

Kelvin - the other metric temperature scale where zero means literally NO TEMPERATURE, water freezes at 273 K and boils at 100 units of temperature higher (like the centigrade scale) at 373 K.

No Degrees for the Kelvin scale either.

Equality - any two or more measurements that are the same, and can be converted into a conversion factor.

A conversion factor is based upon an equality.

Density - a math construct that is equal to the mass of a substance divided by the volume it takes up. Most often the units are grams per centimeter cubed (g/cm^3) but can be g/mL , or any other units, although they would be unhelpful. Density is a constant for a pure substance, the mass and volume are in a directly proportional relationship.

Mass - the amount of stuff in a sample of matter, most often measured in grams

Volume - the amount of space a sample of matter takes up, usually in cm^3 or mL.

Solid - one phase that has the particles of matter nearly fixed in position, in a repeating, orderly pattern. The particles of a solid still “vibrate” but mainly stay in place. The only time they stop vibrating would be at absolute zero temperature (which is only theoretical). Solids have the lowest kinetic energy.

Example - a metal key

Liquid - one phase that has the particles of matter attracted together, but not stuck together. Ex: water

Gas - one phase that has the particles of matter separated by vast distances compared to their actual size, moving very fast, not sticking together. Gases have the highest kinetic energy. Ex: air.

Element - one of 118 known pure substances that cannot be broken down into other substances. The smallest part of an element is an atom. They're all listed on the Periodic Table of the Elements, in special order.

Atom - the smallest bit of pure matter than has any properties of the substance. Atoms are made up of protons and electrons and neutrons. There are 118 elements but nearly 1500 kinds of atoms. All atoms have multiple “flavors” or atoms with different numbers of neutrons. They are chemically identical but have different masses (isotopes).

Meniscus - the bottom of the curve of a liquid in a tube (like a graduated cylinder). The edges are “higher” due to capillary attractions to the glass. We measure the volume of a liquid by the meniscus.

Alloy - a mixture of two or more metals (or metals and nonmetals) which are most often melted together, then allowed to cool into a solid phase. Alloys only mix things together but end up with combinations of properties that are “better” than the individual metals alone. For example, silver is too soft for silver ware, so by melting some copper into the silver, to form the alloy sterling silver, it retains the shiny luster of silver, but gets the durability and strength that the copper provides (invisibly) Alloys have no formulas as they are only mixtures, but certain proportions provide maximum properties for certain combinations. Too much Cu in your sterling silver is still an alloy, but not so lustrous anymore.

Molecule - the smallest part of a covalent or molecular compound formed when 2 or more nonmetals bond together. Examples are water and carbon dioxide

Particle - generic term for either atom, molecule, ion, or formula unit.

Periodic Table - the organized system of all the atoms. Tables are all different in what information they include or omit, but the table has 18 up and down groups, and 7 periods. The atoms are organized so that a variety of properties follow patterns or trends on this table.

Pure - referring to substances that are made up of one kind of particle. These include the atoms and all compounds. Anything that has its own formula can be understood as a particle. Particles are most often much too small to see with your eyes.

Mixture - a physical blend of different substances. No new compounds form, no new properties form, and there is no formula. Mixtures can be separated by non-chemical means by taking advantage of their different physical properties, such as freezing or boiling point, density, size, magnetic attraction, etc.

Substance - pure "stuff", includes elements and compounds. Substances are pure forms of matter. They have formulas such as CO_2 , H_2O , Fe, Ne, and NaCl.

Homogeneous - means the same throughout, all substances are the same throughout

Heterogeneous - means different throughout. Many mixtures are not the same throughout, although many mixtures can be homogeneous too.

Phase - indicates particle arrangement of a substance or mixture, can be solid, liquid, or gas.

State - another way to say phase, or referring to the 50 different sub-governmental zones of the USA.

Aqueous - sometimes called the 4th phase, it means that a substance is dissolved in water. When a solid, such as table salt NaCl is put into water, it changes phase from solid to aqueous. Substances, such as sodium chloride could never "be aqueous" without the water.

Compound - when 2 or more atoms bond chemically together they form a new pure substance, with a formula and with unique properties, and that is called a compound. Ex: NaCl, CO_2 , table sugar $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.

Distillation - the physical process to separate mixtures based upon differences in their boiling points. By heating the mixture of multiple substances, once you warm the mixture up to the boiling point of the substance with the lowest boiling point, that substance can boil away, separating itself from the rest of the mixture. By capturing the gas of this boiling substance, you can condense it into a container by itself. The other parts of the solution will just get hot and not phase change into a gas.

Filtration - the physical process to separate mixtures based upon differences in their particle sizes. Ex: when sand is mixed into water, the sand particles are "huge" in comparison. By running this mixture through a filter, the filter allows the tiny water molecules to pass through, but captures the bigger sized sand particles. The mixture is separated by taking advantage of particle size.

Chromatography - the physical process to separate mixtures based upon differences in their ability to dissolve into a solvent (often water) and their densities. For example, when you allow the color of a magic marker to dissolve into water on filter paper, the "color" is made up of particles that are carried by the water. Some particles are not soluble and don't budge. Some are denser and move only a little, while the less dense particles move the furthest. When the water evaporates away, these particles are separated, and you can see the different colored (and different density) particles separated apart from each other.

Solute - the part of the mixture that dissolves into the solvent. Usually this is the smaller part of a solution.

Solvent - the part of a mixture that the solute dissolves into. Usually this is the larger part of the mixture.

Particle diagram - a cartoon that shows atoms, molecules, ions, etc. It has a key. It can also show phases of matter, depending upon how one draws the cartoons.

Chemical symbol - symbols that indicate particular atoms or compounds. Ex: copper is Cu, water is H₂O.

Law of conservation of matter - Law that states: matter cannot be created or destroyed in any chemical reaction or in any physical change (phase change). Matter is conserved.

Law of conservation of charge - Law that states: charge cannot be created or destroyed in any chemical reaction or in any physical change (phase change). Charge is conserved.
This refers to electrochemistry or “redox”.

Law of conservation of energy - Law that states: energy cannot be created or destroyed in any chemical reaction or in any physical change (phase change). Energy is transferred.

Chemical change - process that matter changes from one substance to another. Compounds can form or break up into simpler substances (smaller compounds or elements). New properties form.

Physical change - refers to a phase change, no change in formula or properties.

TOPIC-B - the indicators that a chemical reaction has probably occurred (although not a “rule”) The letters stand for temperature change, odor change, precipitate of a solid, irreversibility, color change and bubbles of a new gas.

