Scientific Method

- Identify a problem (Purpose of the experiment)
    - Observations your have made to write a questions that addresses a problem/topic you want to investigate
- Form a Hypothesis
    - Predict how one variable will affect another, usually in the form of: If… then… because…
- Create an experiment
    - A step-by-step procedure for testing your hypothesis. Develop a procedure for a reliable experiment and address safety rules
- Perform the experiment
    - Follow the steps in the procedure to perform the experiment. Be sure to record your observations.
- Analyze the data
    - Check if the data is reliable and whether the experiment supports the hypothesis.
    - If the data is inaccurate or the experiment is flawed, modify the experiment and then perform it again.
- Publish results
    - Write a conclusion that summarizes the most important parts of your experiment and its results.

Conducting Experiments

- Results
    - Qualitative Results - Results that cannot be measured, often being the five senses (sight, sound, touch, smell, and taste).
    - Quantitative Results - Numerical measurements
- Variables
    - Variables are factors that that affect the experiment and are changed to produce different results.
    - Independent variables are those that cause things to happen and are not affected by the experiment.
    - Dependent variables are affected by changes in the independent variable, and are the outcome or result of the experiment

    - Control variables are variables that need to be kept constant for the experiment to be fair. Violating these will result in some bias, rendering the experiment meaningless.

Lab Safety

- Safety goggles should be used all the time to protect the user from injury to the eyes
    - Prescription glasses are ineffective because they can shatter, sending many tiny shards of glass into the user's eyes
    - There are also gaps in the glasses in which objects could harm you
- Basically, use common sense when it comes to these types of questions
- Symbols:
    - Octagon is Danger
    - Triangle is Caution
    - Diamond is Warning
    - WHMIS
        - Compressed Gas
        - Flammable/Combustible
        - Oxidizing Materials
        - Corrosive
        - Dangerously Reactive

Biology

Cell Theory

- All living things are made up of one or more cells
- The cell is the simplest unit of life that carries out basic life processes
- All cells are made up from other cells, they don't come from non-living matter

Organism Hierarchy

    - Prokaryotic (Does not have a nucleus)
        - Does not have a nucleus
        - Simple, single-celled organisms
        - Do NOT contain membrane-bound organelles
        - Ex. Bacteria

- Eukaryotic
    - Contain a nucleus
    - Complex, single-celled and multicellular organisms
    - Complex internal organisms through membrane-bound organelles
    - Larger than prokaryotes
    - Ex. Protists, fungi, animals, plants

The Cell

Organelles

- Organelles are cell structures that perform a specific function of a cell and is located inside a eukaryotic cell.
- Cell Membrane
    - Both in animal and plant cells, the cell membrane is a semi-permeable, double-layered membrane that supports the cell and allows nutrients to flow into the cell and waste to flow out of the cell.
- Cell Wall
    - Only in plant cells, the cell wall supports the plant, and is a rigid, outer layer primarily composed of cellulose. The cell wall is permeable and maintains the plant cell's shape regardless of turgor pressure.
- Nucleus
    - Both in animal and plant cells, the nucleus is a roughly spherical structure and acts like the brain of the cell, containing the genetic information of the cell as chromatin before division
- Nucleolus
    - Both in animal and plant cells, the nucleolus is a roughly spherical structure located in the nucleus that assembles ribosomes
- Nuclear Membrane
    - Both in animal and plant cells, the double-layered nuclear membrane encloses the nucleus and helps maintain the spherical shape of the nucleus
- Chromosomes
    - Both in animal and plant cells, the chromosome is a structure that carries the genetic information for living things in the form of genes, and is imperative for successful division.
- Centriole
    - Only in animal cells, centrioles are small cylindrical structures that secrete the spindle fibers used in mitosis
- Centrosome
    - Only in animal cells, centrosomes contain centrioles, the area from which spindle fibers develop
- Microtubule Organizing Centre (MTOC)
    - Only in plant cells, the MTOC comes into play during prophase of plant cell mitosis and is a broader spindle pole region for spindle fibers to develop and push chromosomes towards the equatorial plate.

- Cytoplasm
    - Both in animal and plant cells, cytoplasm is a jelly-like substance mainly composed of water that suspends all organelles and carries nutrients and waste around the cell
- Mitochondria
    - Both in animal and plant cells, the mitochondria provide energy for the cell by combining glucose and oxygen.
- Endoplasmic Reticulum
    - There are two types of endoplasmic reticulum, there is a rough ER, because it is studded with ribosomes, and the smooth ER, which is not. The rough ER is found in both animal and plant cells, but the smooth ER is only found in animal cells. The endoplasmic reticulum is a 3d network the transports materials like proteins throughout the cell.
    - Fluid-filled tubes responsible for transporting materials, such as proteins, through the cell
- Ribosomes
    - Both in animal and plant cells, ribosomes are small particles that helps in protein synthesis and is embedded in the rough ER
- Golgi Apparatus/Body
    - Both in animal and plant cells, the Golgi Apparatus collects and processes materials that need to be removed from the cell, and also makes and secretes mucus. The Golgi Apparatus is the only organelle that can be capitalized and looks like individual ellipses that are close together (is not connected).
    - Specialized cells that produce mucus
    - Collect and process materials to be removed from the cell
- Lysosome
    - Only in animal cells, lysosomes are spherical structures that degrade a cell's waste with enzymes and recycles the waste.
- Vacuole
    - Both in animal and plant cells, vacuoles are a single-layered sac filled with fluid. There are many small vacuoles in animal cells, and one big vacuole in plant cells.
- Chloroplast
    - Only in plant cells, chloroplasts produce energy for plants through photosynthesis, in which it turns carbon dioxide, water, and sunlight into oxygen and glucose.

