure beneath the place that we call “home” is discussed. The composition of the different layers of the earth is presented and how they affect their structure and properties.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1. Differentiate the structures and composition of the solid earth.
2. Discuss the composition and the importance of the lithosphere.

Course Materials:

The Four Layers of the Earth

The earth is made up four (4) spherical layers namely inner core, outer core, mantle and crust as shown in Figure 1.

The center of the earth is the core with a diameter of approximately 25000 km. It is believed that the high temperature, earth’s rotation and its density caused iron to move to the center of the earth. As it moved to that direction, the iron came in contact with siderophiles (iron-loving elements) such as nickel. This is the reason why the earth’s core is made up of iron and nickel predominantly present in their reduced form.

a) The inner core

   The *inner core* which is like a rotating solid metal ball that is made of iron and nickel with a diameter of approximately 2440 km.

b) The outer core

The *outer core* is also made up iron and nickel but in the liquid form. This part of the earth is what generates the electromagnetic field of the earth as a result of the turbulent current of the earth is heated through the radioactive decay of uranium and thorium which causes turbulent current which in turn generates the electromagnetic field of the earth.

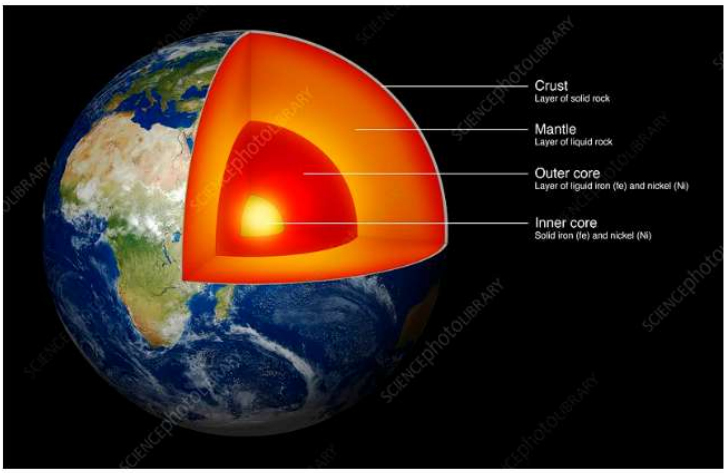


Figure 18: The layers of earth. Image from www.sciencephoto.com

d) The mantle

The *mantle* surrounds the core and it has a thickness of approximately 2900 km. It is made up of high-density silicates of magnesium and iron and is further divided into three layers: the lower mantle, the transition and the upper mantle. The lower mantle contains water that is believed to have a greater amount than that of the oceans at the surface. These water is contained within the magnesium and calcium crystals that it is composed of.

d) The crust

The *crust* surrounds the mantle and is considered as the thinnest among the layers of the earth: it is approximately 8 km from the bottom of the oceans (oceanic crust) and an average of 40 km under the continents (continental crust). It is primarily made up of oxygenated silica and aluminum. The components of the earth's crust is predominantly in their oxidized form. The upper part of the crust is made up of gigantic broken pieces known as the tectonic plates that move slowly. The cause of movement, however, is not yet fully understood until now.

The Lithosphere

The *lithosphere* is the solid outer part of the earth. It is made up of the upper mantle and the crust. It has two types: the oceanic lithosphere and the continental lithosphere.
The lithosphere defines a great deal on the kind of life we have. It is believed that the uppermost part of the mantle is what the tectonic plates ride upon. The thermal energy present from the mantle is believed to cause the movements of the tectonic plates which defines territories and geographical landmarks. Moreover, the lithosphere is where the process of weathering occurs. Weathering is the one of the factors that determines the formation of our landscapes and the distribution of minerals and nutrients among soils. It is the soil that the growth of living organism are highly dependent on.

