Physics

Unit 1: No Astronomy on Test (Massive W)

What is a Physical Quantity?

A physical quantity is anything you can measure.

What is a Measurement? What does it contain?

A measurement tells us about a property of something. It contains a number and a unit.

What are Significant Figures/Significant Digits?

Significant figures/significant digits are the number of digits in the measured value, giving us the maximum accuracy of the measurement.

What is Uncertainty?

Uncertainty is the margin of error in a measurement. For a digital device, it is +- the lowest division. For an analog device, it is +- half of the lowest division.

What are SI units?

SI units are the International System of Units, the metric system used nowadays. It contains length (meters, m), weight (Kilograms, kg), time (seconds, s), temperature (Celsius, C), electric current (Amperes, A), luminous intensity (candela, cd).

What is a Light Year?

A light year is the distance that light travels in a vacuum (empty space) in one year, which is equal to $9.46 * 10^{12}$.

What is the Speed of Light?

The speed of light in space is constant at 300,000 km/s.

What is the distance between the Earth and Sun?

The distance between the Earth and Sun is one Astronomical Unit (AU), it is approximately 150 million kilometers.

What is the distance between the Earth and Moon?

The distance between the Earth and Moon is 400,000 km.

What is Megaparsec?

A Megaparsec is used to describe the distance between galaxies. 1 Megaparsec = 1 million Parsecs, 1 Parsec = 3.26 light years.

What are all the metric prefixes?

The metric prefixes are Tera (10^{12}), Giga (10^{9}), Mega (10^{6}), Kilo (10^{3}), Deci (10^{-1}), Centi (10^{-2}), Milli (10^{-3}), Micro (10^{-6}), Nano (10^{-9}), Pico (10^{-12}).

What are Imperial Units?

Imperial units are English Units, which arose when the kings and queens decided measurements for the land, and still used by the Americans and British. Some examples are pounds, yards, inches, feet, gallons, miles.

What are Natural Units?

Natural Units are the most sophisticated choice of units, where the fundamental units, such as the speed of light, are set to 1, and all the other quantities are based off these fundamental units.

What is Dimensional Analysis?

Dimensional analysis is a conversion factor (written as a fraction) to relate two units.

What is the Big Bang Theory?

The Big Bang Theory is the theory of the creation of the universe, taken place approximately 13.8 billion years ago, where everything originated from the singularity’s explosion.

What is Redshift?

Redshift is the evidence behind Big Bang Theory, discovered by Edwin Hubble, where universes are zooming out and stretching. In 1925, Edwin Hubble observed the data for 45 galaxies, and noticed that their wavelengths were all longer than expected, towards the red end of the spectrum, leading to the appearance of red-shifted light. The amount of observed redshift is always proportional to the source, for example, if a galaxy was moving away from us at 3% the speed of light, the lines of its spectrum would also be redshifted by 3%.

What is Blueshift?

Blueshift contradicts Redshift, where things are zooming in and coming closer.

What is Wavelength? What is Frequency?

Wavelength is the distance in meters between repeats in a wave. Frequency is the number of waves that pass a certain point per second.

What is the Doppler Effect?

The Doppler Effect is the sound version of Redshift, and the change in pitch or frequency of sound waves as you move closer or further away is called Doppler Shift.

What are the parts of an Electromagnetic Spectrum?

The electromagnetic spectrum contains Gamma, X-Ray, Ultraviolet, Infrared, Microwave, Radio.

What is Newton's First Law of Motion?

Newton's First Law of Motion states that every mass will continue its state or rest or uniform motion unless an unbalanced force acts on it. This concept was included in his work, Principia, published in 1687. He also proposed that gravity attracts objects on Earth.

Unit 2:

Radioactivity and Nuclear Reactions:
History:

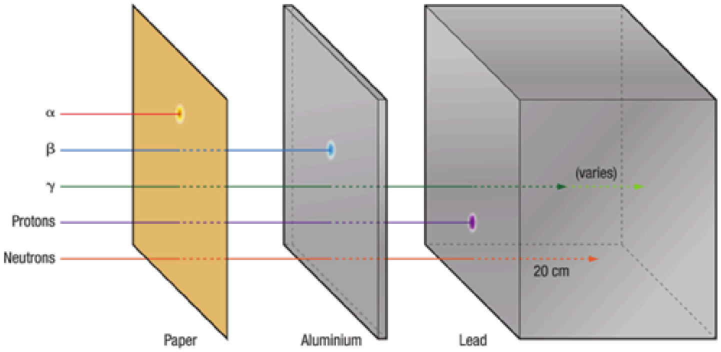
- **Henri Becquerel**: studied **fluorescence** (ability of certain chemicals to give off visible light after absorbing radiation)
- **Pierre and Marie Curie**: continued Becquerel's research
    - More radiation was emitted from the uranium ore than from refined uranium
    - Discovered 2 new elements in the ore: polonium and radium

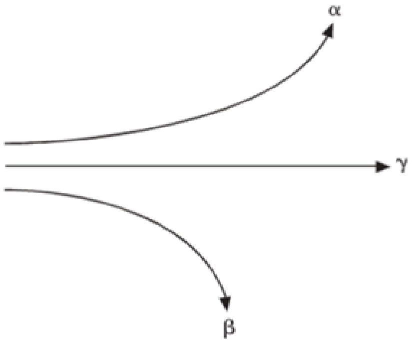
Types of Radiation:

1. **Alpha particles** α: high-speed helium nuclei with charge of +2 and mass of 4
2. **Beta particles** β: electrons
3. **Gamma particles** γ: highest form of electromagnetic radiation known

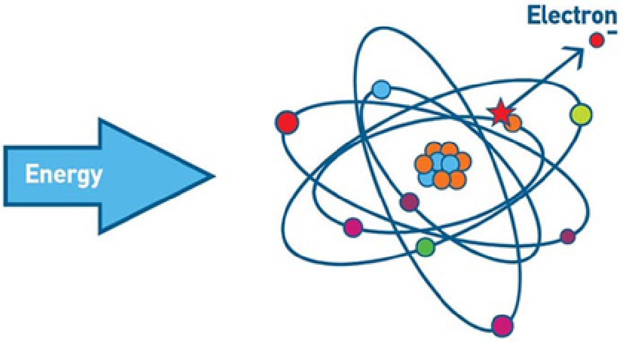
Properties:

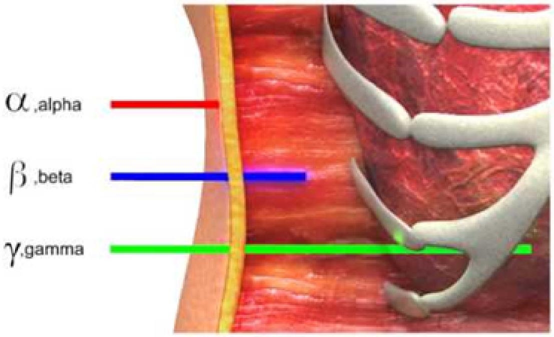
- **Penetrability**:
    - Gamma > beta > alpha
- **Deflection**:
    - Beta > alpha > gamma
    - A and B are charged, so they can be deflected, but in opposite ways because of their opposite charges
    - A particles have twice the charge but higher mass, so they are deflected less than B
    - Gamma rays have no charge, so it's not deflected





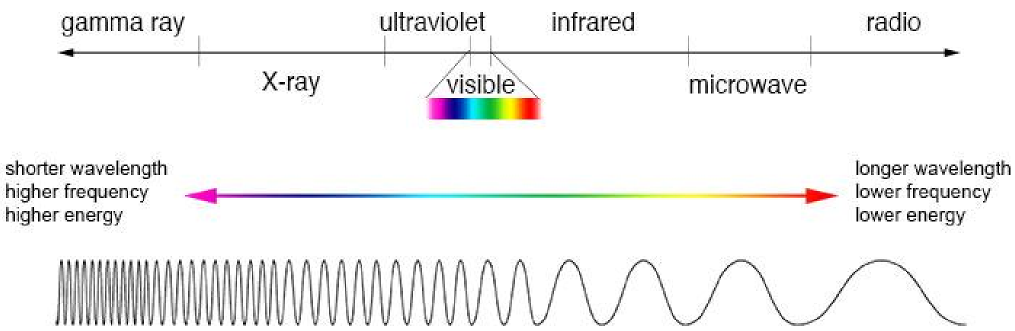
- **Ionizing**:
    - Alpha > beta > gamma
    - All types of radiation strip electrons from atoms and molecules, causing them to become ionized
    - A has the most mass, knocking off many electrons, G is the least ionizing but still has enough energy to eject electrons





- **Health Problems**:
  - Gamma > beta > alpha
  - A is the least dangerous if it doesn't enter the body, but if it is ingested or breathed in, it is dangerous and can be absorbed by cells
  - B and G are more dangerous, and can damage living tissue, causing radiation burns, cancer, and death
    - Also can be used to treat cancer by killing bad living cells

Radiation and Radioactivity:
- **Radiation**: the release of particles or waves from the nucleus
  - **Non-ionizing radiation** (low-energy parts of the electromagnetic spectrum): ultraviolet, light, infrared, radio waves, microwaves
  - **Ionizing radiation** (radiation that can remove an electron from its orbital): high energy electromagnetic radiation, particle radiation (alpha & beta)



- **Radioactivity**: the property of certain elements to spontaneously emit radiation, resulting from the decay or rearrangement of an atom's nucleus

Isotopes: atoms of the same element that have different numbers of neutrons
- Same number of protons (same atomic number), but different number of neutrons (different mass number)
- **Mass number**: mass of 1 specific kind of isotope
- **Atomic mass**: the average mass of all naturally occurring isotopes
- **Natural abundance**: percentage of isotope found in nature
  - **Average atomic mass** = natural abundance of isotope1 × mass of isotope1 + natural abundance of isotope2 × mass of isotope2…etc

Radioactive Decay: the process where unstable nuclei lose energy by emitting radiation
- Unstable nuclei either have too many neutrons or too many protons
  - Attempts to balance themselves by giving off the excess neutrons or protons
- **Radioisotopes**: isotopes capable of radioactive decay
- ${}^{mass\ number\ A}_{atomic\ number\ Z}element\ symbol$
- **Alpha decay**: loss of an alpha particle (2 neutrons, 2 protons)
  - Mass = 4, charge = +2

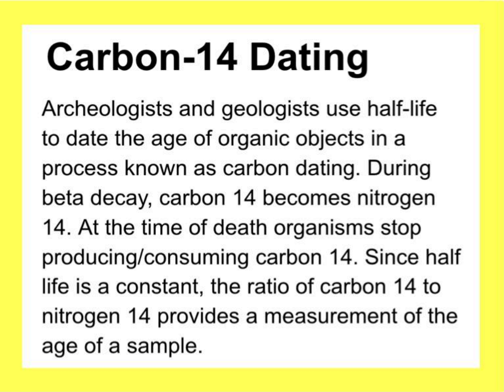
  - Only decay that will produce daughter nuclei with different mass numbers
  - The new element formed is 2 places lower on the periodic table
  - Ex. ${}^{235}_{92}U \rightarrow {}^{231}_{90}Th + alpha\ particle + gamma\ ray\ OR\ {}^{231}_{90}Th + {}^{4}_{2}He + {}^{0}_{0}\gamma$
    - Not all reactions emit Gamma radiation, but if they do, a ${}^{0}_{0}\gamma$ must be indicated
- **Beta-minus decay**: changing a neutron into a proton and an electron (beta-minus particle β^{-})
  - The proton is retained by the atom and the electron is lost
  - The new element formed is 1 place higher on the periodic table
  - Ex. ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + beta\ minus\ particle\ OR\ {}^{14}_{7}N + {}^{0}_{-1}e$
- **Beta-plus decay**: changing a proton into a neutron and **positron** (beta positive particle)
  - Positrons have the same mass as electrons but an opposite charge
  - ${}^{23}_{12}Mg \rightarrow {}^{23}_{11}Na + beta\ plus\ particle\ OR\ {}^{0}_{+1}e$
- **Gamma decay**: ${}^{231}_{90}Th \rightarrow {}^{231}_{90}Th + {}^{0}_{0}\gamma$

Reasons for Unstable Nucleus:

- **Nucleus is too big**
  - A force called "**strong nuclear force**" is responsible to hold a nucleus together
    - 100x stronger than the electrostatic repulsion that pulls the nucleus apart, but gradually drops off and not enough force to hold the nucleus together
  - Alpha decay decreases size of nucleus
- **Non-ideal number of protons and neutrons**
  - In general, the nucleus prefers neutrons > protons
    - Too many neutrons = beta negative decay, neutron breaks down to proton and electron (1 less neutron and 1 more proton)
    - Too many protons = beta positive decay, proton breaks down to neutron and positron (1 less proton and 1 more neutron)
- Gamma emission occurs when nucleus is in an excited state (when elements decay, the nucleus has too much energy)