Cell Cycle

Interphase

- This stage accounts for 90% of a cell's life
- Senses environment waiting for proper conditions and orders to replicate
- G1 (Growth 1) - Cell increases in size and grows
- R (Rest) - Cell enters temporary or permanent period of rest

- S (Synthesis) - Cell replicates DNA
- G2 (Growth 2) - Cell grows, produces proteins and prepares to divide
- DNA is copied into two identical strands

Division

- This stage accounts for 10% of a cell's life
- Is important for Reproduction, Growth, and Repair
    - Reproduction - All cells come from pre-existing cells
        - Asexual (Mitosis)- One parent divides into two new offspring that are identical to the parent
        - Sexual (Meiosis) - Two cells, one from each parent, join to produce an offspring
            - Each parent cell (gamete) contains half the DNA
            - Two gametes join to form a zygote
        - Growth
            - Number of cells increases as organisms grow
    - Cells can't just get bigger because they are limited by their surface areas to volume ratio; if they get too big, nutrients, gases, water, and waste won't be able to flow in and out of the cell properly
        - Material transfer occurs through diffusion or osmosis
            - Diffusion - Movement of solutes from an area of high concentration to low concentration
            - Osmosis - Movement of water
        - Both diffusion and osmosis take time to occur
        - Cells must be small enough to allow all parts of the cell to receive nutrients in a short amount of time
    - Repair - Must occur quickly enough to keep us alive
        - Some cells divide faster than others like red blood cells or skin cells
- Mitosis
    - Prophase
        - Nucleus and nuclear membrane disappear
        - Chromatin coils, condenses, and shortens to form clearly visible chromosomes, made up of two identical strands of DNA called sister chromatids, which are joined at the kinetochore inside a centromere
        - Two pairs of centrioles move to opposite sides, or poles, of the cell

        - Tiny fibres of protein called spindle fibers form around each pair of centrioles and radiate out from the centrosomes, creating a star-like appearance called asters (spindle fibers that don't go out for the kinetochore)
    - Metaphase (Middle)
        - Chromosomes line up along the middle (or equator) of the cell, called the equatorial plate. Chromosomes are guided here by spindle fibers
    - Anaphase (Away)
        - Chromatids are split at the centromere, producing two identical single-stranded daughter chromosomes
        - The spindle fibers from the centrioles pull the separated daughter chromosomes towards opposite poles by becoming shorter
        - Anaphase is finished once chromosomes arrive at each of the poles
    - Telophase (Two)
        - Chromosomes unravel and become less visible again
        - Nuclear membrane forms around each set/group of daughter chromosomes
        - Two nuclei are visible within a single cell
        - Spindle fibers and asters disappear
        - Cell membrane pinches in the middle creating a cleavage furrow, which begins to pinch the two new daughter cells apart

Cytokinesis

- Cleavage furrow deepns until two separate daughter cells are formed
- Two cells that are identical to each other and parent are made, and now enter interphase
- Each cell has 23 chromosomes
- Cytoplasm divides
- New nuclear membrane forms around each group of daughter chromosomes

Difference between plant and animal cells

- Centrioles and centrosomes:
    - Plant cells don't have centrioles or centrosomes for spindle fibers to originate from, rather they have an MTOC (Microtubule Organizing Centre), which is a broader spindle pole region
- The Cell Wall and Cytokinesis

        - Plant cell cytokinesis must include formation of a cell wall
        - During telophase, phragmoplasts (a set of short microtubules) form in the centre region of spindle fibers and serves as a scaffold for the new cell wall
        - Microtubules guide vesicles containing materials for construction of the cell plate form the Golgi Apparatus to the phragmoplast to form the cell plate
        - Fusion of vesicles expands the cell plate radially until it spans the cell
            - Cellulose in the vesicles from cell wall

Cancer

- Group of diseases where cells grow and divide out of control
- Due to DNA changes, the cell is prevented from staying in interphase for the normal amount of time
- Daughter cells divide uncontrollably because one or more of the checkpoints failed
- Cancer has hereditary and/or environmental causes; it is not infectious

Cell Growth Rates & Cancer:

- A cancer cell is a cell that continues to grow despite messages from neighbouring cells and its nucleus to stop
- A tumour is a mass of cells that continue to grow and divide without any obvious function in the body
- Benign tumours do not interfere with the processes of surrounding cells, but it can grow so large that it physically crowds surrounding cells and tissue
- Malignant tumours interfere with the processes and functions of neighbouring cells and is cancerous
- Metastasis is when cancer cells break away from the original tumour and start producing secondary tumours elsewhere in the body.

Causes of Cancer:

- Mutations are random changes in the DNA
- Very rarely, mutations happen in DNA that controls cell division
- Carcinogen; something in the environment that INCREASES CHANCES of cancer, such as tobacco, x-rays, uv rays, other forms of ionizing radiation, hepatitis B, etc.
- Some cancers are hereditary like breast and colon cancer

Smoking and Cancer

- Lung cancer is one of the most common type of cancer in Canadians over 40
- 9 out of 10 cases of lung cancer caused by smoking

Cancer Screening

- Cancer screening; checking for cancer even if there are no symptoms
- This tells whether inherited DNA is linked to any kind of cancer
- Breast cancer screening is done by checking for lumps
- Cervical cancer is screened by pap test, which is a sample of cervical cells
- Testicular cancer can be screened by self examination
- Prostate cancer can be screened by a prescribed blood test called a PSA
- Colon cancer is screened via a blood test
- Skin cancer is screened by skin checks for moles
- ABCD of moles is “Asymmetry, Border, Colour, Diameter”

Risk Reduction

- Factors that can affect the risk of cancer; carcinogens, lifestyle, personal medical history
- Have healthy diets, such as fruits and vegetables, and less fatty meats
- Some cancer fighting foods (superfoods) include figs, tomatoes, avocados, carrots, grapefruits
- A healthy body weight helps the immune system function and keeps hormone levels in check
- Lifestyle changes; eat more veggies, don’t use tobacco, be physically active, etc.