Spectra - energy given off by substances when electrons are returning to the ground state from the excited state. They “gained” energy by heat, radiation, or electricity, and emit it as visible light called spectra.

Ground state - the organization of the electrons into their orbitals. The electrons are normally in their lowest energy state, or ground state. All electron configurations on the periodic table are in ground state.

Excited state - when atoms or compounds are energized in a variety of ways, unique amounts of energy can be absorbed by the electrons, bumping them from the normal or ground state, into an excited state. This puts electrons into higher than normal orbitals. This is also an unstable state of existence, and when these electrons return to their normal, or ground state, they emit this unique amount of energy they just gained previous to move to this excited state, this “emission” of energy can be seen as spectra.

Electrons - the smallest subatomic particles found flying around the nucleus in orbitals (or energy levels). In high school chem they have no appreciable mass, but they DO have mass. These have a -1 charge

Protons - the subatomic particle in the nucleus with a +1 charge which is equal but opposite the charge of an electron. In high school the proton has mass of 1 AMU but it is really slightly higher than 1.0

Neutrons - the other subatomic particle found in the nucleus of an atom. It has no charge. In high school its mass is also 1 AMU but it is actually slightly higher than 1.0, and it’s slightly different than the mass of a proton. Neutrons have NO charge at all.

Nucleus - the central portion of an atom that has all of it’s mass (in High School). Nuclei have positive protons and neutral neutrons, so the “net nuclear charge of any atom” is always a positive number.

Orbits - old fashioned locations for electrons. Also called energy levels. Think planets flying around the Sun

Orbitals - current idea of where electrons fly around the nucleus. Not at particular radius from nucleus, rather it's more of a "zone" or cloud. Orbitals are truly statistical models of where the electrons are most likely to be found. Usually in a diagram, the darker the cloud, the more often electrons are found "there" as opposed to the less dark parts of the drawing of the electron "cloud".

Energy levels - electrons are in orbitals, which are energy levels. The ground state energy levels are lowest energy but excited electrons (energized electrons) are found in higher energy levels or higher orbitals than normal.

Spectra emission lines - when excited electrons return to the ground state, they emit a unique amount of energy, the same exact unique amount it took to excite them in the first place. The color they emit, that you can see with your eyes, can be "broken apart" by a refractive lens, and the exact color of light, at specific wavelengths, can be measured as emission lines. These lines are known and can be used to figure out what substances are present because these lines are unique for all substances in the Universe.

Refractive lenses - special lenses that can break up a mixture of light into the unique colors of light that make it up. The silly cardboard and plastic glasses that turn daylight into rainbows are refractive lenses.

Flame test - when you put some of a substance into a flame, the color of flame that shows indicates the spectra of that substance in the color of the flame. It's not an exact measurement, but is helpful in determining some substances from another.

Metal - a type of element that has "metallic properties" such as luster, malleability, ductility, conduction of heat and electricity, forms cations, etc. All elements to the left of the "staircase" on your periodic table except for hydrogen which is a nonmetal.

Nonmetal - a type of element that has "nonmetallic properties" such as an inability to conduct electricity or heat, brittleness or exists as a gas at STP, forms into anions. All elements on the right of the staircase on your periodic table plus hydrogen are nonmetals.

Metalloid - 7 elements that touch the "staircase" on your periodic table (not Al or Po) which are nonmetal that exhibit some metallic properties, such as silicon being lustrous and able to conduct electricity. Also includes metals such as Sb or antimony which have metallic properties but are brittle like nonmetals

Alkali metal - metals in group 1 on the periodic table, from lithium to francium. These only form +1 cations

Alkaline earth metal - metals found only in group 2, from beryllium to radium. These only for +2 cations

Transitional metal - metals in groups 3 to 12, plus the metals included in the triangle formed by Al, Po, and Tl. Most of these metals can form multiple possible cations

Halogens - group 17 elements, include only F, Cl, Br, and I. All are diatomic, and this group shows electron dispersion attraction very well as F and Cl are gases at STP, but Br is a liquid, and I is solid.

Noble gas - group 18 elements which by definition do not make compounds or bond with any other atoms. Under some unusual conditions, some noble gases can form into compounds, but this is exceptional.

Inner transitional metals - these are the 2 rows of elements at the bottom of the table that include the "Lanthanum Series" from La to Lu, all of which are in Group 3 and Period 6, as well as the "Actinium Series" including Ac through Lr, all of which fit into Group 3, Period 7. Your periodic table does not show this well.

Dmitri Mendeleev - the “father” of the Periodic Table of the Elements. He put the original table together about 1869.

Democritus - Greek philosopher who coined the term “atomos” or atom, which he said meant indivisible part of a whole. He thought that you could have an atom of anything, the smallest part of a fish was called an atom of fish; smallest part of a tree was an atom of a tree. Good word, silly from our perspective.

John Dalton - Father of Atomic theory. Put chemistry together as a science in the 1700’s. His theory includes the “famous phrase” simple whole number ratios, which applies to chemical formulas and to balancing chemical equations. His model of the atom was the “Billiard Ball Model” which somehow showed that atoms had different masses, but otherwise all looked like different balls on a pool table. Very simplistic from our point of view today.

JJ Thompson - the man that discovered the electron using a cathode ray tube. His model of the atom was called the “plum pudding model” which had his electrons embedded as bits of chopped up plums in a bread pudding. Think “chocolate chip cookie model” where the chips were the electrons embedded in a some sort of positively charged ‘stuff’. The atoms were known then to be neutral, since electrons were negative, the mass of his atom had to be + charged. Also amusing from our perspective.

Ernest Rutherford - my chemistry hero, an Australian chemist who figured out that the electrons were flying around the outside of the atom, leaving the positive portion of the atom to be the “nucleus”. His gold foil experiment showed that atoms were mostly empty space and that the volume of an atom was due to the flying electrons. Many scoffed at this idea when it was first presented. He was right.

Niels Bohr - student of Rutherford, used his math skills to “prove” that electrons could fly around the nucleus without losing energy (for Hydrogen, anyway) and that these electrons existed in energy levels he called orbits (oops!) and that they could be in ground state, or get excited and then emit unique spectra that could be measured. Wow!

James Chadwick - not really part of high school chemistry (shame) but he discovered the neutron!

Linus Pauling - Double Noble Prize winner, explained electronegativity and much of bonding

Amadeo Avogadro - old Italian chemist who studied gases, came up with “Avogadro’s Hypothesis” and is honored with what we call Avogadro’s number

Cation - a metal atom that has lost (transferred) one or more electrons, forming into a positive ion.

Anion - a non-metal atom that has gained one or more electrons, forming into a negative ion.