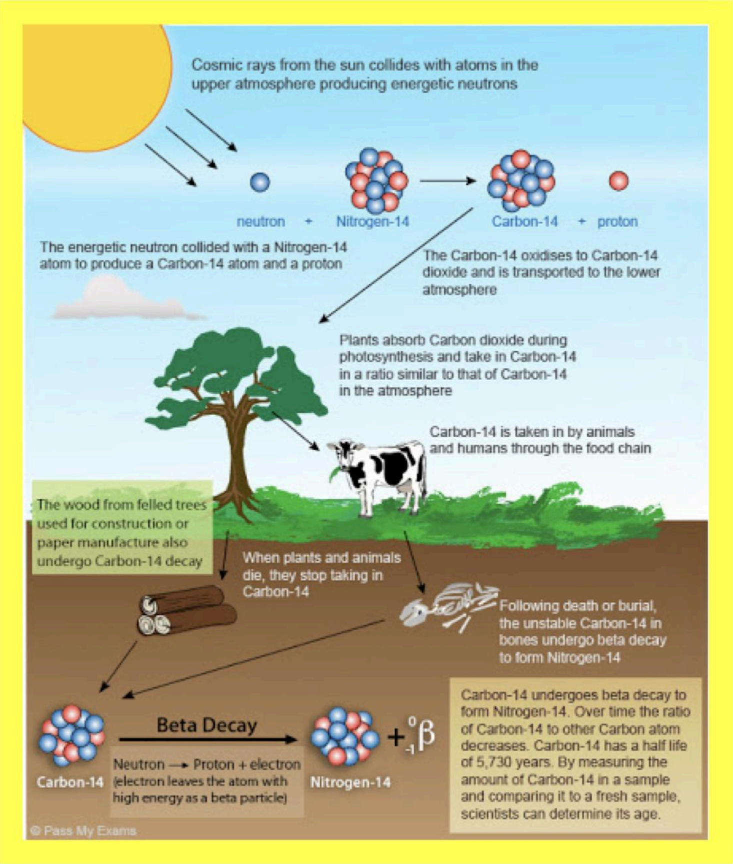
Half-Life: the time required for half the unstable nuclei of a radioactive isotope to decay (rate of radioactive decay)

- A constant for any radioactive isotope
- **Decay curve**: a curved line on a graph showing the rate



Carbon-14 Dating

Archeologists and geologists use half-life to date the age of organic objects in a process known as carbon dating. During beta decay, carbon 14 becomes nitrogen 14. At the time of death organisms stop producing/consuming carbon 14. Since half life is a constant, the ratio of carbon 14 to nitrogen 14 provides a measurement of the age of a sample.



Radiocarbon Dating: the process of determining the age of an object by measuring the amount of Carbon-14 it remains

- Carbon is extremely common on Earth and in living organisms
- During beta decay, C-14 becomes N-14
- At the time of death, organisms stop producing C-14, decreasing over time
- The ratio of C-14 : N-14 then provides a measurement of the organism's age
- C-14 has a half-life of 5730 years (only reliable for the duration of 10 half-lives)

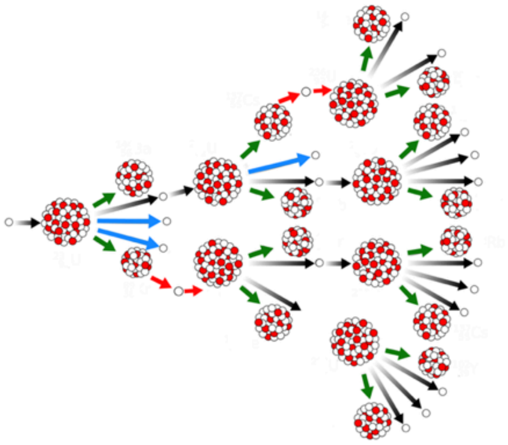
Nuclear Reactions: a process in which an atom's nucleus changes by gaining or releasing particles or energy

- Can release 1-3 types of **subatomic particles** and gamma rays
- Nuclear reactions can be introduced by smashing nuclei with alpha, beta, and gamma radiation to make nuclei unstable

Nuclear Fission: splitting the nucleus

- Most known fission reaction: Uranium-235 (Nuclear reactors and atomic bombs)
- Nucleus of U-235 is hit by neutron → splits into 2 smaller atoms → not always the same 2 atoms, but always releases 3 neutrons and energy → these neutrons hit 2 other nuclei and release 3 more neutrons and energy, etc.
  - A lot of energy is released quickly

$${}_{0}^{1}n + {}_{92}^{235}U\ (unstable\ U-236) \rightarrow {}_{36}^{92}Kr + {}_{56}^{141}Ba + 3{}_{0}^{1}n + energy$$



Chain Reaction: ongoing process in which 1 reaction initiates the next reaction
Electron Microscope: allows to see down to the atomic scale

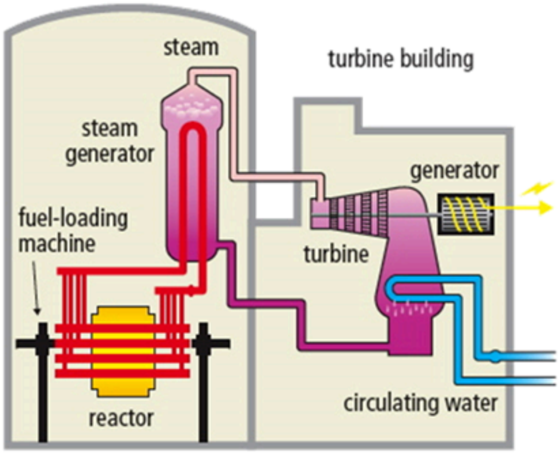
- Atoms are smaller than **photons** (wavelength of visible light)
- Uses a beam of electrons for greater magnification and better resolution

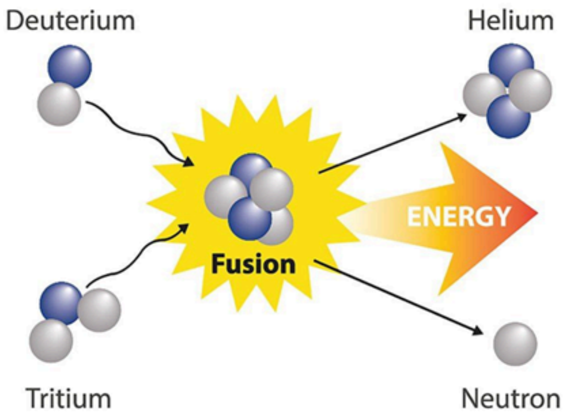
Nuclear Reactors: modern-day devices used for generating power