Diagnosis

- Many forms of cancer show no early symptoms
- Endoscopy is used for colon cancer
- A fiber optic cable with a tiny camera is put into the colon to send images to the doctor
- Mammograms are used for breast cancer x-rays
- Pregnant women shouldn’t undergo x-ray examinations because dividing cells in the fetus are harmed by the radiation
- Ultrasound uses ultra-high frequency waves to generate an image

- CT/CAT scans take multiples x-rays to generate an image otherwise unseen by a regular x-ray scan
- MRI uses radio waves and a strong magnetic field to generate even better images that CAT scans
- If a test shows abnormalities, a sample of the suspected cancer cells should be examined
- Leukemia for example can be diagnosed by looking at a blood sample
- A biopsy is when a small sample of tumour cells is removed surgically
- Malignant cells will be irregularly shaped and may be smaller or larger than surrounding cells

Treatment

- Surgical treatment uses the physical removal of the cancerous tissue
- However, even if the tumour is removed, cancerous cells can still remain
- Chemotherapy is a drug treatment that slows or stops cell division in cancer cells and kills them
- Chemo can be taken orally or via an injection
- Some side effects include hair loss, nausea, or fatigue
- The aim of chemo is to shrink the tumour for surgical removal
- Cancer cells are easily damaged by radiation because they divide rapidly, and radiation can damage the DNA to the point where the cancer cells cannot divide properly
- The DNA of many of the cancer daughter cells will be damaged by the radiation because they have a lesser healing ability than normal cells
- The effects of the radiation are reduced by either using a focused beam or implanting a radioactive source in the tumour
- Biophotonics is an emerging field and uses uses beams of light to detect and treat cancer
- It is considered better treatment than other methods because of the fewer side effects

Hierarchy of Structure in Animals

- Cells are the basic unit of life, but even specialized cells can’t do everything. Consequently, cells organize into groups to achieve certain functions such as feeding, breathing, moving, and reproducing.

Levels of Organization

From least complex to most,

1. Cell
2. Tissue - Any group of similar cells that perform the same function
3. Organ - 2 or more different types of tissue that perform a certain task
4. Organ system - One or more organs that work together to perform a vital function
5. Organism - Made up of different organ systems working together

Tissues

Muscle

- Bundles of long cells called muscle fibers that contain special proteins (actin and myosin) capable of contracting. There are three types of muscle; there are skeletal, which make bones move and ,by extension, you move, cardiac, which facilitates the heart pumping blood, and smooth, which surround the digestive tract
- Muscle cells have to have a lot of energy and so have a lot of mitochondria

Epithelial

- Thin sheets of tightly packed cells covering the external and internal body surfaces. Its primary function is to protect against dehydration and prevent organ rubbing. Some examples are skin and the lining of the digestive tract

Connective

- Various types of cells and fibers held in a liquid, solid, or gel matrix. Its primary function is support and insulation. Some examples of connective tissue are: blood, tendons, and bone

Nervous

- Long, thin cells with branches, capable of conducting electrical impulses. Its primary function is sensing, coordinating movement, transmitting information within the body, and most importantly, communication. Nervous tissue can be found in the brain (Central nervous system) and nerves in sensory organs

Organ

- A group of 2 or more different types of tissue working to perform a certain task
- For example, you stomach utilizes all 4 types of tissue; it has muscle tissue to churn and mix food with digestive juices, epithelial tissue lining the inside and outside of the stomach, connective tissue supplying oxygen and nutrients to the stomach, and nervous tissue, which activates the muscles are signals the release of digestive enzymes

Organ Systems

- A group of organs working to perform a certain task
- Examples: Circulatory system, digestive system, and respiratory system

Plants

- Typically green in colour because of the chlorophyll inside them for photosynthesis
- Anchored by roots and cannot move
- Need to exchange gases with their surroundings
- Require an internal transportation system to move water and nutrients around within their body
- Must have a way to reproduce

Systems

Body Systems

- Shoot System
    - Specialized to perform photosynthesis and produce flowers for sexual reproduction. Made up of leaf, flower, and stem
    - Leaf
        - Main photosynthetic structure of plant(rich in chloroplasts)
        - Some leaves are specially designed for support, protection, reproduction, and attraction
        - Some are edible such as lettuce, spinach, onions, tea, and herbs
        - Sources of wax and medicine
        - Sunlight + CO_2 + O_2 → $C_6H_{12}O_6$ (Glucose) + O_2
    - Flower
        - Specialized structure for sexual reproduction
        - Can contain male or female reproductive features or both
            - Male: Pollen grains (anther)
            - Female: Eggs (pistils)
        - After fertilization, seed is stored within a fruit
        - Rice, wheat, corn, vanilla, chocolate, coffee, bananas, apples, mangoes, cotton, and some medicines
    - Stem
        - Supports the branches, leaves, and flowers and provides a way to transport substances from the roots, leaves, flowers, and fruits
        - Some are specialized for food storage, protection, photosynthesis, and reproduction
- Root System
    - Part of the plant that is underground
    - Anchors plant
    - Absorbs water and minerals from soil
    - Stores food

Tissue Systems

- Both body systems are made up of 3 types of plant tissue systems
    - Dermal tissue system
        - Tissues covering outer surface of plants
    - Vascular tissue system

        - Facilitates transport of water, nutrients, and waste in and out of the plant
        - Made up of xylem
            - Tubes that carry water throughout the plant
        - Phloem
            - Tubes that carry nutrients throughout the plant
    - Ground tissue system
        - Filler between dermal and vascular tissue, manufactures nutrients in the green part of plants, stores nutrients in the roots and stems, and provides support

Photosynthesis

- Process in which plants build up glucose using water, carbon dioxide, and sunlight
- Chlorophyll is necessary for photosynthesis and is found in chloroplasts in the palisade and spongy mesophyll layer
    - Palisade layer is located on the upper part of the leaf where the most sunlight hits
    - Spongy mesophyll layer is located on the bottom of the leaf and has many gaps for the gas needed in photosynthesis
- Carbon dioxide enters the leaf through the spongy mesophyll layer, specifically through stomata, which open and close to allow gases through and prevent excess loss of water through transpiration (plants lose water)
- Xylem brings water for photosynthesis from the roots, up the stem, and into the leaves

Plant Cell Division

- Cell division in plants occurs in certain areas of the plants called meristems and continue to grow for as long as they live.