Positive charge - charge of one proton, opposite but equal in magnitude to the charge of an electron

Negative charge - charge of one electron, opposite but equal in magnitude to the charge of a proton

Neutral charge - the “lack of charge” of a neutron, or of any atom with equal numbers of protons and electrons

Lustrous - physical property of metals associated with being very shiny or reflective

Melting point - physical property of any substance, the temperature between solid and liquid phases

Freezing point - physical property of any substance, the temperature between the liquid phase and the solid one

Condensing point - physical property of any substance, the temperature between gas and liquid phases

Boiling point - physical property of any substance, the temperature between liquid and gas phases

Malleable - physical property of a metal, meaning when you pound on it, it gets flat without cracking apart.

Ductile - physical property of a metal, meaning when you squeeze it through a hole, it becomes wire shaped, without cracking apart

Brittle - property of a non-metal, meaning when you pound on it, it cracks apart, not malleable

Electron configuration - the pattern of electrons into their specific orbitals. Sodium, or Na, has a 2-8-1 electron configuration, meaning that 2 electrons are in the smallest and lowest energy level, 8 electrons are in the middle orbital, and one electron is in the third orbital (also called the valence orbital, holding the one valence electron). In high school we use simple patterns and overlook the sub-orbitals. Sodium really has a $1s^2 2s^2 2p^6 3s^1$ arrangement

Periodic Law - when the elements are arranged in order of increasing atomic number, their physical and chemical properties repeat in the groups of the periodic table. Atomic number is number of protons and is also the number of electrons. The table is in this order. When put into this “odd” shape, the atoms that are chemically similar are in groups together (up and down columns).

Avogadro's Hypothesis - Equal volumes of different gases at the same temperature and pressure have the same number of particles and the same number of moles.

Subatomic particles - include protons, neutrons and electrons in high school chem. In physics and advanced chem they include over 100 smaller particles including hadrons, quarks, mesons, bosons, etc.

Gold foil experiment - an experiment by Rutherford that shot alpha particle radiation at a thin sheet of gold foil. Most of the alpha particles flew right through the foil, indicating that the atoms of gold are mostly empty space. These positive charge particles also occasionally bumped into the gold atoms, dinging the alpha particles off at angles, showing that the gold atoms must have a positive nucleus that was dense and larger than the 4 amu sized alpha particles. Rutherford stated that the neutral gold atoms must have a positive nucleus, with the negative electrons flying around the outside, taking up most of the volume with almost no stuff (electrons are so tiny). Flaws in his theory are that electrons somehow don't fly away from the gold atoms they are associated with, that the electrons are somehow not drawn into the nucleus (opposite charges should attract).

Isotopes - atoms of one element with different numbers of neutral neutrons in the nucleus. These extra (or less than normal number of) neutrons change the atomic mass, but have almost no effect chemically. These isotopes exist in different proportions that can be very accurately measured. When one calculates the average weighted atomic mass, these proportions cause the atomic mass to have decimals

Average weighted atomic mass - math technique that combines the mass of each naturally occurring isotope of an atom, multiplied by their decimal proportion. Sum them together to obtain the “official” mass of any element. Do not include man made isotopes (you'll see this in nuclear chemistry)

Atomic mass - casual rounded to the nearest whole number mass of an atom from the periodic table. The nearest whole number mass is the mass of the most common isotope of that element

Atomic theory - theory put forth by John Dalton in the late 1700s that included: the ideas that: Elements are made of extremely small particles called atoms; Atoms of a given element are identical in size, mass, and other properties; Atoms cannot be created or destroyed, or simplified; Atoms combine in simple whole-number ratios to form chemical compounds; In chemical reactions, atoms are combined, separated, or rearranged, but are not lost and can be separated back into atoms again.

Cathode ray tube - device used by Thompson that indicated the presence of electrons as independent particles, that he made the first subatomic particle of the atom.

Alpha particles - radiation particles emitted by many radioactive elements including polonium, which was used by Rutherford to produce alpha particles for the gold foil experiment. Alpha particles resemble helium nuclei, in that they are made of 2 protons and 2 neutrons. They are NOT helium nuclei though.

Modern model of atoms - infers a positive nucleus containing protons and neutrons, surrounded by a “cloud” or zone, where the electrons are most likely to be found. It took many scientists, many years to develop this and might still change if new information comes to light.

Bright line emissions - see: spectra emission lines, more vocabulary for something you should know by now.

AlPo Exception - 2 elements, aluminum and polonium, that touch the “staircase” on the periodic table but are NOT metalloids. They are the exceptions to the rule of touch the stairs = metalloid trend

Ionic Compound - compounds formed by metals bonding to nonmetals, by transferring electrons. These are the strongest bonds in high school chemistry. They do not exist as single, double or triple though.

Molecular Compounds - from when 2 or more nonmetals bond by sharing electrons. They can share 1, 2 or even 3 pairs of electrons, as single, double, or triple bonds. Strong but not as strong as ionic bonds.

Share electrons - when atoms of nonmetals share electrons to “get that octet” of electrons, or full orbitals, some of the time when they bond in a covalent bond way.

Transfer electrons - what ions do when they bond ionically. Electrons from metals are “sent” to the nonmetals so that they can follow the “octet rule”, and the opposite charges between cations and anions are wildly attracted together in the strongest bonds in chemistry.

Prefixes - used in covalent or molecular compound names, indicate 1 to 10 (in high school) with prefixes of: mono, di, tri, tetra, penta, hexa, hepta, octa, nona, and deca for 1 through 10.

Roman numerals - used when writing word names (stock names) for transitional metal ionic compounds, if these metals make more than one kind of cation. Ex: titanium makes a +2, a +3, and a +4 cation, so they would be called Titanium II, or titanium III, or titanium IV in their names. Roman numerals from 1 through 7 are used: I, II, III, IV, V, VI, VII, and VIII

Stock naming system - what we call the naming system of the transitional metal ionic compounds that use roman numerals. Ex: CuCl is copper I chloride, while CuCl_2 would be copper II chloride. The roman numeral matches the ion charge for the metal. Sometimes parenthesis are used as: copper (I) chloride; both with or without the parenthesis are acceptable.

Monoatomic ions - cations or anions formed from one atom, such as sodium Na^{+1} or chloride Cl^{-1} .

Polyatomic ions - groups of atoms with extra or fewer electrons, that act together as ions. In our class these are all listed on table E. Examples include OH^{-1} hydroxide, SO_4^{-2} or sulfate, or SO_3^{-2} which is sulfite. Be careful with the names and the exact formulas, some of these are similar others.

