Chemistry (Script)

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Chemistry is the study of the smallest forms of matter, specifically atoms and molecules. Matter is anything that has mass and takes up space. It is often easier to think of what matter ISN'T: thoughts, feelings, ideas, emotions, color. Matter is a term that describes everything with a physical presence, no matter how large or small.

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Atoms are the smallest units of matter that have unique properties. There are smaller forms of matter than atoms, but they lack the diversity and characteristics that we recognize in the matter around us. How small are atoms? One type of atom, known as a hydrogen atom, has a diameter 173 million times smaller than the diameter of a penny! As small as they are, atoms do have smaller matter within them called subatomic particles. More on those later. The atoms within the know universe come in a limited number of types or varieties. There are approximately 90 different naturally-occurring varieties of atoms that make up everything around us. These varieties are called elements.

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Elements are each given a name to help identify them (carbon, helium, sodium, uranium). In addition, they each have a symbol or abbreviation (either a single capital letter or a capital letter followed by a lowercase letter). Carbon = C, Sodium = Na, etc. Atoms of a particular element have properties unique to that element. Some elements are more common than others. In the human body, oxygen, carbon, hydrogen, nitrogen, calcium, phosphorus, potassium, sodium, and iron are the most abundant elements.

The next slide shows the Periodic Table of the Elements, arranged and organized based on there properties and similarities.

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This is the Periodic Table. As mentioned on the previous slide, it lists all of the elements in a systematic way. This may not be evident at the moment, but as we go through the following slides, we will talk about the key information that can be pulled from the table.

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Atoms are usually composed of a combination of three subatomic particles: protons, neutrons, and electrons. In general, all protons have the same properties, all neutrons have the same properties, and all electrons have the same properties, regardless of which kind of atom they belong to. A proton is a proton is a proton! That's why we make a distinction between atoms and subatomic particles: when subatomic particles in specific quantities combine to make an atom, that combination (atom) acquires unique properties not seen in the subatomic particles themselves.

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Protons are one type of subatomic particle found in any atom. They are found at the center of the entire atom, known as the nucleus. They have a positive electrical charge, and they have been assigned a mass of 1 atomic mass unit (a.m.u. or sometimes just referred to as a unit).

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Neutrons are a second type of subatomic particle often found within atoms. They are found in the nucleus of the atom as well. They don't have any electrical charge, and they have the same mass as a proton: 1 a.m.u.

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Electrons are a third type of subatomic particle often found within atoms. They are found orbiting the nucleus of the atom at specific distances. They have a negative electrical charge, and they have such an insignificant mass, even compared to the other subatomic particles, that they are considered to have no mass.

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There are a few important aspects about the atomic structure that will determine an atom's chemical and physical properties and how it will interact with other atoms.

All atoms of the same element have the exact same number of protons. This is one of the defining properties of an atom. We refer to the number of protons in the nucleus as the atomic number. The atomic number of an atom, or the number of protons it has in its nucleus, determines which element and which properties the atom will have.

In addition to determining an atom's atomic number, an atom's mass can also be determined if we know the number of subatomic particles it has. Since each proton has a mass of one unit, and each neutron has a mass of one unit, if we add up the total number of protons and neutrons in an atom, we can determine the atom's atomic mass. Notice that electrons, having no significant mass, do not count when calculating the mass of the atom.

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The periodic table has all of the elements arranged according to atomic number. Boron is an element towards the top right of the table and is abbreviated with "B". On the top of the box is the number 5; this is the atomic number. This means that all boron atoms have 5 protons. On the bottom of the box is the atomic mass, 10.81. Typically we round the reported atomic mass on the table to the nearest whole number. So boron atoms typically have a mass of 11 units. We can use this table to determine how many neutrons an atom of any element typically has. If the mass of a boron atom is 11, and 5 of that is due to the protons, then that means that boron atoms typically have 6 neutrons (5+6=11). Atomic mass minus atomic number = number of neutrons.

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The negatively-charged electrons of an atom orbit the nucleus due to their attraction to the positively-charged protons in the nucleus. Electrons can be found orbiting the nucleus at specific distances called energy levels. Each of these levels/distances is numbered, with the closest level being energy level 1. Some of the largest atoms have as many as 7 energy levels, or 7 distances in which electrons can be found orbiting the nucleus. In terms of in which energy level an electron is likely to be found, they prefer to occupy the lowest energy level possible; however, only a certain number of electrons can be found within each of the energy levels. Energy level one, for instance, can only hold a maximum of 2 electrons before it is considered full. If a third electron is present in the atom, it will be found in the second energy level, or orbiting at the next distance from the nucleus. The second through seventh energy levels can hold a maximum of 8 electrons before being considered full.