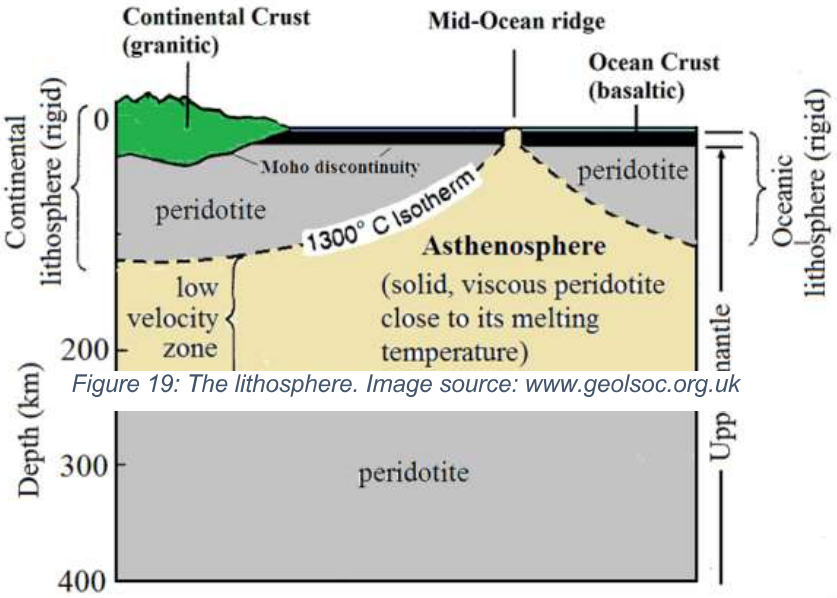


Figure 19: The lithosphere. Image source: www.geolsoc.org.uk

Activities and Assessment:

1. What are the three layers of the earth and their respective compositions?
2. What comprises the lithosphere?
3. Why is the lithosphere important?

LESSON 12: CHEMISTRY OF THE LITHOSPHERE
UNIT 2: Rock Classifications and the Rock Cycle

Introduction:

The lithosphere is where most of our lives are spent. Rocks and minerals are very important part of the lithosphere as it provides habitant to numerous living organisms. Whatever changes they undergo will result to changes in the ecosystem and the lives that depend on it. A better understanding on how these rocks were formed will give us insights on how to keep the balance going. In this lesson, we are to have an overview on the different classifications of rocks, their chemical compositions and the processes they undergo.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1. Differentiate the three different classifications of rocks and their sub-classifications.
2. Discuss the processes on how the different rock classifications are formed.
3. Describe how the rock cycle works.

Course Materials:

Rock Classifications

The continental crust is usually made up of different kinds of rocks which are classified as (1) igneous, (2) sedimentary and (3) metamorphic.

a. Igneous rocks

Igneous rocks are formed when hot materials cool and solidify. Its primary content is silica dioxide (SiO_2) with their percent content as the basis on how they are classified. However, SiO_2 does not exist on the rock in the said form but as a part of a more complex structure. Studies also show that in igneous rocks, as the SiO_2 content decreases, the magnesium oxides (MgO) or calcium oxides (CaO) content increases. It is the SiO_2/MgO ratio found in the rock that serves as the basis for their classifications. For *granite*, the ratio is 72.0/0.5; for *diorite*, the ratio is 54.5/3.8; for *basalt*, the ratio is 48.4/8.1; and for *peridotite*, the ratio is 43.5/34.0. In addition, the quartz-rich rocks are called *felsic* or *silicic* while basic rocks are called *mafic*.

There are two types of igneous rocks which are classified according to the mechanism on who they were formed. *The intrusive (plutonic) igneous rocks* are those that are formed inside the earth while the *extrusive (volcanic) igneous rocks* are those that are formed outside the earth.