Diatomic elements - seven elements on the periodic table that are unstable as individual atoms. In their pure forms as elements, each has two identical atoms bonded together.

HONCIBrIF twins - the 7 diatomic atoms, easy to remember: H_2 , O_2 , N_2 , Cl_2 , Br_2 , I_2 and F_2 . In their pure forms, these 7 elements exist as “2 identical atoms bonded together”, doubled up.

Oxidation numbers - positive and negative numbers in the top right corner of the periodic table boxes, usually refer to the nonmetal elements. These are NOT ion charges in this case, they are just numbers that need to be combined in a 1:1 or different ratio to determine what compounds are possible or impossible. For instance, if you look at carbon: C has a -2, a +2 and a +4 oxidation number. Oxygen has only a -2 oxidation number. The only combinations that sum to zero are the +2 and -2 in a 1:1 ratio (CO is in a 1:1 ratio) or with a +4 and two -2 oxygen atoms (in a 1:2 or CO_2 ratio). Those are the ONLY carbon-oxygen compounds possible.

Selected oxidation state - the official name for oxidation numbers on the periodic table

Groups - the 18 columns on the periodic table, each group contains atoms that are chemically similar

Periods - the 7 rows across the periodic table. Each period (1 to 7) contains atoms with that number of orbitals

Valence electrons - the outermost electrons that are in the valence orbital

Valence orbitals - the outermost orbital of an atom

Staircase - the dark line that separates the metals on the left from the nonmetals on the right of the periodic table. On the staircase line itself are the metalloids (7 atoms, plus Al and Po which are not metalloids)

Isoelectric - when an atom gains or loses enough electrons to get the same electron configuration as a noble gas. The ions that form DO NOT become noble gases, they get the same electron configuration. This stable electron configuration allows them to bond together in a stable fashion.

Formula unit - the smallest part of an element is either an atom or a molecule for the HONCIBrIF twins. The smallest part of a molecular compound is a molecule. Ionic compounds exist ONLY as crystal solids which have a repeating matrix pattern, most of them can exist as loose ions in aqueous solution. Few don't ionize in water and remain matrix solids. A single “unit” of NaCl (for example) just does not exist in the way a single molecule of water can. They are not alone. Still, one could “imagine” a single NaCl unit, a unit of the formula. This is an idea rather than a real thing, but you can still calculate a molar mass from it, even though as an actual particle it cannot exist.

Moles - just as you could have a dozen roses, or even a single pair of shoes, a bunch of atoms in chemistry is called a mole of atoms (or a mole of molecules, or a mole of formula units). A mole means having 6.02×10^{23} particles. It's a big number, so big it has a name: Avogadro's number.

Molar mass - the mass in grams of one mole of particles of any atom or compound. If an atom of sodium has a rounded to the nearest whole number mass of 23 amu, a mole of sodium would have mass of 23 grams. No math is required for this conversion. One water molecule has mass of 18 amu, the molar mass of water is 18 grams/mole.

Gram formula mass - a silly way to say molar mass of an ionic compound is this

Gram molecular mass - a silly way to say molar mass of a molecular compound is this

Avogadro's number - the number of particles in one mole of that thing 6.02×10^{23} particles is one mole

Mole ratio - in a balanced chemical equation, it's the ratio of moles of each part of the equation to each other, It's always simple whole number ratio, just like John Dalton said. For example: the balanced chemical equation showing the synthesis of ammonia is $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$, the mole ratio here is 1:3:2 for nitrogen to hydrogen to ammonia

Percent composition by mass - the proportion between part of the whole and the whole of a substance written as a percent. For example water has a molar mass of 18 g/mole. Of those 18 total grams, just 2 grams are hydrogen and 16 grams are made of oxygen.

Oxygen would make up $16/18 \times 100\% = 88.9\%$ by mass of water

AMU - atomic mass unit, the mass unit used to measure atoms and molecules. One AMU = 1/12 of a carbon atom with mass of 12 AMU by definition. Carbon has 6 protons and 6 neutrons, so 1 proton or 1 neutron is almost exactly 1 AMU. In high school one proton = 1 AMU and one neutron = 1 AMU as well. In real life this is not quite the case exactly.

Atomic mass unit - same thing as an AMU

Empirical formulas - chemical formulas are written in the simplest whole number ratios most of the time, but for many organic compounds (containing carbon atoms) since carbon atoms can chain together, or make all sorts of loops and rings, this simple whole number concept doesn't always hold true. Empirical formulas are the simplest ratios of atoms to atoms in a compound, but you write them so they look like a chemical formula. This is very silly to do and often confuses new chemists. For example, glucose formula is actually $\text{C}_6\text{H}_{12}\text{O}_6$, the atoms are in a 6:12:6 ratio - which is not what Dalton would expect. The simplest ratio would be a 1:2:1 ratio. Rather than just say the compound has atoms in a 1:2:1 ratio, an empirical formula can be written as CH_2O . This HAS a 1:2:1 ratio, but is NOT glucose and IT CANNOT ACTUALLY EXIST. Empirical formulas are math ratios written to look like formulas, for no good reason other than to confuse you. And if that's not bad enough, the formula for water H_2O is also its empirical formula. Go figure!

STP - this stands for standard temperature and standard pressure

Standard Temperature and Pressure - standard temperature is 273 Kelvin which equals 0°C . Standard Pressure is 101.3 kPa which is also the same as 1 atm, or 14.7 psi or even 760 mm Hg. It's just shorthand.

Net mass - the mass of just what you are trying to measure. For example if you put a beaker on the scale that contains water and the total mass is 123.00 grams, but the beaker itself has mass of 101.00 grams, the mass of the water alone, the NET MASS of the water is $123.00 - 101.00 = 22.00$ grams.

Synthesis - a type of chemical reaction that combines two or more smaller substances into a new one that is larger. It's sometimes called a combination reaction. Ex: hydrogen and oxygen form water

Decomposition - the reverse of synthesis, always start with a single reactant that breaks into 2 or more smaller products. Ex: copper (II) chloride forms copper and chlorine

Single replacement - a chemical reaction starting with one aqueous solution and something acting as atoms - which can be atoms like metal atoms, or halogen twins like F₂, Cl₂, Br₂, or I₂. Of the three parts of this reaction, the atom part, the cation in solution, and the anion in solution you will always find 2 of them on one side of table J (the activity series) or the other side. Which ever is the "higher on the list" is more active and will end up in solution. If the atom is higher than the cation, the metal atom replaces the cation, and the cation forms into an atom which will precipitate out as a solid or gas. If the atom going in is a halogen, and is higher than the anion, the anion is replaced. The third part might not even be on table J, that does not matter. That third part is called the spectator ion, it's there but does not get replaced or does replacing. If by chance the atom is lower on table J, the more active atom is already in solution, no reaction will occur.