Meristems

- Plant meristems are unspecialized cells that develop into specialized cells as the plant grows
- Apical meristems
    - Located at the tips of roots and shoots
    - Cells allow plants to grow longer
    - Three regions:
        - Meristem region of cell division
        - Region of elongation
        - Region of maturation
- Lateral meristems
    - Around the stem and roots
    - Cells allow plant to grow wider
    - Outer lateral meristem produces new dermal tissue (cork)
    - Inner lateral meristem produces new phloem tissue on its outer surface and new xylem tissue toward its interior

    - Phloem and cork form the bark of the growing tree and the rings of xylem tissues form the interior of the tree trunk

Chemistry

- Matter is anything that takes up space and has mass

Particle Theory of Matter

1. All matter is made up of tiny particles that have empty spaces between them
2. Different substances are made up of different types of particles
3. Particles are always in constant random motion
4. Particles of a substance move faster when temperature increases
5. Particles attract each other and the force of attraction grows as particles are closer together.

States of Matter

- Solid
    - Strong attraction
    - Particles only vibrate
- Liquid
    - Weaker attraction
    - Particles slide past each other
- Gas
    - Attraction is very weak
    - Particles are far apart
- Changes in states are known as state changes or phase change
    - Solid to liquid - Melting
    - Solid to gas - Sublimation
    - Liquid to solid - Freezing
    - Liquid to gas - Evaporation
    - Gas to solid - Deposition
    - Gas to liquid - Condensation

Classification of Matter

- Matter
    - Mixture
        - Contains 2 or more substances like pizza or chocolate milk
        - Homogeneous Mixture (Solution) - Contains one visible component, and is uniformly mixed (Alloys, which are combinations of a metal and another metal like tin and lead for solder)
        - Heterogeneous (Mechanical) Mixture - Contains more than one visible component (A cat, a mechanical pencil)
    - Pure Substance
        -

        - Elements
        - Molecular elements
        - Compounds

Properties of Matter

Physical Properties

- A property that can be determined by using the five senses as well as measuring instruments
- Can determined without making any changes to the substance
- Can be quantitative (Can be measured) or qualitative (Cannot be measured but can be described such as colour)
- Hardness: Relative ability to scratch or be scratched by another substance
    - Diamond is very hard to scratch and so is hard, while talc is very easy to scratch and so is soft
- Malleability: The ability of a material to be hammered into a thinner sheet or molded
    - Silver is very malleable while glass shatters
- Crystal Form
    - Arrangement of particles in matter
- Viscosity: Resistance of a substance to flow or pour readily. Something with a HIGH viscosity will be HARD to pour while something with a LOW viscosity will be EASY to pour
    - Honey has a high viscosity and so takes a lot of time to pour
- Density: Measure of its mass in relation to its volume
    - Wood has a density lower than 1 g/mL, allowing it to float on water
- Electrical Conductivity: Ability of a substance to allow an electric current to pass through it
    - Copper is a very good conductor, while rubber is not
- Freezing point
    - Temperature at which a substance changes state from a liquid to a solid
- Melting point is equal to the freezing point for any substance
- Boiling Point
    - Temperature at which a substance changes state from a liquid to a gas
- We can take advantage of freezing and boiling point of substances so that we can identify them and modify them to suit our needs

Physical Changes

- A change in which the chemical composition of a substance is not changed; this type of change leaves the substance unaltered and no new substances are produced.
- Physical changes often result in a change of the substance's form or state and is usually reversible
- Common examples are: Cleaving an object, melting an ice cube, dissolving sugar in water, colour, texture, taste, smell, melting point, boiling point, etc

Chemical Properties

- Chemical properties describe the ability of a substance to undergo changes and to produce new substances
- Examples of chemical properties are: a substance reacting with another substance to produce a new substance in a solid, liquid, or gaseous form, a substance's toxicity, stability, or combustibility

Chemical Change

- Change in colour (Be wary of using dyes since dyes are a physical change, not a chemical one)
- Change in odour
- Formation of bubbles, indicating the presence of a gas
- Formation of precipitate; a new substance that does not dissolve in the mixture and shows up as a solid
- Change in temperature or light; produced through the release or absorption of thermal energy

Table of Elements

- Created by Dmitri Mendeleev
- During its creation, Mendeleev put empty spaces on the periodic table for elements that hadn't been discovered yet and predicted the properties of those elements

- Element
    - A pure substance that cannot be broken down into a simpler chemical substance
    - Elements are the building blocks of all substances
    - Each element has its own symbol on the periodic table
    - All elements are on the periodic table
- Compound
    - A pure substance composed of two or more different elements that are chemically joined

Metals

- Metals are elements characterized by their lustre, malleability, ductility, and ability to conduct heat, and electricity.
- Not all metals are lustrous; lithium, sodium, and potassium have a white coating because of their reactivity with air and their metal sheen can only be soon after being freshly cut
- Metals have a vast number of applications
    - Copper and aluminum are used in pots and pans because of their high thermal conductivity
    - Copper is used for electrical conductivity because of its high malleability and ductility

    - Gold and silver are used in jewellery because of their lustre, malleability, and resistance to corrosion
- Located on the left and central parts of the periodic table

Non-Metals

- Easily distinguishable from metals because most are either gases or powdery substances
- Not shiny, malleable, or ductile
- Bromine is the only liquid non-metal
- Non-Metals are generally poor conductors of thermal energy and electricity, making excellent insulation for homes
- Located in the upper right portion of the periodic table

Metalloids

- Elements that share metal and non-metal properties
- Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium, Polonium
- Located along the staircase line of the periodic table