Figure 20: Samples of Igneous Rocks. Image source: www.sandatlas.org

b) Sedimentary Rocks

Sedimentary rocks are results of erosion and from the interaction of igneous and sedimentary rocks with different factors in the environment. These rocks have lower silica contents compared to the igneous and metamorphic counterparts. Their SiO_2/CaO content ratio determines whether its classification. Limestones have a ratio of 8.2/40.5 while sandstones have 74.3/34.9.

Sedimentary rocks have three types: (1) clastic, (2) organic and (3) chemical. *Clastic sedimentary rocks* are those that are formed from pieces of other rock materials while *organic sedimentary rocks* are those that are formed from biological materials that were compressed into rocks.

Clastic and organic sedimentary rocks are formed through weathering and erosion. Exposed rocks are broken down into segments through *weathering* and are transferred to other locations through *erosion*. At the new location, the segments are collected until it forms a new solid rock formation.

Chemical sedimentary rocks are those that are form through the process of *chemical precipitation*. This occurs when the minerals in the rocks are dissolved by water and transfer elsewhere. The dissolved minerals are precipitated during the evaporation process.

Figure 21: Samples of Sedimentary Rocks. Image Source www.sandatlas.org

c) Metamorphic rocks

Metamorphism is the process on which rocks undergo physical and chemical alterations due to their exposure to high temperature and pressure. This is how *metamorphic rocks* are formed. There are two types of metamorphic rocks: (1) foliated and (2) non-foliated. The *foliated metamorphic rocks* has evidences that it underwent the process of foliating. *Foliating* is the formation of aligned elongated or platy minerals perpendicular to the pressure of force exerted. *Non-foliated metamorphic rocks* are formed the same way but with the absence of foliation. They can also be formed by undergoing the process of metamorphism when they come in contact with magma.

Figure 22: Samples of Metamorphic Rocks. Image Source www.sandatlas.org

The Rock Cycle

The different classifications of rocks described above are formed through different physical processes that are part of the rock cycle.
The contents of a rock are broken down into pieces and are transported to other locations where they are collected. This process forms the sedimentary rock which goes through changes under high temperature and pressure forming the metamorphic rock. Further changes may take place to transform to an igneous rock from which the contents are broken down to start a new cycle.
However, it should be noted that a rock has two routes that may undergo in the rock cycle. The sedimentary rock may undergo either the same cycle of wreathing and erosion that it went through or the process of metamorphosis to form the metamorphic rock.

The metamorphic rock may undergo the cycle of weathering and erosion the sedimentary rock underwent or be formed into igneous rocks through the process of metamorphosis.
The igneous rock may undergo metamorphosis to form back to the metamorphic rock or the weathering and erosion processes that the rock contents need to undergo to complete the cycle.