Double replacement - another reaction starting with 2 aqueous solutions. When mixing them together, the two pairs of cation/anions end up on one beaker. Sometimes a cation from one solution combines with an anion from the other solution, and they are so attracted together that they precipitate out of solution as a solid. This precipitate is the proof that a double replacement reaction occurred. If 2 ionic solutions mix, but no precipitate forms, then no reaction occurred, this was just a mixture. Table J will tell you what the compound was that formed an insoluble solid precipitate.

Combustion - a 5th type of chemical reaction where a hydrocarbon reacts with oxygen and forms CO₂ + water, releasing energy exothermically. The only variable is what hydrocarbon you start with (thousands to choose from). A hydrocarbon is a compound made up only of carbon and hydrogen such as methane CH₄ or octane C₈H₁₈. Some compounds such as sugars or alcohols are oxygenated-hydrocarbons, or hydrocarbon like molecules that contain oxygen; they burn well but are technically NOT combustion by definition.

Abstract - using letters to describe a chemical reaction Ex synthesis might be shown as $A + B \rightarrow AB$ these letters, A and B are not actual elements, rather substitutions to represent smaller substances combining into larger ones.

Balanced chemical equation - while using proper chemical symbols for atoms and compounds, this sort of equation let's one show the actual numbers (or moles) of each and that they balance on both sides of the arrow, proving the law of conservation of matter. All real chemical equations balance.

Skeleton equation - before you actually balance an equation, you first write out the symbols properly. Only from that point can you balance things properly. The starting point, this skeleton, does not balance. For example, a skeleton might be: $N_2 + H_2 \rightarrow NH_3$, where all the parts are written properly, but is not balanced. The balanced equation would be $N_2 + 3H_2 \rightarrow 2NH_3$

Catalyst - something that can be added to a chemical equation that can speed it up without changing the reactants, products, or energy emitted or absorbed. All catalyst do is lower the energy needed to start a reaction, or offer a different (lower energy) pathway for the reaction to go forward. It makes it go faster, but the same overall reaction occurs. Sometimes this faster reaction appears so different that one might believe a different reaction happened, but it's the same exactly except for how fast it happened.

Word equation - using words to describe a chemical reaction, no symbols. For example: Nitrogen reacts with hydrogen form into ammonia. This could be restated as ammonia forms from the combination of nitrogen and hydrogen. There is no one exact way to state a word equation, but all parts must be included and you should not attempt to be confusing.

Activity series - in our course this is Table J in the reference table. It lists metals (plus hydrogen) on one side, in order of their reactivity levels. Most reactive is at top, least reactive on the bottom of the list. On the right side are the four halogens, also in the same order, most reactive on top. This table is also used in redox to determine which metal bar is the anode and oxidizes, and which is the cathode and is the side for reduction.

Cation replacement - in single replacement, when a metal is introduced to a solution, and the metal is more reactive (see table J - activity series above), the atoms will replace the cation in solution because it's more reactive than the cation already in solution. This forces that cation out of solution and makes it an atom and it will precipitate out of the solution. Metals can of course only become cations.

Anion replacement - in single replacement, when a non-metal is introduced to a solution, if it is more active it will replace the anion in solution, forcing the original anion out of a solution as an atomic precipitate or gas. Non-metals can of course only become anions.

Spectator ion - the third part of the single replacement reaction not actually replacing or being replaced in solution. This part, this ion, is necessary, and remains in solution. Since it seems to be "just watching and not participating", it's called the spectator ion.

Precipitate - when a new compound forms in a double replacement reaction, and that new product is insoluble, it cannot exist in solution, it quite literally falls out, as snow might fall from the sky in winter. This "falling out" of solution is called precipitation, and it's the precipitate that precipitates out of solution.

Soluble - when something can dissolve in solution, for instance if an ionic compound is soluble in water, it dissolves, or is said to be soluble in water. Some molecular compounds dissolve into water as well, like dissolves like, polar compounds ex: sugars are soluble as well. Soluble refers to all substances, and not just to water as a solvent. If the solute dissolves into the solvent, the solute is soluble.

Insoluble - compounds that do not dissolve into the solvent (ex: oil into water, or silver chloride into water) are said to be insoluble, or not able to dissolve into the solvent. The solvent does not have to be water.

Dissolve - to become invisible in solvent, becoming ions, or molecules and to be soluble in the solvent

Ionize - when ionic compounds are soluble, they not only get smaller, they break apart into loose ions in solution; literally sodium chloride becomes sodium cations and chloride ions, loose in water. Only ionic compounds ionize when they are soluble in solution. Some ionic compounds that are NOT soluble do not ionize in solution as they don't dissolve.

Disassociate - another vocabulary word for ionize in solution, meaning the ionic compound comes apart into loose ions when dissolving into the solvent.

Hydrocarbon - a molecule or compound made up of only carbon and hydrogen. Technically it does not include the oxygenated-hydrocarbons like sugar or alcohol (etc.) either.

Solution - most often in high school a wet mixture, such as a solid dissolving into water, but is actually any homogenous mixture, such as air or the alloy brass (made of melting copper and zinc together)

Stoichiometry - the part of chemistry that allows you to use a balanced equation and play math tricks with it, such as figuring out how many grams of a product form when you use a number of liters of a gas as a reactant. It's terribly simple and requires a fair amount of practice and care to watch out for the shark.

Mole ratio tunnel - part of the "stoich" math, where you can use the mole ratio to connect between two parts of a balanced chemical equation.

Mole Island Map - the directions to all stoich math, shark included, you were supposed to put that under table H on your reference table (and into your head). Oh yeah, on the regents exam there will ONLY be moles to moles problems, use the MR, no other calculations. That whole thing is just a Vestal thing. (haha!)

Kinetic energy - the energy of "motion", the higher the kinetic energy the faster the particles are moving. Likewise, the slower your particles move, the lower the KE. We often measure temperature in C or K units, which is somewhat similar to KE. Remember MJ's hand and glove.

Potential energy - this is the "other" energy, the energy of position or phase. It is only important in our class to explain the energy of phase changes. During a phase change there is no change in temperature, but energy is being added (or removed). Since energy (heat) is being added or removed, KE changes accordingly - but not in a phase change. During the flat parts of the heating and cooling curves (phase changes) it's the Potential Energy that changes.

Vaporization - the physical process where liquids become gas, this includes what happens during boiling when all the liquid has the energy to vaporize, and during evaporation, which happens at all temperatures and many fewer particles at a time undergo.