1. **Fuel Elements**
    - Thin rods, contains fissionable nuclei like U-235 and U-238
2. **Moderator**
    - Fuel elements are placed in water (moderator)
    - Slows down the speed of high energy neutrons so they can be used in chain reactions
3. **Control Rods**
    - Controls the number of spare neutrons at any given time to control the rate of chain reactions

CANDU Reactor: Canadian Deuterium Uranium Reactor, uses natural uranium as a fuel and uses heavy water as a moderator

- Deuterium is an isotope of hydrogen -1 that is twice as heavy (has both a proton and neutron in its nucleus)





Nuclear Fusion: atomic nuclei join to form large nuclides

- In the core of the sun, 2 hydrogen nuclei join under tremendous heat and pressure to form a helium nucleus and release large amounts of energy
- ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + energy$
- Advantages: lightweight nuclei release huge amounts of energy, and doesn't produce radioactive products

Nuclear Energy Power Source:

- Pros: reliable, cost-effective, low carbon emissions, generates lots of energy
- Cons: non-renewable, radioactive waste, environmental danger, water intensive (overuse of water)

Unit 3:

Industrialization: driven by **steam**, making mining, manufacturing, and transportation more effective
Forms of energy: mechanical, nuclear, chemical, electrical, electromagnetic, thermal

Transfer of Thermal Energy:
Heat transfer: heating & cooling (energy input or transferred away)

1. **Conduction**:
    - Direct particle-to-particle contact
    - When high-energy particles touch low-energy particles, energy is transferred
        - Faster particle slows down to lose thermal energy, vice versa
    - If objects remain in contact, the energy transfer will continue until the **thermal equilibrium** is achieved (balance of energy)
    - Metals are good conductors; wood, cotton, wool, etc. are bad conductors
2. **Convection**
    - Fluid movement (liquid/gas) transfers heat
        - Hotter items rise, colder items sink (hot items have less density)

3. **Radiation**
    - Transferring heat through space by electromagnetic radiation
    - Ex. absorbing the heat of the sun
    - Factors that affect absorbing radiant energy: shape, texture, color, temperature, and type of substance

Matter: made of constantly moving tiny particles
- Particles have kinetic energy because they are moving
- Particles move further apart from solid to gas states

Kinetic Molecular Theory:
- All matter is made of particles constantly in motion, more energy, faster movement
- A substance's temperature = average kinetic energy of the particles

Kinetic energy: energy a substance has due to its motion

Potential energy: energy stored within the substance

Thermal energy: (kinetic energy + potential energy) * number of particles in an object

Heat: transfer of thermal energy from one object to another
- Due to differences in temperature (warmer objects → cooler objects)

Law of Conservation of Energy:
- Energy cannot be created or destroyed, but only changed in form or transferred between objects

Thermometer: measures the average kinetic energy of the particles in an object
- Essentially measuring its own temperature (when a thermometer reaches thermal equilibrium, the temperature of the thermometer and the substances it is measuring becomes the same)

Temperature measurements:
- SI Units **Celsius °C**
- **Kelvin K**
    - Starts at 0K (absolute zero), a theoretical temperature where a substance has no thermal energy
- **Centigrade C**
    - Melting point to boiling point of water

Specific Heat Capacity:
- Quantity of heat (Joules) absorbed per unit mass (kg) of the material when the temperature increases by 1K (or 1°C)
- $Q = mc\Delta T$: $heat\ energy = mass \times specific\ heat\ capacity \times change\ in\ temperature$

Water's specific heat capacity: 4182 J / kg°C
- Regulates and cools objects
- Helps maintain homeostasis in human bodies, functions of the organism

Biology

Unit 4:

DNA: deoxyribonucleic acid
RNA: ribonucleic acid
Base pairs: Adenine & Thymine, Cytosine & Guanine
Complementary sequence: nucleotides in other strand

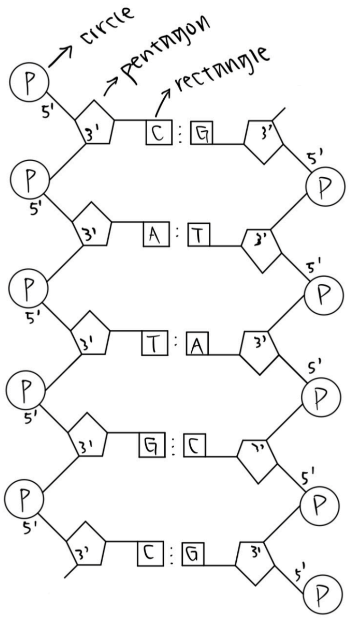
DNA vs RNA:

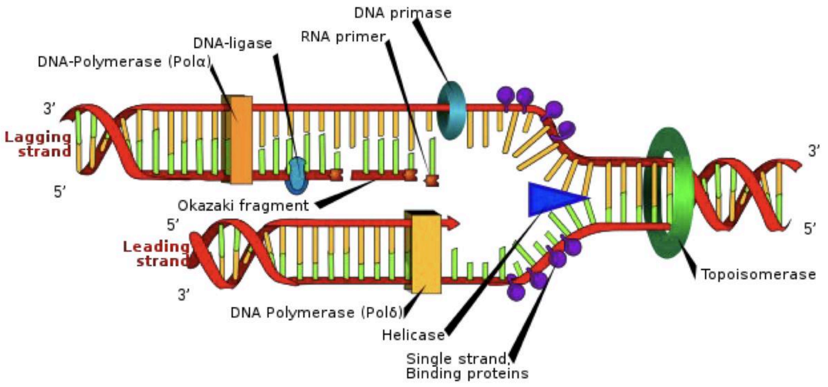
1. Sugar: DNA deoxyribose, RNA ribose
2. Strands: DNA 2-strand, RNA 1-strand
3. Bases: DNA ACGT, RNA ACGU

Nucleotides: building blocks of DNA, 3 parts

1. **Sugar (pentose)**
2. **Phosphate group**
3. **Base** (**purines**, 2-ringed A&G; **pyrimidines**, 1-ringed C&T&U)

Hydrogen bonds: links between bases, breaks apart easier for DNA replication
Covalent bonds: backbone of nucleotides





DNA Replication:

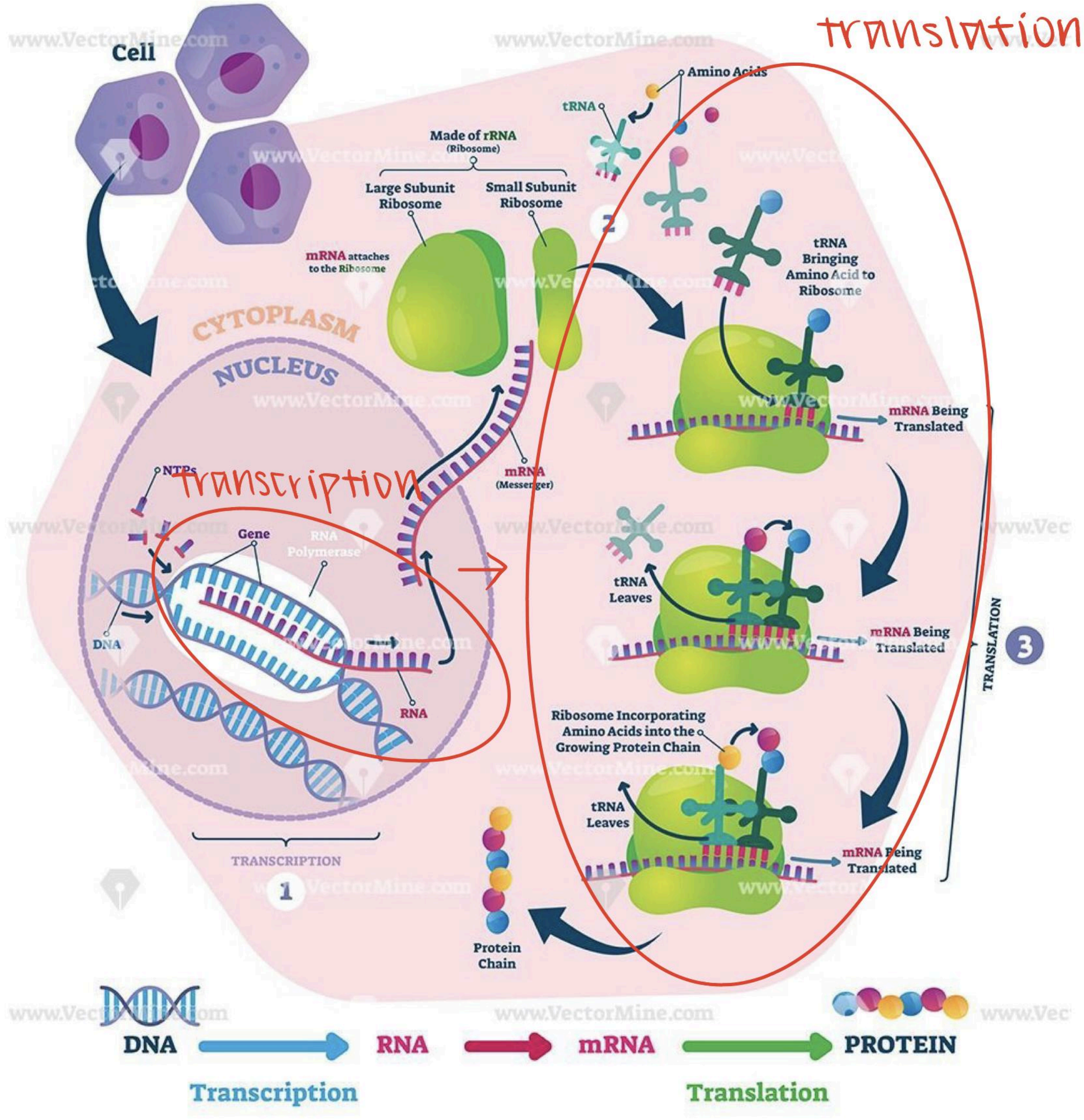
1. **Unwinding**: old strands of DNA unwound and unzipped by the **helicase** (special enzyme)
2. **Complementary base pairing**: new complementary nucleotides are positioned
3. **Joining**: complementary nucleotides join to form new strands, each daughter DNA contains 1 old and 1 new strand
    - Steps 2 & 3 by the **DNA polymerase**, led by the primer

- **Leading strand** & **Lagging strand** (**okazaki fragments**): 3’ → 5’or 5’ → 3’ direction

Functions of DNA:

- Carries oxygen in blood (**hemoglobin**)
- Carries out different functions for DNA replication using enzymes (ligase, primase, helicase, polymerase, etc.)

Gene: segment of chromosomes that contains info to make proteins
Amino acids: building blocks of protein
Polypeptide: chain of many amino acids (linked by **peptide bonds**)



Protein Synthesis:

1. Nucleus receives a chemical signal to make a specific protein
2. **Transcription**: DNA message for the protein is copied into the **mRNA**
3. mRNA leaves the nucleus through the **nuclear pore** and lands on the **ribosome**
4. RNA message is read in **triplet code/codon**
    - Each codon codes for an amino acid, starting the codon with AUG until the **stop codon**, connected by a **peptide bond**
5. **Translation**: the tRNA reads the mRNA code, comes up with an amino acid for each **anticodon**, and brings it to the ribosome
6. The protein is made, entering the **endoplasmic reticulum**
7. A **vesicle** forms off the end of the endoplasmic reticulum and carries the protein to the **Golgi body**
8. The Golgi body repackages the protein, a vesicle forms off the end of the Golgi body to carry to the **cell membrane**, and the vesicle attaches to the cell membrane to release the proteins out of the cell

Chromosomes:
- When the chromosomes replicate in S phase of **interphase**, each copy is called a **sister chromatid**
- Chromatids attached at the **centromere**
- Humans have 23 pairs of chromosomes (largest → smallest)
    - 22 pairs of **autosomes**, 1 pair of **sex chromosomes** (male XY, female XX)

Karyotype: typical number of chromosomes
- Taken during the **metaphase** stage before chromosomes split up
- **Karyogram**: mage of karyotype

Genetic Mutation: permanent change in the sequence of bases in DNA
Germ-line mutations: mutations in sex cells, can be passed through generations
Somatic mutations: mutations in body cells, not passed through generations but can lead to cancer
Mutagens: factors that cause mutations (alters genes)
1. **Physical mutagens**:
    - Ex. ionizing radiation, X-rays
2. **Chemical mutagens**:
    - Ex. toxins
3. **Biological mutagens**:
    - Ex. bacteria, viruses

Genetic Diseases:
1. **Albinism**: lacks ability to produce melanin, pigment to give skin its color and to protect skin from UV light
2. **Hemophilia**: clotting factor in blood
3. **Sickle Cell Anemia**: the defective gene causes **hemoglobin** (oxygen carrier in blood) to stick together, resulting in an **elongated red blood cell** that is inefficient at carrying oxygen, some develop an immunity to malaria

Chromosomal Mutations: change of chromosome structure

1. **Inversion**: chromosome segment breaks off and flips around backwards (ring shape)
2. **Deletion**: a part of the chromosome breaks off and is lost
3. **Translocation**: part of 1 chromosome is transferred to another chromosome (exchanging genetics)
4. **Addition/Duplication**: a gene sequence is repeated in the chromosome
5. **Nondisjunction**: failure of homologous chromosomes to properly separate/ (monopsony or trisomy - 1 or 3 copies of a pair)