Patterns

- Elements are arranged by increasing atomic mass
- Lightest element is hydrogen and the elements increase in mass as you move along the rows of periodic table
- Elements are also organized into columns of similar physical and chemical properties
- The 7 rows of the periodic table are known as periods and organized by increasing atomic mass
- The 18 columns of the periodic table are known as groups/family of elements with similar properties

Alkali Metals

- Lithium, Sodium, Potassium, Rubidium, Cesium, Francium
- Silvery, soft
- Highly reactive because they have 1 electron too many for a full valence shell
-
- Not often encountered in their elemental form in nature because readily combine with other elements to form compounds

Alkaline Earth Metals

- Beryllium, Magnesium, Calcium, Strontium, Barium, Radium
- Not as reactive as Alkali Metals
- Burn with bright, colourful flames, and so is often used in fireworks

Halogens

- Fluorine, Chlorine, Bromine, Iodine, Astatine
- The only group in which all three states of matter exist at room temperature

- Chlorine and fluorine are gases, bromine is a liquid, iodine and astatine are solid at room temperature
- Highly reactive since they are 1 electron away from a full valence shell
- Most are poisonous in large amounts
- Chlorine is used in small amounts to disinfect swimming pools, Iodine is dissolved into alcohol to disinfect cuts, and bromine is used in halogen lights

Noble Gases

- Helium, Neon, Argon, Krypton, Xenon, Radon
- Most stable elements since they have a full valence shell)
- Grow very brightly when an electrical current is passed through them, producing the light in neon signs
- Each gas glows a different colour
- With the exception of radon, they are non-toxic

Reading Elements

- Atomic Number is the number of protons an atom has in its nucleus
- Atomic Mass is the number of protons and neutrons in an atom
- With isotopes, the number given beside an isotope corresponds to the weight of that isotope.
    - Carbon-14 has an atomic weight of 14 amu. Carbon has 6 protons, which means that carbon-14 has 8 neutrons
- The first shell holds 2 electrons
- The second holds 8 electrons
- The third holds 8 electrons

Theories of the Atom

Democritus' Atom

- Democritus thought matter could be divided into smaller pieces over and over until an indivisible particle is reached. He named this indivisible particle "atom" for *atomos* which means indivisible.
- Democritus proposed that atoms are made of different sizes, in constant motion, and had empty spaces between them

Aristotle's Atom

- Aristotle believed that everything was made of 4 basic elements; earth, air, fire, water
- He also rejected the belief of an atom

Billiard Ball Model

- Proposed by John Dalton, he thought that all matter is made up of tiny, indivisible particles called atoms
- Atoms of an element are identical
- Atoms of different elements are different
- Atom are rearranged to form new substances in chemical reactions but are never created or destroyed

- The atom was a tiny, solid, indestructible sphere

Plum Pudding Model

- Proposed by J.J. Thompson, he believed that atoms contain negatively charged particles called electrons in a positively charged sphere
- Used a cathode ray tube to conduct experiments
- Discovered the electron when some particles were attracted to the positive end of the circuit

Nucleus and Proton

- Ernest Rutherford discovered the proton through his Gold Foil experiment
- Sent alpha particles at the gold foil and expected them to go right through
- When some were deflected towards the source, Rutherford theorized that the nucleus of atoms is positively charged and atoms are mostly made up of empty space

The Neutron

- James Chadwick proposed that the nucleus contains positively charged neutrons and neutrally charged neutrons

Electron orbits

- Proposed by Niels Bohr, electrons are located in specific orbits
- Each electron has a specific amount of energy. The amount of energy increases as electrons are farther away from the nucleus
- When electrons jump from orbit to orbit, they release energy as light
- Each orbit can hold a certain maximum number of electrons

Putting Atoms Together

Elements

- Consist of only one kind of atom
- Cannot be broken down into a simpler type of matter by either physical or chemical means
- Can exist as either elements or molecules

Molecules

- Can consist of 2 elements that are the same (Diatomic elements) or different (Compounds)

Diatomic Elements

- Diatomic elements are most stable when in a pair
- There are 7 elements that form molecules consisting of a pair of atoms
- Hydrogen, Oxygen, Fluorine, Bromine, Iodine, Nitrogen, Chlorine (H_2, O_2, F_2, Br_2, I_2, N_2, Cl_2); Hoff-Brinkle

Compounds

- Consist of 2 or more different elements bonded together
- Can be broken down into a simpler type of matter (elements) by chemical means (but not by physical means)
- Have properties that are different from the component elements
- Always contain the same ratio of component atoms (constant composition)

Chemical Formulas

- The notation used to indicate the type and number of atoms in a pure substance

Octet Rule & Ions

- Octet rule is a simple chemical rule that states that atoms gain, lose, or share electrons so that they have 8 electrons in their outer valence shells, similar to noble gases
- In essence, atoms are more stable when the outer shells of their atoms have 8 electrons
- Hydrogen and helium only need to fill the first energy shell to become stable
- When an atom loses or gains electrons, it becomes charged and is known as an ion
- Atoms that gain electrons and become negatively charged or anions
- Atoms that lose electrons and become positively charged or ations
- Ions have full outer orbit/energy level/ shell and are stable

Ionic Bonding

- Ionic bonds are formed between metal elements and non-metal elements
- Ionic bonds are formed by the attraction of 2 oppositely charged ions
- The positively charged ion, cation, loses 1 or more electrons and the negatively charged ion, anion, gains 1 or more electrons so that the compound is stable
- The anion's name comes second and ends in -ide
    - Potassium Chloride
    - Magnesium Fluoride
- Reduce compounds to simpler compounds (Mn_2o_4 becomes MnO_2)
- Adding oxygen makes the ending -ate

Covalent Bonding

- Covalent bonds are formed from non-metal elements
- Unlike ionic bonds that are formed from ions that have lost or gain electrons, covalent bonds are formed from atoms that share electrons
- The attraction of 2 atoms for the shared pair of electrons results in a covalent bond
- Two or more atoms joined by covalent bonds from a molecule
- Elements are given a numbered prefix depending on the number of atoms present; mono-, di-, tri-, tetra-, penta-, hexa-, octa-, nona-, deca-

Splint Test

Oxygen Gas

- Light a splint, then blow it out so there is a glowing ember on the end. Then insert the glowing splint into he gas. If the ember grows into a flame, the gas is oxygen.