Evaporation - the process that some liquid particles get enough energy (usually by collisions and random chance) to jump into the gas phase. This happens at ALL temperatures, and is slow.

Sublimation - the physical process that some solids undergo when they change directly to gas without being liquids first. Usually this is because the melting point and boiling point are so close together that you miss the liquid phase, or at normal pressures it happens so easily that no liquid needs form. You saw solid iodine become that pretty purple gas in lab.

Deposition - the opposite of sublimation, whereby gases turn into solids without an apparent liquid phase.

Heating curve - a graph that shows the solid to liquid to gas phase for any substance. All of these graphs are more or less identical, except for the title and the actual temperatures of melting and boiling. The "lower" flat part represents the heat of fusion, which is smaller than the heat of vaporization, which is the longer "higher" flat part of the graph. It takes more energy to vaporize a mass of liquid than it took to melt that many grams of solid to liquid. Usually heat is added at a constant rate.

Cooling curve - the opposite of a heating curve. These have the same longer "higher" flat portion, and the shorter "lower" flat part as well. All cooling curves are also nearly identical, except for the condensing temperature and the freezing points (and title!) Heat is usually removed at a constant rate.

Phase change - the process of changing from one phase to another (solid, liquid, and gas). There are 6 of these that you should be able to define. Melting + freezing, vaporizing + condensing, and sublimation + deposition.

Phase diagram - another type of graph that shows all three phases at nearly all temperature and pressure combinations. All are pretty similar, except for the placement of the lines as all substances have different phase change temperatures.

Normal boiling point - the boiling point at normal pressure. For water that's 373 K or 100°C. Water boils at lower temperatures with lower pressure, and water boils at higher temperatures at higher pressures. You could check a phase diagram, or even table H (vapor pressure) to calculate these boiling point temperatures.

Normal freezing point - this is the freezing point at normal pressure. For water it's 273 K or 0°C. The freezing point can also change with pressure, this you need to consult with a phase diagram to see.

Triple point - on a phase diagram, many substances can exist at all 3 phases at once, usually a low pressure and cooler temperature. At this exact pressure and temperature all phases exist and all 6 phase changes are in dynamic equilibrium.

Critical point - on a phase diagram, at the "top" of the curve between liquid and gas, most substances reach a point at very high temperature and pressure that the "difference" between how a very hot liquid or gas ceases, and at this point (or above) the words liquid or gas make no sense. This won't happen in your life, except as a vocabulary word on the regents exam.

Vapor pressure - this (unfortunately) is one hard vocabulary word for high schoolers. All liquids evaporate, how fast depends upon 2 things, temperature and intermolecular attractions. Most often hotter liquids would evaporate much faster as more particles have sufficient kinetic energy to leap into the gas phase. Some liquids have stronger hydrogen bonding making them less likely to escape into the gas phase. Some liquids have no hydrogen bonding at all. When you place a liquid into a closed system, say under a glass bell jar, there is air pressure inside that bell (on top of the liquid). As the liquid evaporates, and turns into gas, this extra gas in a closed system adds particles (and collision) and causes the pressure inside to increase. This increase is called the vapor pressure. Lower vapor pressure means evaporation is not happening well, due to either lower temperatures or stronger intermolecular attractions. Higher vapor pressure usually indicates lower intermolecular attractions - this liquid evaporates more readily.

760 mm Hg - standard pressure measured as millimeters of mercury, in an "old fashioned" mercury barometer

14.7 psi - standard pressure measured in normal USA units of pounds per square inch

101.3 kPa - standard pressure measured in kilo-Pascals, a metric unit of air or gas pressure

Intermolecular attractions - attractions between particles (atoms or molecules), including electron dispersion attraction (the weakest), dipole attractions, and hydrogen bonding (the strongest).

Thermochemistry - the branch of chemistry that studies energy (most often being released or absorbed)

Calorie - a "food calorie" which is actually a kilo-calorie, or 1000 calories

calorie - a smaller unit of energy, this is the amount of energy needed to change the temperature of one gram of water by one degree centigrade (or by 1 Kelvin). 1000 of these calories = 1 Food Calorie

Joules - a smaller standard unit of energy; 4.18 Joules = 1 calorie

Kilojoules - 1000 joules, another unit of energy

Delta "T" - change in temperature, often shown with the Greek letter delta this way: ΔT .

The change in temperature in centigrade = the change in temperature Kelvin.

Delta "H" - this is written mostly as ΔH , and refers to the change in heat. When you have a $+\Delta H$ that indicates that energy is absorbed endothermically. A $-\Delta H$ indicates heat is being released exothermically.

Exothermic - chemistry talk for heat is being released by this process (things feel hotter to you)

Endothermic - more chem talk for heat is being absorbed during this process (things feel colder to you)

Calories vs. calories - Calories with a capital "C" stand for Food Calories or kilo-calories. Small "c" calories are smaller, in fact it takes 1000 calories = 1 Calorie

Heat of fusion = the amount of energy required to be added to melt one gram of a substance into 1 gram of that as a liquid with NO temperature change. For water, this $H_F=334$ Joules/gram. All substances have their own heat of fusion constants. Of course this is the exact same amount of energy that needs to be removed from 1 gram of a liquid substance to convert it into a solid (with no change in temperature).

Heat of vaporization - the amount of energy required to be added to vaporize one gram of a liquid substance into 1 gram of that as a gas with NO temperature change. For water, this $H_V=2260$ Joules/gram. All substances have their own heat of fusion constants. Of course this is the exact same amount of energy that needs to be removed from 1 gram of a gas substance to convert it into a liquid (with no change in temperature).

Specific heat capacity constant - yet another constant, the amount of energy required to change the temperature of one gram a substance by 1 degree centigrade (or 1 Kelvin). For liquid water this constant, $C = 4.18$ Joules/gram \cdot K, which means it takes 4.18 Joules to change one gram of water by 1 K or by 1 $^{\circ}$ C. Each phase of H₂O has it's own "C" constant. For ice this number is about 2.10 J/g \cdot K, and for steam it's about 1.9 J/g \cdot K

Calorimeter - a machine that measures the amount of energy in food, also called a bomb calorimeter as the food is burnt up inside of it to release the energy as quickly as possible to more easily measure it.

KMT - the abbreviation for the Kinetic Molecular Theory of Gases, that explains what gases are, how they work and how they remain gases.

Kinetic Molecular Theory of Gases - includes such tidbits as: gases are composed of particles that behave like hard, spherical objects in a state of constant, random, straight line motion; these particles collide elastically with each other and the container walls, these collisions cause gas pressure; these particles are much smaller than the distance between particles -most of the volume of a gas is empty space; there is no force of attraction or repulsion between gas particles; no energy of a gas particle is lost when it collides with another particle or with the walls of the container; the average kinetic energy of a collection of gas particles depends on the temperature of the gas and nothing else.