Point Mutations:

1. **Silent**: no changes in amino acid, last letter of codon changes, less severe → same protein produced
2. **Nonsense**: changes first letter of codon, mutates to a stop codon (most severe)
3. **Missense (conservative)**: amino acid changed but property not changed, same structure (3rd most severe)
4. **Missense (non-conservative)**: amino acid changed, property different (2nd most severe)

Frameshift Mutations: insertion or deletion of 1 letter in the DNA sequence, results in everything shifting across, completely messing up the code

Unit 5:

Gregor Mendel: hypothesized inheritance patterns using peas

Reproduction in flowering plants:

1. **Self-pollination**:
    - **Pollen** contains **male gamete**, produced by the **stamen**
    - **Ovary** contains **eggs**, found inside the flower
2. **Fertilization**
    - **Pollinators** carry pollen to the eggs for fertilization
    - **Self-fertilization/Cross-fertilization** (same/different flowers)
3. **Germination**: growth of the flower

Trait: an observable characteristic

- **Phenotype**: what you see, ex. brown eyes or blue eyes
    - **Phenotypic ratio**: ratio of alleles
- **Genotype**: the actual code, ex. BB, Bb, bb
    - **Genotypic ratio**: ratio of the code (3 ratios)
- **Polygenic trait**: many genes affect 1 trait

Allele: different versions of a gene

- Uppercase dominant, lowercase recessive
- 1st letter is chosen to identify the allele

- BB homozygous dominant, Bb heterozygous (only dominant), bb homozygous recessive

Purebred: same trait by self-pollination

Test cross: a cross with an unknown and a homozygous recessive

Codominance: both alleles expressed together, using uppercase letters with superscripts

- Ex. blood type (I^A I^B)

Incomplete dominance: 2 alleles combined together (dominant doesn't completely mask recessive)

- Ex. RR (red) + rr (white) = Rr (pink)

P Generation: parent generation

F1 Generation: 1st filial generation, often hybrids

F2 Generation: 2nd filial generation, from self or cross pollination

Monohybrid cross experiment: follows 3 generations to find inheritance patterns

Punnett Square: used to find probability of genetic crossing results

Sex determination: some traits are located on sex chromosomes

- Most are X-linked (larger chromosome)
- All shown by superscripts

Pedigree: genetic family tree to track genetic conditions and disorders

- Squares males, circles females
- Fully colored has trait, half colored is carrier

Autosomal dominant:

- Every affected person at least has 1 affected parent
- Males and females equally affected

Autosomal recessive:

- Affected person may not have affected parents, might have carrier parents or skip generations
- 2 carrier parents = 100% affected children
- Males and females equally affected

X-linked dominant:

- Very uncommon
- Females > males, 2:1
- All daughters but no sons of an affected male will be affected

X-linked recessive:

- Males > females, 8:1
- Males will transmit to all daughters but no sons

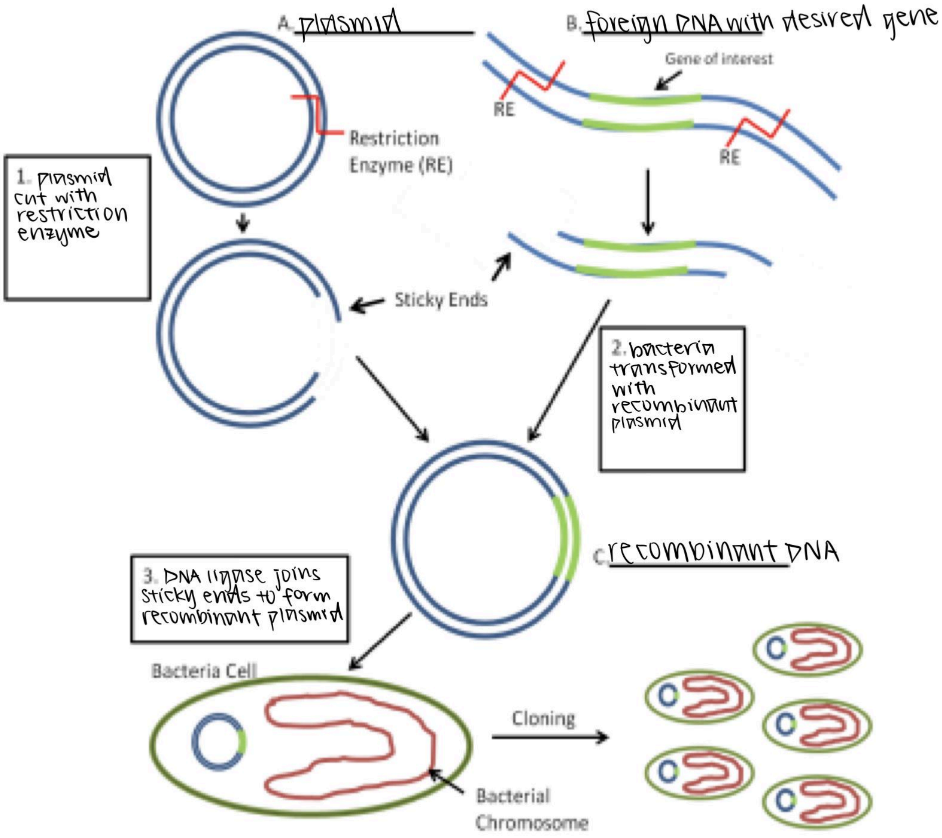
Mendel's Law of Inheritance:

1. **Law of segregation:** when gametes form, alleles are separated so that each gamete only carries 1 allele for each gene
2. **Law of independent assortment**: alleles for 1 gene assort independently to other genes
3. **Principle of dominance**: recessive alleles will be masked by dominant alleles

Biotechnology: techniques to modify/make changes to a gene

- Genetic code is **universal** to all species

- **Genetic engineering ≠ cloning**
  - Genetic engineering: DNA1 + DNA2 = new
  - Cloning: DNA1 x2
- Steps to clone a gene in bacteria:



1. **Isolate** the DNA segment to clone, and choose a **vector** for cloning
   a. Vectors are carriers of the DNA to be cloned so that it can be copied in a foreign cell
   b. A common vector is a **plasmid** (a circular piece of DNA that remains distinct from the bacterial chromosome)
2. **Insert** the chromosomal DNA into the vector
   a. Relies on the use of **enzymes** that can **cut** DNA and help different pieces **join** together
      i. The **site of cleavage**, the **sticky ends**, are connected by **DNA ligase**, and can easily find other sticky ends through complementary base pairing
      ii. Cleavage occurs by the **Restriction Endonucleases** (enzymes), cutting DNA
   b. Annealing attaches specific genes, the resulting DNA molecule, including genetic material from different sources, is called **recombinant DNA**
3. **Transformation**, **treating foreign cells** so that they can take in the DNA
   a. Many copies of the cloned gene or DNA fragment will be made by the **host cell**