As an example, consider an atom that has 11 electrons. According to the rules previously mentioned, 2 of the 11 electrons would be found in the 1st energy level, a total of 8 in the 2nd level, and 1 last electron of the 11 having to orbit in the 3rd energy level; in other words, the electrons in each expanding level would be 2-8-1.

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When atoms interact with each other, it is the outermost electrons that will interact. Because of this, these electrons are considered on their own and are called the atom's valence electrons. If an atom only has enough electrons to have a the first energy level, then it will either have 1 or 2 valence electrons. If the atom has a two, three, or more energy levels, then it could have anywhere from 1-8 valence electrons.

In the previous example, our atom had 2 electrons in the 1st level, 8 in the 2nd, and 1 in the 3rd. Therefore, while the atom has a total of 11 electrons, it only has 1 valence electron: the one in its outermost energy level, which happens to be the 3rd energy level. If that 1 electron should leave the atom, the 3rd level would no longer exist, and the second level would become the outermost. This would mean the atom has 8 valence electrons.

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If an atom has an equal number of protons and electrons, then the atom is said to be neutral. This means that despite there being both positively- and negatively-charged particles within the atom, when they are equal in number, they cancel each other's charges out.

If you know an atom's atomic number and are told it is neutral, then you know how many protons (atomic number) and electrons it has (same).

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Atoms have a tendency to try to have a full outermost energy level; in other words, a full amount of valence electrons. When an atom does have a full outermost energy level, it said to be stable. To do this, atoms will try to complete a nearly full outermost energy level by taking electrons from other atoms, eliminate a relatively empty outermost energy level and using the previous, full energy level as the outermost by allowing electrons to be taken away, or by finding another atom that will share electrons with it to allow them both to complete their nearly-full outermost energy levels.

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As mentioned before, atoms have a strong desire to become stable. In some cases, they are willing to give up being neutral if it means they can become stable. Some atoms are very close to having a full outermost level of electrons. If an atom's outermost level is one that can hold a maximum of 8 electrons (levels 2-7) and it has 5, 6, or 7 valence electrons, it will seek to take 3, 2, or 1 electron(s) from neighboring atoms to fill that outermost level and become stable. If it does, the atom is gaining negative electrons and, therefore, it will become a negatively-charged atom: an anion. If the outermost level is level 1 and it needs one more electron to fill it, the atom can also try to gain 1 electron to become stable, becoming an anion.

If an atom has very few electrons in its outermost level (valence electrons of 1, 2, or 3), it will tend to allow those electrons to be taken away. This allows the atom to lose its current outermost level which is not full and allow the previous, full energy level to become the outermost. The atom will lose 1, 2, or 3 electrons, and when losing particles that are negatively charged, the atom becomes positively charged: a cation.

Remember: when an atom gains negative electrons to become stable, the atom becomes negative (an anion); when an atom loses negative electrons to become stable, the atom becomes positive (a cation).

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Very often, atoms exist as part of a combination with other atoms. A molecule is the term for any combination of two or more atoms bonded together.

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Atoms can have an attractive force between them that causes them to be bonded for various reasons. If a negatively-charged atom is close to a positively-charged atom, their opposite charges will cause them to move closely together and stay bonded due to the attractiveness of oppositely-charged objects. Just like negatively-charged electrons are drawn to positively-charged protons in the nucleus, anions and cations are drawn to each other. This force is called an ionic bond. It is considered to be moderately weak.

If two atoms are able to achieve stability due to sharing electrons, the attractive force that holds them together to be able to share electrons is called a covalent bond. This is the strongest of bonds.

Sometimes atoms from neighboring molecules can feel an attraction for each other. A hydrogen bond is a very weak attractive force between a partially positive atom in one molecule and a partially negative atom in another molecule.

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Electrons have been transferred from one atom to another to make them both stable. As a result, one atom becomes positive and one atom becomes negative, causing them to have an electrostatic attraction for each other (ionic bond).

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Electrons are being shared to help both atoms become stable. An attractive force occurs that keeps them close enough to allow them to continue to share electrons (covalent bond).

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Due to unequal sharing of electrons within each molecule, one end of a molecule takes on a partially positive charge, and when close to a similar molecule, the partially positive end of one molecule feels a slight attractive force for the partially negative end of a neighboring molecule (hydrogen bond).