Pressure - is caused by the collisions of gas particles, and is measured in kPa, mm Hg, psi, or atm.

Temperature - is measured in centigrade or Kelvin in chemistry, is directly connected to the kinetic energy of the particles. More temp means more KE, lower temp means less KE.

Periodic Law - When the atoms are arranged in order of increasing atomic number (in this weird shaped table) there is a periodic repetition of their chemical and physical properties in the GROUPS.

Combined gas law - a simple version of the mathematics of gas chemistry. It has the original pressure multiplied by original volume, divided by the starting temperature in Kelvin equal to the new pressure multiplied by the new volume, divided by the new temperature in Kelvin. Any units are fine, except temperature must be in Kelvin, and the units must be consistent across the equal sign. Any of the 6 variables can be the unknown in a problem. This formula is on the back of your reference tables, and should be in your head.

Inversely proportional - means that 2 variables are equal to each other while being multiplied together, as is the “top” part of the combined gas law: $P_1V_1 = P_2V_2$ As one variable increases, the other must decrease.

Directly proportional - means that 2 variable are equal across an equal sign while in a fraction or division problem, such as the Pressure : Temperature relationship, which is $P_1/T_1 = P_2/T_2$ - or the Volume : Temperature relationship which is $V_1/T_1 = V_2/T_2$ As one variable increases, so does the other one, in proportion

Real gas - all gases are real, any substance in the gas phase is a real gas

Ideal gas - ideal gases are not real, they are used only to help describe what gases are, how gases work, etc.

Atomic size - the size of atoms, or even molecules, often measured in picometers, or trillionths of a meter.
On Table S atomic radius is the last column on the right, in pm.

Picometer - a crazy small size, one trillionth of one meter

Trend - a pattern that repeats itself, refers to a variety of patterns, or trends on the periodic table of elements

Net nuclear charge - a trend on the PT, the charge of any nucleus, which is the sum of the protons and neutrons in any nucleus. Since the neutrons have no charge, the net nuclear charge would always be positive, how positive you might ask? As positive as how many protons are present. Ex: hydrogen has one proton, it's net nuclear charge is +1. Magnesium has 12 protons, so it's net nuclear charge is +12.
Always include this + sign

Electronegativity - another trend on the periodic table, this refers to how much a particular atom pulls on the electron it shares in a bond with another atom that it's bonding to. Fluorine has the highest EN at 4.0 with no units. It shares electrons with other nonmetals, but has the greatest tendency to pull that electron to itself. The two atoms in a bond have a “difference in EN Value”, the greater this difference, the more polar the bond is. The atom with the higher EN value tends to be slightly more negative than the other atom, since this higher EN value means it pulls (and gets) this electron more often than the second atom in this bond. This scale has no units, and all atoms are measured against fluorine. That makes it both an arbitrary scale and a relative one.

1st ionization energy - another trend on the periodic table, this refers to the amount of energy required to remove a mole of valence electrons from one mole of atoms. Most atoms do not want to be +1 cations - in fact only group 1 atoms form stable +1 cations. In high school this is more a vocabulary word, in real chem there is also a second, third, fourth, etc. ionization energy, and to make a +2 cation, a mole of Mg atoms would first require the 1st ionization energy PLUS the 2nd ionization energy (which does not exist in our tables, but does in the real world of chem). Nonmetals have no interest in losing any electrons, nor do noble gases, but with sufficient energy you could force them to become +1 cations as well (or at least grasp how much energy it might take to do this!)

2nd ionization energy - the energy required to form a second order, or +2 cation for a mole of particles

Group trend - trends that occur going down a group on the periodic table. Trends increase or decrease.

Period trend - trends that occur going across a period on the periodic table. Trends increase or decrease.

Allotropes - an almost random vocabulary word, which means different forms of a pure element, which bond together differently, and therefore have different properties. The most famous is graphite and diamond - both being pure carbon. In our class the more "important" one is oxygen and ozone O_2 and O_3 , since I am from Ozone Park in Queens!

Eka-aluminum - what Mendeleev called the missing element he predicted below aluminum that was yet to be discovered. So confident was he in his new periodic table design that he felt that a few elements were undiscovered; he told scientists what sorts of properties to look for and they found gallium (in this case) and several more elements he predicted.

Lewis Dot diagrams - a diagram system that shows the valence electrons of atoms, of ions (in brackets), of molecules (sharing electrons) and of ionic compounds (with all ions in brackets). Only show valence electrons, remember that electrons are more stable paired up than apart.

Inner electrons - these electrons are the electrons not in the valence orbital, and tend not to participate much in bonding. Of course in some cases they do, but chem is filled with exceptions. They're inner because they're not the valence electrons.

Ionic bonding - bonding between a metal and a non-metal that occurs when metals TRANSFER electrons to nonmetals. This situation creates ions of opposite charge, which are wildly attracted together. This is the strongest bond in regents chemistry class. (think love!) By definition, ionic bonds are polar (a positive cation bonds to a negative anion) but are not single, double, or triple, they are just strongly attracted together.

Covalent bonding - bonding between non-metals, that occurs when atoms SHARE electrons. These bonds can be single when atoms share one pair of electrons between them, or double (two pairs) or even triple (three pairs of electrons shared). These bonds are also polar or nonpolar, depending upon the difference between the electronegativity values of the atoms making this bond.

Molecular bonding - another name for covalent bonding, as the bonded atoms form into molecules, or molecular compounds

Intermolecular bonding - these are not "true" bonds, rather they are attractions between many particles. They include: Electron dispersion attraction, Dipole attraction, and Hydrogen bonding.

Electron dispersion attraction - this is caused by the temporary attraction between particles due to the moment to moment dispersion, or motion of the electrons. Since these electrons do not move smoothly, at any point in time they can bunch up (creating a temporary negative spot in the electron "cloud") or they can be "over there" (creating a temporary positive spot on the electron "cloud"). These moments of positive or negative allow particles to be temporarily attracted to particles around them. The more electrons present in the substance, the more the movement creates more and stronger moments of attraction between particles. All substances have this, it's the weakest attraction and often is just unimportant in high school chem. Group 17 shows that as the number of electrons increases, this attraction can change the halogens from gases (F_2 & Cl_2) into liquids (Br_2) and even solids (I_2)!