Example of gene modification: **insulin**

- **Diabetes**: inability to produce insulin
  - Insulin helps blood sugar enter body cells to provide energy
- **E.coli bacteria**: where plasmids are found

- **Insulin genes** can be found in pancreas of pigs
    1. The **plasmid** is cut, the insulin gene is inserted, and the plasmid is enclosed by the **ligase**
    2. **Recombinant DNA** is created, leading to **transgenic bacteria**
    3. The bacteria grow in **culture**, and later insulin is able to be extracted

Genetic engineering:

- The process of scientifically **altering the genetic makeup of an organism**
- **Eliminates selective breeding** with more accuracy
- Introduces **foreign DNA** into an organism's genome, resulting in transgenic organisms
    - A type of **genetically modified organism** (GMO)
        - Pros: improves health, environment, and economy
        - Cons: toxicity, some cause allergic reactions and cancer

Superbugs: strain of bacteria and viruses in your body that have become immune to small amounts of antibiotics through selective pressure over generations of repaid reproduction, thus some antibacterial may not work for a certain individual

Transgenic plants: Ex. golden rice, BT corn

CRISPR (1st gen) - makes something transgenic

- Used with protein **Cas9**
- Way of finding specific DNA inside cell and editing it like genetic scissors
- Programmable system, cheap and easy to strengthen immune cells

Example of Biotechnology: **PCR (Polymerase chain reaction)**

- Way for DNA sample to be copied many times within a test tube
    1. **Denaturation**: heat to separate DNA strands
    2. **Annealing**: cool to allow primers to form hydrogen bonds with ends to target sequence
    3. **Extension**: Taq polymerase adds nucleotides to 3' end to primer
    4. **DNA Synthesis** (repeats the process)
- Application: testing for COVID - uses reverse transcriptase
- Reduce time required to identify a sample from months to days

Genetic variation:

- **Evolution**: the cumulative changes in heritable characteristics of a population over time
- **Mutation**: a permanent change in an organism's genome
    - Benefit mutation: leads to new versions of proteins that help organisms adapt to changes in the environment (essential for evolution to occur)
- **Natural selection**: a process that results in an organism's characteristics changing over time
    - At random, but individuals with certain heritable traits are more successful in specific local conditions, and may pass their alleles to the next generation through reproduction, therefore this mutation will continue for more generations
    - Must be genetic diversity or variation for natural selection to occur
- **Selective pressure**: an environmental impact on an organism's ability to survive

- **Selective advantage**: a genetic advantage of one organism compared to its competitors over time

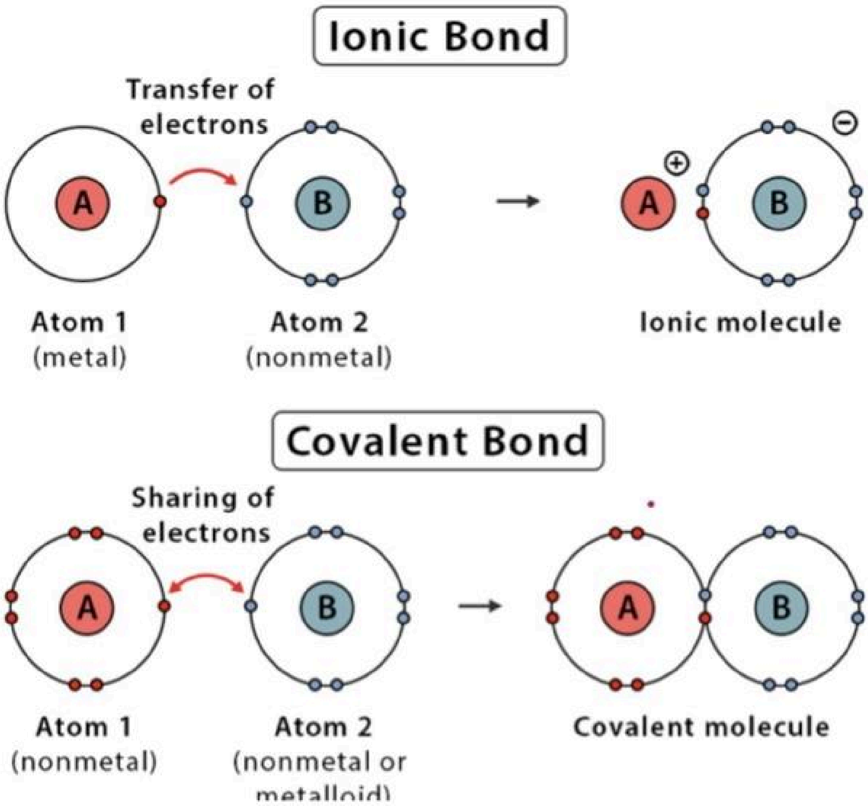
Chemistry

Unit 6:

Chemical Reactions: maintains and sustains our health and the health of all life of Earth
- Involves 1+ pure substances' interaction to form a different substance(s)

Chemical Changes: a result of chemical reactions when new substances are created
- **Reactants**: the original substance(s)
- **Products**: the change into new substance(s)

Chemical Bonds: electrostatic attractions that hold atoms or ions together
- In order to break these bonds, energy must be added until the atoms or ions are no longer held together
- When chemical bonds form and the atoms achieve full valence shells of electrons, the atoms gain **stability**



Law of Conservation of Mass: in a chemical reaction, the total mass of the substances used = total mass of the substances produced

- An observation by French chemist Antoine Lavoisier in a study with a compound of mercury II (oxide) and HgO
- He performed many experiments measuring the mass of the substances before the reaction, performing the reaction in a **closed system** (in a sealed container), and then carefully measuring the mass of the substance after the reaction

Word Equation: simplest form of a chemical equation
Skeleton Equation: shows the formulas of the elements/compounds
- Shows atoms, but not quantities of atoms
- Will need to be balanced

Types of Reactions:
1. **Synthesis**: A + B = AB
    - 2 elements combine
2. **Decomposition**: AB = A + B
    - 1 reactant only
3. **Single Replacement**: A + BC = AB + C
    - 1 element and 1 compound
4. **Double Replacement**: AB + CD = AD + CB
    - 2 compounds react
5. **Neutralization**: something resulting in H2O
    - Acid-base reaction
6. **Combustion**: something resulting in CO2 + H2O
    - Organic compound with oxygen