Hydrogen Gas

- Put a burning splint into the gas, if there is an audible pop, the gas is hydrogen.

Carbon Dioxide Gas

- Insert a burning splint into a test tube of gas, if the flame goes out, the gas is carbon dioxide

Electricity

Static Electricity

- Static electricity is an imbalance of positive and negative charges on the surface of an object

Law of Electric Charges

- Opposite charges attract each other
- Like charges repel each other
- Charged objects attract neutral objects

Electroscope

- A device used to detect electric charges

Pith-ball Electroscope

- Consists of a small ball made of pith, cork, or styrofoam hanging from a thread
- When the electroscope is neutral and there is a neutral object, the pith-ball does not move
- When the electroscope is neutral and there is a charged object, the pith-ball moves towards the object

Metal-leaf Electroscope

- Consists of a metal ball connected to 2 thin metal strips/leaves

- When the electroscope is neutral and there is a neutral objects, the leaves hang straight down
- When the electroscope is neutral and there is a charged object, the leaves spread apart

Charging Objects by Friction

- This method charges objects by rubbing 2 neutral objects together to transfer electrons from one object to another
- One object loses electrons and the other gains electrons, making one positively and negatively charged respectively. This makes the two objects attract each other.
- Some objects have a stronger pull on electrons than others, and their pull on electrons is given by their position on the Electrostatic Series

Electrostatic Series

- Objects higher on the Electrostatic Series indicates they are most likely to lose electrons
- Objects lower indicate they are more likely to gain electrons
- The Electrostatic Series helps engineers avoid being shocked by certain materials, especially when working with extremely high voltages. In those scenarios, a small spark can easily turn into a short circuit, potentially leading to the loss of human life.
- Electrostatic Series shows relative attraction of electron for different substances

Charging Objects by Conduction

- The method of charging objects involving the contact between a charged object and a neutral object
- The neutral objects gets the same charge as the charged object since the charged object shares its charge with the neutral object, causing them to repel each other

Grounding

- When a charged object touches a large neutral object like the Earth, the charged object becomes grounded and loses its net charge
- If a negatively charged object is grounded, electrons from the object will go to the ground
- If a positively charged object is grounded, electrons from the ground will flow into the object

Charging Objects by Induction

-the method of charging objects involving no contact between a charged and a neutral object

-Temporary Induction

-the overall charge of the neutral object does not change but the different sides of the object are charged

-positively charged object and neutral object

-the electrons in the neutral object move towards the charged object while staying in the neutral object

-the protons in the neutral object move away from the charged object

-negatively charged object and neutral object

-the electrons in the neutral object move away from the charged object while staying in the neutral object

-the protons in the neutral object move towards the charged object

-Permanent Induction

-temporary induction occurs first

-the neutral object is grounded to change its overall charge

-positively charged object and neutral object

-electrons jump from the ground to the neutral object since it is negatively charged towards the charged object and positively charged towards the ground

-negatively charged object and neutral object

-electrons jump from the neutral object to the ground since it is positively charged towards the charged object and negatively charged towards the ground

Electric Discharge

-Lightning

-air currents in clouds cause a build up of negative electric charge at the bottom of the cloud and positive electric charge at the top of the cloud

-the negative charge at the base of the cloud repel the negative charges on the ground (the protons stay at the top of the ground while the electrons move away)

-the ground has an induced positive charge since it is left with a positive charge

-when the difference in charge between the ground and the cloud becomes large enough, the electrons in the cloud jump to the ground

-the current flow between the earth and the cloud produces lightning

Conductors and Insulators

-Conductors

-electrons are free to move around within the conductors

-a material that allows electrons to flow through it easily

-often called “sea of electrons”

-usually metal

-examples: silver, gold, magnesium, nickel, platinum, copper, aluminum, tungsten, mercury, iron

-Insulators

-electrons are not free to move around the object

-they can move from one side of the atom to the other but they are unable to leave the atom

-prevents electrons from flowing through it

-to prevent electric shocks, a conductive wire is wrapped in an insulator

-examples: plastic, wood, glass, rubber, silk, paper, wax, ebonite, wood, fur

Current Electricity

-the controlled movement or flow of electrons along a conductor

-current electricity moves easily through a conductor and poorly through an insulator

-Electrical Energy

-the energy provided by the flow of electrons in an electric circuit

-measured in joules (J) or kilowatt hour

-Electric Circuit

-a controlled path for the flow of electric current

-4 main components to a circuit…

-Source of Electrical Energy

-examples: dry cells, batteries (combination of cells), solar cells

-Electrical Load

-converts electrical energy into another form of energy

-examples: light bulb, motor, resistor

-Conducting Wire/Conductors

-pathway for electrons to flow

-examples: wire

-Switch

-controls the flow of current

-examples: switch

-when a switch is open, the flow of electrons is stopped

-when a switch is closed, the flow of electrons passes

-2 forms of current electricity…

-Direct Current

-the flow of electrons in one direction through an electric circuit

-produced by an electric cell or batteries

-Alternating Current

-the flow of electrons that alternates in direction in an electric circuit (electrons move back and forth)

-produced by generators at electric generating stations

Cells

-converts chemical energy into electrical energy

-Battery

-consists of 2 or more electrical cells linked together

-made up of 2 electrodes (made of 2 different conductive materials) in a conducting solution (electrolyte)

-the electrons are repelled by the negative electrode and exit through the negative terminal

-the electrons are attracted to the positive electrode and flow through the wire into the positive terminal