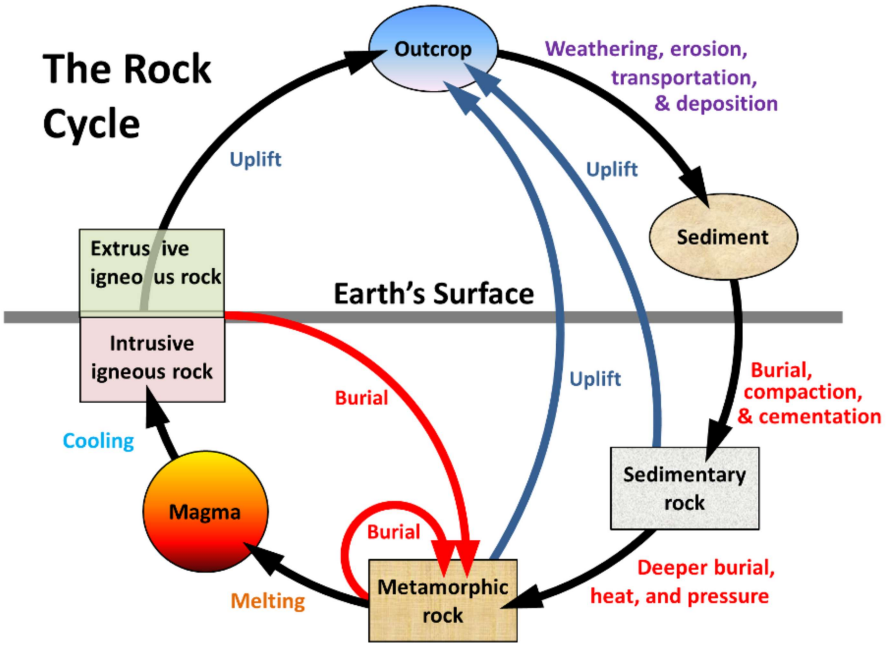


Figure 23: The Rock Cycle. Image Source opentextbc.ca

Activities and Assessment:

1. What are the three classification of rocks?
2. What are the two types of igneous rocks and how do they differ?
3. What are the three types of sedimentary rocks and how did they differ?
4. What are the two types of metamorphic rocks?
5. Explain how the following processes takes place: (a) weathering, (b) erosion, (c) chemical precipitation, (d) metamorphose and (e) foliating.
6. Briefly describe how the rock cycle takes place.

LESSON 12: CHEMISTRY OF THE LITHOSPHERE
UNIT 3: The Process of Weathering

Introduction:

Weathering is the process of breaking down of rocks into smaller pieces that can be done through physical or chemical changes. It is an importance process that occurs in the lithosphere as the creation of landscapes is highly dependent on it. Moreover, weathering is also an important of soil formation which we are highly dependent on. In this lesson, the different methods on how weathering occurs is discussed to help the student understand the underlying chemistry principles behind landscapes formation and soil formation.

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1. Define the process of weathering and its importance.
2. Differentiate the three classifications weathering.
3. Describe how the different mechanical weathering processes take place.
4. Describe how the different chemical weathering processes take place.

Course Materials:

Weathering

Weathering is the process that rocks undergo where they are broken down into pieces or their mineral contents are dissolved. Weathering followed by the erosion processes has a great contribution on how different landscapes on the planet are changed.

Weathering is also considered as one of first processes in the formation of soil. The minerals and nutrients that are found in soils determines the kind of plants that can survive on it. The minerals and nutrients present in soils is dependent on the type of weathering that occurs in the place. The weathering process can be characterized as mechanical, chemical or biological in nature.

Mechanical Weathering

Mechanical weathering is also known as *physical weathering* wherein rocks are broken down into pieces without altering their chemical composition. It can be classified into two: (1) those that forces the rock apart like a wedge and (2) those that causes the rock to expand.

Mechanical Weathering by Wedging

a) Salt wedging

   When saltwater comes in contact with the rocks, they enter in it through the cracks and pores. The salt is left behind after evaporation. These salt crystals grow that causes the rocks to fall apart. This process is known as *haloclasty or salt wedging.*

b) Frost wedging

Water can get into the rocks through rocks and crevices. The water freezes when the temperature drops which cause it to expand. This water expansion causes the cracks to widen. When the ice melts, the liquid water carries out the tiny fragments. This process is known as *frost weathering* or *cryofracturing*. Moreover, the contact of water with the rocks may also cause abrasion as the water washes away some of the particles from the rocks.

c) Root wedging

The growths of plant roots causes damage on the rocks as they widen the cracks and eventually breaks them into pieces. This process is known as root wedging.

Mechanical Weathering by Expansion

a) Thermal expansion and contraction

The changing temperature also causes rock destruction as it undergoes thermal stress. The rocks expands when heated, contracts when cooled. As the rocks undergo this *expansion-contraction cycle*, it weakens and cracks are produced.

b) Exfoliation

Changing pressures can also cause rock expansion which makes the rocks vulnerable to breakage. Exfoliation occurs when the outer layer of rocks break off in slabs or sheets as a result of the outer layer's expansion due to change in pressure.

c) Impacts and abrasions

Wind. The wind carries particles that has the capability to cause abrasion on the rocks such as solid particulate matters.

