

Hypothesis- testable explanation of observations

Theory- Widely accepted explanation of the cause & effect relationships have been extensively & rigorously tested by independent scientists

Law- when a theory has been so extensively tested and confirmed that the scientific community accepts it as a fundamental basis of science.

-conservation of mass, conservation of energy, conservation of angular momentum

Theory of Gravitation

-Classical mechanics (Newton, 1687)

-gravitational force is proportional to masses of interacting bodies and inversely proportional to the square of the distance between them
-by the late 1890's, scientists said this didn't work

-General Relativity (Einstein, 1915)

-space time is curved by matter, and free-falling objects move along locally straight paths in a curved spacetime
-explains mercury's orbit, and much more
-simplifies to classical mechanics at velocities \ll speed of light

-Quantum relativity?

-general relativity is incompatible with quantum mechanics

Paradigm Shifts

-Very rarely, scientific discoveries are made (or develop) that cause major changes in the way scientists think about their discipline.

-Full of conflict and debate

-Require re-examination of previous knowledge to reassess

-Ptolemaic to Copernican model of the cosmos

-Uniformitarianism to theory of plate tectonics

-Classical physics to theory of relativity

Thermodynamics

-Thermodynamics the branch of physical science concerned with the interrelationship and interconversion of different forms of energy

-Thermodynamics addresses the behavior of macroscopic systems

Conservation Laws

-Conservation of mass

-Conservation of energy (1st law of thermo)

-Entropy (2nd law of thermo)

Mass

-mass exists as a solid, liquid, gas or plasma, has mass, and occupies space

-in a **closed system** (meaning mass and energy cannot enter or leave the system) mass will remain constant over time

-mass can be transformed from one form of matter to another, but the total mass of a closed system cannot increase or decrease

Conservation of Energy

-in a closed system (energy cant come in or leave)

-the total amount of energy remains constant over time

-energy can change from one form to another and can be redistributed, and cant be created or destroyed

-forms of energy include:

-**kinetic** (energy of motion)

-**potential** (energy due to the arrangement of the system)

- other forms of energy such as chemical - (combinations of kinetic and potential)

Entropy

-when energy is transferred by any process, the system moves from a more-ordered to less-ordered state if there is no force to counteract this tendency.

-**entropy- the disorder in a system**

-for instance, when a log is burnt, the highly structured form of the log which includes the en

-living organisms resist entropy by getting energy from food and photosynthesis

-dead organisms get no energy and through decomposition lose their organized structure

Elements

- matter is composed of elements, which exist alone or in combination with other elements in the form of molecules
- an element is a chemical substance with a specific set of properties dependent on the details of its atomic structure.
- an element can't be broken down into substances with other properties.

Atoms

- atoms are composed of
 - protons (positively charged mass $\sim 1.6726 \times 10^{-27}$ kg)
 - electrons (negatively charged) 9.1094×10^{-31}
 - neutrons (no charge)
- nucleus of an atom contains proton and neutrons, while the electrons circulate around the nucleus in the "electron cloud"

Atomic Number, Mass, and Weight

- the atomic number of the element is the number of protons in the nucleus- carbon has 6 protons and an atomic number of 6
- the mass number is equal to the total number of protons and neutrons in an isotope
- the atomic weight of an element (shown in periodic tables) is the average weight of the atoms of an element, taking into account isotopic abundances.
- atomic weights are expressed relative to the mass of an atom of the stable isotope of carbon/12 = $1.660538921(73) \times 10^{-27}$ kg (a unified atomic mass unit)

Ions

- when an atom has no electric charge, the number of electrons in the electron cloud equals the number of protons
- atoms become ions if the # of protons and electrons is not the same, resulting in a net electric charge on the atom
 - + charge results if the # of protons is more than the # of electrons
 - - charge results if # of electron is more than the number of protons

Isotopes

- an isotope of an element is an atom with the same # of protons and electrons, but a different number of neutrons
- because the mass of the isotope is different, the behavior of the isotopes are slightly different in physical, chemical and biological processes

Isotopic Fractionation

- isotope fractionation occurs when a physical, chemical or biological process causes the relative abundance of isotopes in a sample of matter to change
 - ex) molecules of H_2O that include lighter isotopes of oxygen evaporate more quickly from liquid water (because they are lighter), causing the vapor to be slightly enriched in molecules with a lighter isotope.
 - ex) as temperatures increase, more of the heavier isotopes can evaporate from the liquid water
- the abundance of heavier isotopes is therefore a proxy for temperature.