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The term solute is used to describe any substance that is placed into a liquid to be mixed. They can be gases, other liquids, or solids and can exist in a wide range of sizes. A real-world example would be hot cocoa powder that gets added to milk to make hot chocolate, or salt crystals that are added to boiling water when cooking. The term solvent refers to the liquid in which the solute is being placed (the milk or water in the previous examples). The term solution refers to the mixed combination of solute and solvent (hot chocolate or salt water). However, the finished combination of solute and solvent has to have certain properties in order to earn the name 'solution'. The solute particles added need to be around the same size as the solvent particles receiving them (in other words very small), the resulting combination needs to allow light through (transparent), the solute particles need to be able to pass through biological membranes, and the combination needs to show no evidence of the solute settling when left standing still. So the term 'solution' is a special kind of mixture. Hot chocolate usually shows signs of settling and is murky; however salt water is a good example of a solution: the actual solute itself (sodium chloride) is an electrolyte and gets separated into sodium and chloride ions (small), the combination is transparent, the water, sodium ions, and chloride ions can all pass through biological membranes, and the ions are always evenly dispersed throughout the solution.

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An electrolyte is a molecule that breaks up into individual ions when placed into water. Because the molecule separates into ions, electrolytes can often help generate and play a role in electrical signals within the body. Electrolytes are essential for nerve and muscle functions. The most common ions are sodium, potassium, calcium, magnesium, and chlorine ions.

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There are 2 really, really important types of electrolytes called acids and bases.

Acids are electrolytes that release hydrogen ions when placed into water. They are called "Hydrogen Donors" since they add hydrogens to the fluid. An example is HCl, hydrochloric acid. When placed into water, HCl will break into H^+ and Cl^- ions. They increase the amount of free hydrogen ions in the fluid.

Bases are electrolytes that accept hydrogen ions when placed in water. They decrease the amount of hydrogen ions in the fluid.

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A pH scale is used to measure relative acidity or alkalinity (basic) of a fluid. The scale measures the amount of free hydrogen ions present in a fluid. Due to the type of math used to calculate the pH of a fluid, the more hydrogen ions there are present in a fluid, the lower the actual pH value is. The scale goes from 0 to 14. pH values from 0-7 are considered to be in the acid range, and the closer the value is to 0, the more acidic the fluid is. pH values from 7-14 are considered to be in the alkaline or basic range, and the closer the value is to 14, the more basic the fluid is. A pH of 7 is considered neutral (neither an acid nor a base).

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In this slide we can see every day things that span the wide range of the pH scale. Acids will be from 1-7 on the pH scale and bases will be from 7-14 on the scale.

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The molecules in the body can be broken into inorganic and organic molecules.

Organic molecules have a significant amount of carbon atoms within the molecules, meaning that one or more carbon atoms are central to the formation of that molecule. Inorganic molecules do not contain carbon.

We are going to focus on the key organic molecules, our proteins, carbohydrates, lipids, nucleic acids, and ATP.

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Carbohydrates are one of the important organic molecules. They are most commonly known as sugars and starches. You can often recognize the name of a carbohydrate because it frequently ends in –ose. They are primarily used in the body for energy.

The basic structure of carbohydrates is a carbon ring made of 6 carbons, 12 hydrogens, and 6 oxygens. So, the basic chemical formula is $C_6H_{12}O_6$ or 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms. The arrangement of these 24 atoms may vary slightly, creating different variants. These basic forms of carbohydrates may also be strung together to form larger carbohydrates.

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Monosaccharides are a single ring and the simplest form of a carbohydrate. Three of the most common monosaccharides are **glucose, galactose,** and **fructose**. **Glucose** is the most important for humans. This is the form that our body uses most commonly for energy and is also referred to as blood sugar. **Galactose** is similar to glucose, it varies only in the location of one OH group. Although it is similar to glucose, it is not easily used by our bodies but can be easily converted to glucose. **Fructose** is the third important monosaccharide. It is the sugar found in fruit and honey. It, too, gets converted into glucose in our bodies and then used to make energy.

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Disaccharides are two monosaccharides bonded together. **Sucrose** is also called cane sugar, **lactose** is milk sugar, and **maltose** is present in some grains. Disaccharides are also used primarily for energy; a specific enzyme is used to break apart the bonded monosaccharides.

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Polysaccharides are long chains of monosaccharides. **Cellulose** is a polysaccharide made of sugars but used by plants for strength, support, and structure. We do not have the enzymes to digest cellulose, so we consume it as dietary fiber (roughage), which is beneficial for colon health. **Starches** are polysaccharides used by plants for the storage of sugars for energy at a later time. When we consume them, we are able to digest them into single monosaccharides and obtain all of the energy they contain. **Glycogen** is a long chain of glucose molecules used by animals to store excess glucose and energy for later. We primarily find glycogen in our liver and muscles.

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A second type of organic compound is lipids. Lipids are also composed of carbon, hydrogen, and oxygen atoms, but proportionately they contain many more carbon and hydrogen atoms than they do oxygen atoms. Often, the carbon atoms occur in linear chains surrounded by mostly hydrogen atoms. Other lipids have four rings of carbon bonded together. Lipids are hydrophobic, meaning that they are not compatible with water. And unlike carbohydrates, lipids come in more varied types and carry out more varied functions.