-Fuel Cells

-an electric cell that combines hydrogen and oxygen to produce electrical energy

-unlike other electric cells, it requires a continuous supply of fuel (hydrogen and oxygen) and produces a waste product (water)

-the process of removing hydrogen from fossil fuels requires lots of energy, produces pollution, and contributes to climate change

Energy

-Non-renewable Energy Sources

-a substance that cannot be replenish as it is used in energy-transforming processes

-examples: nuclear energy and fossil fuels

-Renewable Energy Sources

-a substance with an unlimited supply or a supply that can be replenished as the substance is used in energy-transforming processes

-examples: solar energy, hydroelectricity, geothermal energy, wind energy, tidal energy, biofuels

Electrical Power and Efficiency

-Power

-the rate at which energy is used

-measured in watts (w)

-one watt is the rate of converting one joule into another form per second
-the rate at which electrons spend their energy in a resistance

Astronomy

- The Earth is 1 Astronomical Unit away from the sun, or 1.5 x 10^8 km away.
- The next nearest star is Proxima Centauri at 4.01 x 10^13 km away from Earth
- Most stars are more than 1.0 x 10^14 km away from Earth

The Sun

- 5 Billion years old, and will last 5 billion more years
- 4.0 x 10^7 km in diameter; 1 million Earths could fit inside of it
- Sun releases electromagnetic radiation(x-ray, radio, gamma, visible, UV) and thermal energy

- Sun's atmosphere:
    - Corona
        - 5800°C - (1 x 10^6)°C
        - A gleaming, white halo extending millions of kilometers
        - This is what you see as the white part around the moon during a total solar eclipse
    - Chromosphere
        - 65,500°C
        - Layer above photosphere but under corona
    - Photosphere
        - 5500°C - 6000°C
        - Layer beneath chromosphere and where light we detect as sunlight originates
- Sun's Surface:
    - Sunspots
        - Cooler (4000°C), dark spots on the surface of the sun
        - Return every 11 years
    - Solar Flares/Winds
        - Gases and charged particles expelled above an active sunspot
    - Solar Prominences

        - Low energy gas eruptions from the Sun's surface that extend thousands of kilometers into space
        - Arch in space and return to Sun
- Inside of the Sun:
    - Convective Zone
        - Outermost ring of the sun, comprising 30% of the sun's radius
    - Radiative Zone:
        - The section immediately surrounding the core, comprising 45 percent of the radius
    - Core:
        - Hottest part of the sun, reaching temperatures of up to 1.5 x 10^7
        - Nuclear Fusion occurs in this area and continues to move outward until it reaches the photosphere
        - 75% Hydrogen, 25% Helium with trace elements
        - Hydrogen fuses to become Helium, releasing tremendous amounts of energy

- Effects on the Earth:
    - Aurora Borealis, commonly referred to as the Northern Lights, are a result of charged particles from the sun colliding with gaseous particles of the Earth.
    - Solarwinds travelling toward the Earth are deflected by Earth's magnetic field towards its poles, producing a display of light in the night sky

Solar System

- Sun is largest object in the solar system, next come the planets
- Planets:
    - Inner Planets(Terrestrial):
        - Mercury, Venus, Earth, Mars
        - Small and Rocky
        - Located between the Sun and Asteroid Belt
    - Gas Giants(Jovian):
        - Jupiter, Saturn, Uranus, Neptune
        - Large, composed of gas
        - Atmospheres mainly consist of hydrogen and helium
    - All planets satisfy these three rules:

        - Be in orbit around a star
        - Be massive enough to pull it into a stable spherical shape
        - Be massive enough to clear most asteroids out of its path for its orbit, and dominates its orbit
    - Planets that do not satisfy those requirements and known as dwarf planets, which are spherical celestial objects that do not dominate their orbit
- Asteroids:
    - Composed of rock and metal
    - Orbit the sun but are too small to be considered planets
    - Most asteroids lie in the Asteroid Belt, between Mars and Jupiter
- Meteoroids, meteors, and meteorites
    - Meteoroids are pieces of metal and rock that are smaller than an asteroid
    - If they get pulled into Earth's atmosphere by Earth's gravity, it becomes a meteor and creates a bright streak of light
    - Pieces of meteors that make it to Earth's surface are then referred to as meteorites.
- Comets:
    - Large chunks of ice, dust, and rock that orbit the Sun
    - A gaseous tail forms by radiation and solar win approaching from the sun and the tail points directly away from the sun
    - A dust tail forms in the direction the comet originated in
- Earth
    - Earth's rotation:
        - Earth rotates on its axis, similar to a spinning top
        - Rotates in a west-to -east direction
    - Earth's revolution:
        - Earth and other planets revolve around the sun in an elliptical path
        - Orbital Radius
            - Average Distance between an object in the solar system and the sun
            - Earth's orbital radius changes as it completes its orbit
        - Orbital Period
            - Time it takes to complete 1 revolution. It is 365.25 days for Earth

        - Orbital Period is dependent on size, shape, and distance from the sun
- Moon
    - Moon rotates around its axis and revolves around the Earth in the same amount of time (rotation time = revolution time), which means Earth always sees the same side of the moon
    - Phases of the Moon:
        - The Lunar Cycle is the phases of the moon over a period of 4 weeks.
        - New Moon - Can't see moon as Earth's shadow covers it completely
        - Waxing Crescent - Sliver of Moon appears in a crescent shape
        - First Quarter - Half of the Moon can now be seen
        - Waxing gibbous - a sliver of the moon is still shrouded in darkness
        - Full Moon - Entire moon is seen
        - Waning Gibbous - Sliver of moon in darkness
        - Third Quarter - Half moon
        - Waning Crescent - Sliver of moon still visible
        - New Moon
    - Tides
        - Alternate rising and falling of the surface of large bodies of water
        - Moon's gravitational force pulls Earth and the oceans towards it causing high tides
        - 6 hours between tides
        - New and full moon phases cause very high spring tides
        - Quarter phases cause weaker neap tides
- Earth is tilted 23.5° from the vertical, which causes the seasons
    - When Earth is tilted toward the sun, the northern hemisphere experiences summer, as the sunlight spreads over a smaller area
    - When Earth is tilted away from the sun, the northern hemisphere experiences winter, as sunlight is spread out over a larger area
    - Opposite for southern hemisphere
- Solstice = Occurs twice a year, when Earth is tilted as far away or close to the Sun. Summer Solstice (June 22) is closest to Sun, and Winter Solstice (December 22) is farthest
- Equinox: Occurs twice a year, when the hours of daylight is equal to the hours of darkness. Autumnal Equinox (September 23), and Vernal Equinox (March 21)