Diatomic Molecules: molecules that exist with only 2 atoms (N-F, F down to I)

Collision Theory: a model that helps us understand what happens at the atomic level when particles collide (a consequence of the kinetic molecular theory)
- Matter is made up of constantly moving particles
- All particles have energy, but the energy varies depending on the state of matter it is in
- Molecules in the solid state have the least amount of energy, and molecules in the gaseous state have the most energy
- The temperature of a substance is a measure of the average kinetic energy of the particles
- A change in phase may occur when the energy of the particles is changed
- There are spaces between particles of matter

Reaction Pathway:
1. Reactants
    - Must be colliding in the correct **orientation**
2. **Activated complex/transition state**
    - **Activation energy**: amount of energy to react the particles
    - Lives momentarily where all the reactants are jumbled together, and bonds disjoin & join quickly
3. Products

- **Exothermic**: releasing energy
- **Endothermic**: absorbing energy

Rate of Reaction: the rate at which reactants turn into products

- Slows down as time passes (gradient changes, rise/run)

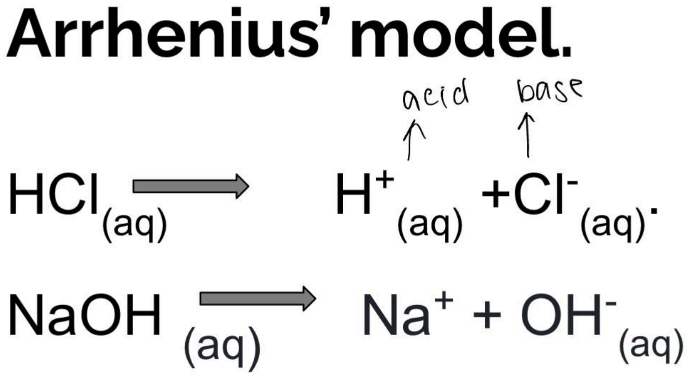
Factors affecting rate of reactions:

1. **Temperature**
    - Temperature increases → more energetic particles → kinetic energy increases → particles moving faster → collides more often → more likely to react
2. **Concentration**
    - Concentration higher → more particles present → higher chance of collision → more reactions
3. **Surface Area**
    - **Solids only react on the surface**
    - Surface area increases → faster reaction → more collisions → higher chance of reactions
4. **Catalysts**: a substance that speeds up the reaction rate by lowering the activation energy
    - Provides an alternative pathway for which less energy is required for the activated complex

Acids and Bases:

- Acids: sour and corrosive substances (pH < 7)
- Bases (alkalis): bitter and slippery substances (pH > 7)

Arrhenius' Model: first person to recognize acids and bases

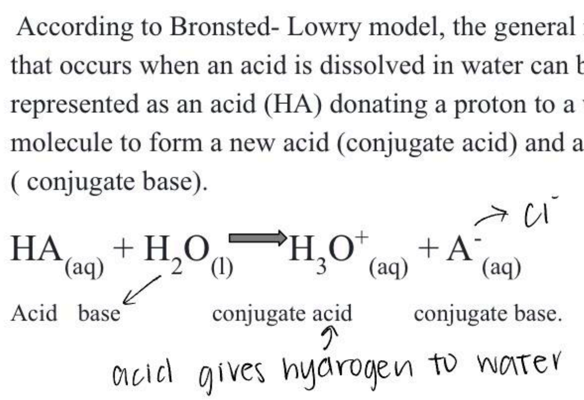


Arrhenius' model.

$$HCl_{(aq)} \rightarrow \overset{\text{acid}}{\overset{\uparrow}{H^+_{(aq)}}} + \overset{\text{base}}{\overset{\uparrow}{Cl^-_{(aq)}}}.$$

$$NaOH_{(aq)} \rightarrow Na^+ + OH^-_{(aq)}$$

Bronsted-Lowry Model: more general description of acids and bases



According to Bronsted- Lowry model, the general reactions that occurs when an acid is dissolved in water can be best represented as an acid (HA) donating a proton to a water molecule to form a new acid (conjugate acid) and a new base (conjugate base).

$\rightarrow Cl^-$

$HA_{(aq)} + H_2O_{(l)} \Rightarrow H_3O^+_{(aq)} + A^-_{(aq)}$

Acid base conjugate acid conjugate base.

acid gives hydrogen to water

Conjugated base: everything that remains of the acid molecule after the proton is lost

- Formed when the proton transfers to the base

pH scale: measures how acidic or basic a solution is

- Scale of 0-14 (goes up by strength of pH power of 10)
- When dissolved in a solution, acids produce hydrogen ions, bases produce hydroxide ions
- Concentration of hydrogen ions = # of hydrogen ions in a specific volume of solution
    - High concentration of hydrogen ions = acidic (low pH); high concentration of hydroxide ions = basic (high pH)

Equilibrium constant (K):

- concentration of products / concentration of reactants → in a reversible reaction

Naming acids:

1. ate → ic + acid
2. ite → ous + acid
3. ide → hydro + ic + acid

Common acids:

- **Formic acid**: simplest carboxylic acid with a single carbon
- **Citric acid**: colourless weak organic acid in citrus fruits
- **Ascorbic acid (Vitamin C)**: to treat/prevent low levels of Vitamin C
- **Lactic acid**: assists cell respiration, glucose production, and molecule signaling

Mole: a unit to measure large quantities of small entities such as atoms and molecules
Molecular mass: 1 mole of atoms in __grams of an element

Avogadro's number: within 1 mole of every atom, there are 6.02×10^{23}molecules
Calculating moles: use conversion factor to cancel out

- Ex. **Number of moles = Mass/conversion factor**
- **Mass → Moles → Molecules**

Calculating moles in a chemical equation: the concentration of all reactants are the same (balanced equation)

- If there is 2 some element, then double its amount to balance the concentration
- Ex.

Using the following equation:

$$Pb(SO_4)_2 + 4\ LiNO_3 \rightarrow Pb(NO_3)_4 + 2\ Li_2SO_4$$

How many grams of lithium nitrate will be needed to make 250 grams of lithium sulfate, assuming that you have an adequate amount of lead (IV) sulfate to do the reaction?

$$250\text{g} \times \frac{1\text{ mol}}{109.94\text{g}} = 2.27\text{ mols}$$

$$2.27\text{mols} \times \frac{4\text{mols}}{2\text{mol}} = 4.54\text{ mols}$$

$$4.54\text{ mols} \times \frac{68.95\text{g}}{1\text{ mol}} = 313.03\text{g}$$