Earthquakes. The large magnitude of forces caused by earthquakes have direct effects on the change on the structure of rocks. As these forces shake the rocks, their structural integrity is compromised that may lead the rocks to be broken down into smaller pieces.

Biological activities. Some animals dig and squash rocks which cause them to deteriorate and crush.

<u>Chemical Weathering</u>

Chemical weathering occurs when the chemical composition of the rocks were changed by virtue of chemical reactions. The following are the common chemical processes that rocks undergo:

a. Dissolution

Dissolution occurs when a component of a rock reacts to a substance such that the resulting product is a soluble compound. With this, when the compound interacts with a solute, it is completely dissolved leaving no residues behind. Dissolution is a major process in the creation of sinkholes.

One form of dissolution in rocks is c*arbonation.* It is a process wherein the carbon dioxide occurring in air combines with water to produce carbonic acid, H_2CO_3. This carbonic acid reacts with other carbonate components of the rock such as calcium carbonate ($CaCO_3$) which is broken down further into its constituents calcium ion, water and carbon dioxide. The calcium iron can be part of another rock, while the water and carbon dioxide will cycle back to nature. The process of dissolution is what occurs to the chemical weathering of limestones, dolomites and metamorphic rock marble.

$$CO_2 + H_2O \rightarrow H_2CO_3 \leftrightarrow 2H^+ + {CO_3}^-$$

$$CaCO_3 + H_2CO_3 \leftrightarrow Ca^{2+} + 2H_2O + CO_2$$

Another means of dissolution is *acidification* such as what happens in the destruction of rocks caused by acid rain:

$$CaCO_3 + H_2S0_4 \leftrightarrow Ca^{2+} + {SO_4}^{2-} + CO_2 + H_2O$$

b. Oxidation

Oxidation is a process that involves the loss of electrons. In chemical weathering, oxidation usually occurs to rocks that contain iron and reacts with oxygen that is usually carried by water to form rust, Fe_2O_3. Since the structural composition of iron has a stronger than that of rust, the more rust is created, the weaker the rock becomes making it more vulnerable to breakage.

The process of oxidation is what makes a basalt rock look reddish due to the production of hematite, Fe_2O_3 from its iron-rich mineral content olivine Fe_2SiO_4. The olivine reacts with carbonic acid (H_2CO_3) and produces dissolved iron, bicarbonate ion and silicic acid. The dissolve iron reacts with the oxygen dissolved in water with the presence bicarbonate to produce the hematite and carbonic acid.

$$Fe_2SiO_4 + 4H_2CO_3 \rightarrow 2Fe^{2+} + 4{HCO_3}^- + H_4SiO_4$$

$$2Fe^{2+} + \frac{1}{2}O_2 + 2H_2O + 4{HCO_3}^- \rightarrow Fe_2O_3 + 4H_2CO_3$$

c) Hydrolysis

Hydrolysis occurs in chemical weathering when a rock component reacts with water resulting to one or more new product(s). An example is the reaction of potassium feldspar ($KAlSi_3O_8$) with water to produce the clay mineral kaolinite ($Al_2Si_2O_5(OH)_4$). Unlike in the process of dissolution, in hydrolysis, not all of the products are ions which can be dissolved. Feldspars and micas are weathered through hydrolysis.

$$2KAlSi_3O_8 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 4SiO_2 + 2K^+ + 2OH^-$$

d) Hydration

Hydration occurs when water molecule is added as an integral part of the molecular structure of the rock. An example is the hydration reaction of a mineral anhydrite with water to produce gypsum.

$$CaSO_4 + H_2O \rightarrow CaSO_4.H_2O$$

Biological Weathering

Biological weathering is when living organisms or once living organisms takes part on the process. Biological weathering can be part of either the mechanical or chemical weathering or both.