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One important lipid in our bodies is a fatty acid. Fatty acids are linear chains of at least four carbon atoms with an acid group on one end (COOH). The carbon atoms are also bonded to hydrogen atoms. Fatty acids can be saturated, meaning that every available bond along the carbon chain is with a hydrogen atom (single bonds between every carbon atom). A fatty acid is said to be unsaturated if at least two of the carbon atoms have the potential to bond with more hydrogen atoms but are not; instead they are choosing to form a double bond with each other.

Fatty acids can be used in the body for energy, or they can be used to assemble more complex lipids.

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A second important type of lipid is a triglyceride. Triglycerides are large molecules composed of three fatty acids attached to a glycerol molecule. The body forms triglycerides from free fatty acids for several uses. Triglycerides are an effective way to store fatty acids for energy use when needed. When stored in adipose (fat) tissue in various areas of the body, triglycerides provide protection from temperature fluctuations (thermal insulation) and protection from trauma (cushioning).

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Here is picture of a triglyceride. The molecule in blue is the glycerol and the other three molecules are different fatty acid. They connect to the glycerol like tails.

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A third important type of lipid is a phospholipid. Phospholipids are two fatty acids attached to a phosphate molecule. This creates a molecule with both a hydrophobic end (fatty acid 'tails') and a hydrophilic end (phosphate 'head'), referred to as amphiphilic. In other words, the phosphate end of the molecule has an affinity for water, while the fatty acid end has an aversion for water. Because of this characteristic, phospholipids are the perfect molecule to use for constructing membranes in and around cells, which will be discussed in chapter 3.

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The fourth type of lipid is steroids. Steroids look very different than the other lipids: they consist of four rings of carbon atoms bonded together. They are still, however, heavily composed of carbon and hydrogen atoms and very few oxygen atoms, and they are hydrophobic. Cholesterol is an example of a steroid. On its own, cholesterol plays a role in helping to stabilize the plasma membrane of cells, ensuring it is not too rigid or too fluid. Cholesterol is also used to make other kinds of steroids, which are frequently used as hormones. These are chemical messengers produced by one cell to circulate and communicate with a other cells in the body.

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The third major category of organic compounds is proteins. Proteins require atoms of carbon, hydrogen, oxygen, and nitrogen. These atoms (along with atoms of other elements at times) must first come together to form smaller molecules called amino acids. Proteins are very large molecules that are an assembly of at least 50 amino acids. Proteins have a wide variety of functions in the body.

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An amino acid is the smallest protein-related molecule. There are 20 different amino acids needed to make all of the proteins in the human body. Nine of these amino acids are considered essential; that is, we must obtain them in our diet. The other eleven can be produced within our bodies. Amino acids can also be used as a communication molecule on their own.

Amino acids are bonded together using a peptide bond; a number of amino acids bonded together are called a peptide. These can be used as hormones or can have more amino acids added to them to make proteins. Once that number of amino acids reaches 50 and beyond, the chain of amino acids can be called a protein.

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Here are four of the twenty amino acids.

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Proteins have many functions within the body. Some provide a **structural** characteristic to an area. **Keratin** provides toughness to skin cells, and **collagen** provides toughness and flexibility to many areas of the body. Sometimes proteins play a role in cellular **communication**. **Receptors** can be found on the surfaces of cells, where they receive specific molecules and trigger the cell to respond accordingly. Cells also have **membrane transport** proteins, such as **channels, gates**, and **pumps,** that help control how molecules get into and out of cells. Some proteins provide the role of **catalysis**, which means that they help speed up reactions. These proteins are called **enzymes**. Cells will extend proteins off of their surfaces as a way to announce that they belong to the body, or are self-cells. In this case, the proteins aid in **recognition**. **Antibodies** are proteins that help with **protection** by circulating in the blood and attaching to foreign material, alerting the body to their presence. Some proteins play a role in the generation of **movement** within muscles, such as **actin** and **myosin**. And finally, some proteins help with **cell adhesion** by binding cells to each other or to associated surfaces.

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The fourth major category of organic molecules is nucleic acids. DNA, or deoxyribonucleic acid, is a huge molecule that contains information along its length for the order of amino acids needed to make the body's proteins. RNA, or ribonucleic acid, comes in several forms, all of which help to interpret the information found along the DNA molecule.

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One final molecule of note is called ATP, or adenosine triphosphate. It is the primary molecule used by the body to store energy released from the breakdown of carbohydrates and other compounds. It consists of an adenosine molecule with three phosphate groups attached to it. Most of the energy is stored between the second and third phosphates.