- Precession
    - Changing direction of Earth's axis (Earth's wobble)
    - Earth wobbles as it rotates on its axis over 26,000 years
    - Polaris seems to stay fixes in the sky (we appear to revolve around the star), and it changes because of precession
- Eclipse:
    - Darkening of celestial object because another celestial object is in front of it
    - Solar Eclipse:
        - Moon is between Earth and Sun
    - Lunar Eclipse:
        - Earth is between Sun and Moon
        - Moon appears to be orange or red

Stars

- Constellations:
    - Grouping of stars as observed from Earth
    - 88 constellations recognized by International Astronomical Union
    - Stars move over many years so constellations changes lightly
    - Star Maps: Maps that show stars in certain regions of the sky, used for navigation
- Celestial Sphere:
    - Imaginary Sphere that rotates around the Earth
        - Divided into north and south hemispheres along the celestial equator
- Celestial Navigation:
    - Using positions of stars to ascertain location and direction when travelling
    - Used for agriculture and religious events, and predict movement of Sun, Moon, and eclipses
- Stars are classified by their size, temperature, and brightness
- Brightness:
    - Luminosity is the total amount of energy produced by a star per second
    - Brightness of a star is characterized by its luminosity and distance from observer
    - The Sun has a luminosity of 1
    - Sirius, the brightest star in the night sky, has a luminosity of 22
    - Sun appears much brighter because it is closer to Earth than Sirius

- Apparent Magnitude:
    - Star's apparent magnitude is its brightness as seen from Earth
- Absolute Magnitude:
    - Its brightness as if the star was located 33 light years (1 parsec) from Earth
    - Smaller Magnitude number means a brighter celestial object to the observer
- Hertzsprung-Russel Diagram
    - A graph comparing a star's surface temperature and absolute magnitude
    - Many stars fall under the main sequence
    - Surface temperature increases as absolute magnitude increases
    - Hot star appears bluish, while cooler stars appear reddish
    - Higher surface temperature makes the star appear bluish-white, while a lower surface temperature makes it seem reddish-white
- Nebula
    - Large cloud of gas and dust
    - Formation of star
- Protostars
    - Gravity makes a region of gas more compact
    - Stars now start taking definite shapes
    - Once the core of protostar reaches 10 million°C nuclear fusion begins and the protostar ignites, becoming a star
- Nuclear Fusion
    - Two nuclei smash together to form a heavier element
    - New stars initially fuse hydrogen together to form helium
- Main sequence Stars
    - An ignited star becomes a main sequence star, which usually fuses hydrogen to get helium, releasing tremendous amounts of energy
    - Takes approximately 10 billion years to consume all hydrogen in main sequence star
- Core
    - Energy is generated from the core
    - Radiative and convective zones move energy out of center of star
    - Weight of all gas and gravity creates immense pressure on the core of the star, allowing fusion to take place
- End of fusion

    - As long as nuclear fusion takes place, the internal forces will push against external forces.
    - Once hydrogen is consumed, fusion stops and mass and gravity causes remaining gas to collapse on the core
- Red Giant
    - Collapsing outer layers cause core to heat up, creating conditions for helium to fuse into carbon
    - Forces regain balance
    - Outer shell expands to 10 to 100 times larger than the Sun (at least 40 million miles across)
    - Red Giants last for about 100 million years
    - Once Red Giant fuses all helium into carbon, the massive outer layers of star rushes into the core and rebound, generating staggering amounts of energy
- Planetary Nebula
    - Cloud of gas that forms around a sun-like dying star
- White dwarfs
    - Pressure exerted on core is not enough to incite helium to fuse into carbon
    - Very dense and very hot core
    - About 8,000 miles in diameter
    - Will cool after 35,000 years
- Black Dwarfs
    - As a white dwarf cools, its light will fade through visible spectrum to black
    - Will continue to generate gravity and low energy radio waves
- Red Supergiants
    - If the mass of a star is 10 times greater than that of our Sun, it will become a Red Supergiant
    - Fuses helium to carbon, then fusion stops and outer layers collapse on the core, producing conditions to fuse carbon into iron
    - Once iron begins to be produced, the star will expand to be between 10 and 1000 times larger than our Sun
- Supernova:
    - Iron is the end of the fusion cycle road, and core of supergiant will collapse in less than a second, causing a massive explosion called a supernova
    - Massive shockwave blows away outer layers of star
    - Shines brighter than galaxies for a few years

- Neutron Star
    - Neutron stars form if the initial mass of the star is between 10 and 30 solar masses(1 solar mass is mass of our Sun)
    - Neutron star made of tightly packed neutrons
    - Very dense
- Black Holes
    - If the initial mass of the star is greater than 30 solar masses, a black hole forms
    - Black hole is a core so dense and so massive, light can't escape its gravitational pull

Big Bang

- 13.7 billion years ago, all matter was compacted into a very tiny hot, dense ball under an immense amount of pressure
- Ball exploded, hurtline matter and energy in all directions
- Proof:
    - Cosmic Background Radiation; a sort of static from the Big Bang
    - Red Shift; as objects move farther away, their light appears redder, as the wavelength stretches.
- Everything is observed to move farther away through redshift, proving that the universe is expanding like a large balloon