Radioisotopes

- some isotopes are "radioactive", decaying (with emission of **radiation** in the process) over time (milliseconds to millions of years) to another isotope of the element
- radioisotopes continue to decay into other daughter radioisotopes until they become a stable isotope that is not radioactive
- the **half life** of a radioisotope is the amount of time needed for half its atoms to transform from one isotope to another.
 - uranium to lead takes 700 million years

Molecules

- atoms of the same or different elements can combine to form molecules
- molecules are more likely to form when the atoms involved can share electrons and thereby reach a lower energy state
- the **chemical formula** shows the number of each type of atom in a molecule (CO_2 O—C—O)
- common molecules of a single element include oxygen (O_2) and nitrogen (N_2) both of which are abundant on earth
- compound molecules are those composed of different elements
- common compound molecules include H_2O , carbon dioxide,

Bonds

- molecules held together by **ionic bonds** reach a neutral state by bringing together positively and negatively charged ions
 - table salt (NaCl) is composed of positively charged sodium ions (Na⁺) and negatively charged chloride ions (Cl⁻)
- Molecules held together by **covalent bonds** reach a neutral state by sharing electrons between the atoms of the molecule

Covalent Bonding

- stable balance of attractive and repulsive forces between atoms when they share electrons
- for many molecules, the sharing of electrons allows each atom t

Solutions

- elements, molecules, and compounds can also come together in the solutions without forming chemical bonds
- for example
 - ocean water (H₂O, salts, minor constituents)
 - Air (N₂, O₂, Ar, CO₂, O₃, CH₄, and other components)

Acids, bases, and pH

- in any **aqueous solution** (water based), a small number of water molecules will split into ions
 - H₂O = H⁺ + OH⁻
- pure water contains equal number of both, and the solution is neutral
- the product of the concentrations of these ions always equals 10⁻¹⁴, so that pure water will have a concentrations of 10⁻⁷ H⁺ OH⁻

pH low = acidic, pH high = basic

- A pH of 7 is neutral
- If the concentration of H⁺ is greater than OH⁻, the solution is acidic and the pH is less than 7
- if the concentration of OH⁻ is greater than H⁺, the solution is basic and the pH is greater than 7
- important - pH is a log scale. so a solution with a pH of 6 has 10 times as many H⁺ ions as one with a pH of 7.

An aside on exponents

- the exponents (or power) of a number says how many times to use the number of multiplication times itself
 - 2² = 2x2 =4
 - 2³ = 2x2x2 = 8 (2 is the base)
 - 10² 10x10 = 100
 - 2⁻² = 1/2²= 1/4= 0.25 in a decimal notation
 - 10⁻³= 1/10³= 1/1000= .001 in decimal notation
- do not drop exponents -

Logarithm

- the logarithm of a number is the exponent by which the base must be raised to produce the number
 - the base-10 logarithm (common logarithm of log) of 1000=10³

Organics and in-organic

- matter is composed of organic and in-organic compounds
 - organic compounds are formed by combining carbon with other elements
 - inorganic compounds do not include carbon-carbon bonds
- hydrocarbons are composed of various combinations of carbon with hydrogen, and can form in long chains and rings
- methane is the simplest hydrocarbon, crude oil is composed of many types of hydrocarbons

Macromolecules

- polymers are long chains of repeated organic compounds
 - play key roles as building blocks in life
- three essential types of polymers:
 - proteins
 - nucleic acids