Assessment:

1. In your own words, what is weathering and why is it important?
2. What are the three classifications of weathering? How does one differ from the other?
3. Explain how the following processes takes place? (a) frost wedging (b) salt wedging, (c) root wedging, (d) expansion-contraction cycle, (e) abrasion and (f) exfoliation.
4. Indicate what is the specific chemical process that occurs in the following chemical changes: (a) pyrite to hematite; (b) feldspar to clay; (c) calcite to calcium and bicarbonate ions.

LESSON 12: CHEMISTRY OF THE LITHOSPHERE
UNIT 4: Soil Pollution, Sources and Effects

Introduction:

The lithosphere is important because it carries the soil that houses our vegetations that we are being feed from. Changes in the chemistry of the soil as effect of the weathering process also affects the soil characteristic; hence, the kind and quality of plants that it could carry. The introduction of pollutants into the lithosphere has an effect on the soil quality; hence, it is important for us to have an idea

Learning Objectives:

After successful completion of this lesson, the students are expected to:

1. Illustrate how pollutants lead to soil contamination.
2. Provide suggestions for better landfill usage.

Course Materials:

Soil contamination is caused by pollutants coming from the atmosphere and the hydrosphere. These pollutants may stay inactive, decompose or react with soil components through the process of oxidation, reduction, combination, precipitation, dissolution and metathesis. The product of the reaction may or may not be environment-friendly as compared to the starting material. On the other hand, if the pollutants are not to stay with the soil, they may end up in groundwater and may pose risk into its quality.

Common sources are as follows:

1) Aerially transported materials

   These are the pollutants that are being carried by the wind and precipitation (snow and rain). Smoke and dusts may carry organic and inorganic pollutants while gases such as sulfur dioxide and nitrogen oxides may damage vegetation. Atmospheric deposition also introduces heavy metals to soil which may lead to plant uptake.

2) Agricultural activities

   Fertilizers, soil additives, pesticides and herbicides are used by farmers in their crops to enhance yield. Sewage sludge are also used as fertilizer and it may contain heavy metals, nitrates, phosphates and detergents. These contain compounds, such as nitrates and phosphates, that may contaminate both the soil and groundwater.

3) Mining activities

   Sulfide from mining processes are oxidized when comes in contact to air. When these minerals come in contact with water, they form acidic aqueous solutions called as the ***acid mine drainage (AMD)***, as represented by the following equation (with Fe as the metal present):

$$FeS_2(s) + H_2O(l) + \frac{7}{2}O_2(g) \rightarrow Fe^{2+} + 2{SO_4}^{2-} + 2H^+$$

The produced Fe^{2+} oxidizes to Fe^{3+} in air at low pH. Then the Fe^{3+} can either hydrolize to form insoluble Fe(III) hydroxide or act as a secondary oxidant to FeS_2:

$$FeS_2(s) + 14Fe^{3+} + 8H_2O(l) \rightarrow 15Fe^{2+} + 2{SO_4}^{2-} + 16H^+$$

The AMD process promotes downstream deposition of insoluble Fe(III) species which may lead to soil contamination as a result to capillary rise and evaporation.

On the other hand, the production of protons and sulfate ions produce H_2SO_4 which has the capability to dissolve minerals resulting to an increase in the metal and nonmetal ion content and acidity level of bodies of water nearby which are active participants in the weathering process.

4) Landfill

Landfills usually involve solid wastes, industrial wastes and sewage sludge that lead to the contamination of land surfaces and neighboring surface waters.

Examples of solid wastes are waste paper, food, street wastes, plastic trash while that of industrial wastes are residual construction materials, pollution treatment wastes, safety items. Sewage sludge are those that are produced from waste water treatment facilities, commercial setting and storm-water runoff.

Activities and Assessment:

1) In your own words, discuss how does acid mine drainage form and how does it affect soil properties?
2) What are the common wastes that are being dumped into the landfills? How can you help in giving our landfills with longer “lives”?