Dipole attraction - the second strongest intermolecular attraction; this occurs when you have polar molecules - mostly with polar bonding as well (but without the atom hydrogen!). The polarity created makes the positive and negative sides of these molecules attract together, and this is much stronger than the motion of the electron dispersion attractions create. All molecules with this dipole attraction also have electron dispersion attraction as well. Dipole refers to the positive side and the negative side of these molecules, 2 poles.

Hydrogen bonding - this refers to the much stronger dipole attraction that forms when hydrogen is part of the polar molecules. Since hydrogen has a much lower EN value than most atoms it bonds to, when hydrogen is present the dipole attraction is much stronger. Hydrogen bonding is truly super dipole attraction and should probably not have it's own vocabulary word. Importantly, it's not between hydrogen atoms, it's between a hydrogen in a polar bond in one molecule and a different atom in a neighboring molecule.

Radial symmetry - when you can cut something (a pizza or a molecule) in half through the center point, at any angle, and always get two identical pieces, this has radial symmetry. This type of symmetry keeps all polar bonds that might exist in "balance" and cancels out their polarity. Molecules with radial symmetry are nonpolar, and have little attraction together (expect for that electron dispersion attraction)

Bilateral symmetry - you have this, one line of symmetry (between your eyes, through your belly button) but this type of symmetry is NOT important in chem. Radial symmetry means nonpolar molecules, anything else is a polar molecule. It's included here to highlight that YOU don't have radial symmetry but you do have this type. This type doesn't matter in chem.

Bond polarity - caused by a difference in electronegativity value in 2 atoms making a bond.

Molecular polarity - is determined by shape, see radial symmetry above

Single bond - when 2 nonmetals share one pair of electrons in a bond (2 electrons = 1 bond)

Double bond - when 2 nonmetals share two pairs of electrons in a bond (4 electrons = double bond)

Triple bond - when 2 nonmetals share three pairs of electrons in a bond (6 electrons = triple bond)

Dipole arrow - something ADDED to a structural diagram, to show the + side of a bond, and the pointy part of the arrow shows where the electron in the bond spends more time (with the atom with the higher electronegativity value). These arrows DO NOT replace the bond itself.

Octet rule - a simple "rule" that atoms tend to get 8 valence electrons when they form into ions, or when they bond covalently. Some atoms break this rule, as they are either too small, or just break the rule because they can, or do!

Polar bond - a covalent bond between 2 atoms with different electronegativity values

Nonpolar bond - a covalent bond between 2 atoms with the same electronegativity value

Polar molecule - a molecule that does not have radial symmetry

Nonpolar molecule - a molecule that does have radial symmetry

Coordinate covalent bond - a truly weird bond, that forms in addition to a different bond, to help atoms follow the octet rule. In our class only CO has this, first a double polar covalent bond, THEN, oxygen “loans” 2 electrons into the center of the atom molecule, letting carbon feel like hit has an octet as well.

Resonating bond - a differently weird bond, where three atoms bond together, one side makes a normal, stable bond, but the other side makes an unstable bond. This stable bond switches places, as does the unstable one, over and over very quickly. This allows both sides of the molecule to be “more stable” than it would be with one stable and one unstable bond. Ozone or O_3 makes this bond, as does NO_2 .

Metallic bond - yet another “weird” bond, that describes how metal stays stuck together. Metals are understood to be packed cations with loose valence electrons. Since these electrons can move quickly so when these cations are smashed together (when metals change shape) the cations don’t repel or crack up, as the electrons squeeze in and neutralize the charge. Imagine packed cations in a “sea of loose valence electrons” (how poetic!)

Loose valence electrons - covalent bonds share electrons, ionic bonds transfer them. Metals have loose valence electrons (see metallic bond)

Packed cations - how metals are thought to be bonded together (see metallic bond)

London Dispersion Forces - an old fashioned way to say electron dispersion attraction

Dipole moment - a fancy way to talk about bond polarity in polar molecules

Structural diagram - when you are smart enough to understand simple bonding, and Lewis Dot diagrams, each pair of dots that forms a bond can be replaced with a “dash”, and the electrons that don’t bond, the unshared pairs of electrons, are omitted, what is left is called the structural diagram. You can see 3 of these in table Q, for ethane, ethene, and ethyne.

Hydrate - a fancy word for water in a compound like $CuSO_4 \cdot 5H_2O$ those five waters are called pentahydrate

Surface tension - because water has strong hydrogen bonding between it’s molecules, at the surface of water these hydrogen bonds create a sharp “edge” between what is water and what is the air, and these hydrogen bonds attract at the surface only sideways and into the water, the surface of the water creates a sort of sheet of strength. Sort of like a trampoline. It has extra strength right on the surface. Below the surface, since the hydrogen bonds go in all directions, there is no “edge” created. All liquids have this, water has it especially strong because the hydrogen bonding in water is quite strong.

Solvation - the process of forming a solution by dissolving into the solute

Colligative properties - the three properties in HS chem that are affected by the amount of solute dissolved into the liquid. In our course we will only discuss water’s colligative properties. The more solute in water, the higher the boiling point becomes, the lower the freezing point becomes, and the vapor pressure is also diminished. This is all due to the polar molecules, or ions, that are in the water.

Saturated - description of a solution that is holding as much solute as possible under the given conditions

Unsaturated - description of a solution that can dissolve more of a solute under the given conditions

Supersaturated - an unusual situation where a hot solution forms, and hot solutions usually hold more solute than colder ones. Most often as the solution cools, solute precipitates out since the cooler solution can hold less solute than the warm. Table sugar and sodium acetate in hand warmers are exceptions. If the solution is cooled gently, the more than normal amount of solute remains dissolved. When this unstable system is given a small shock, the excess solute collapses out of solution quickly. You cannot “make a supersaturated solution” but you can make a saturated hot solution; if you can cool it and this extra solute remains dissolved, the saturated solution becomes supersaturated. Nothing on your Table G can supersaturate, this is not all that common.

Dynamic equilibrium - a situation where two opposing circumstances (say a forward and a reverse reaction) are happening at the same rate. This makes the system appear static, but in fact it's forever changing, but since the rates are the same, it remains steady. This might happen with too much sugar in your coffee. Sugar continues to dissolve into solution, but since this coffee can only hold a certain amount of sugar due to its volume and temperature, the excess sugar continues to precipitate out of the coffee too. The rate of solvation equals the rate of precipitation. This is an ever-changing situation, but the amount of sugar in and out of solution remains steady.

Like dissolves like - a chemistry adage (look that up!) indicating that solvents that are polar (like water is) can only dissolve polar molecules or ions. Oil, being nonpolar cannot dissolve into polar water. Nonpolar oil can dissolve easily into gasoline, which is also non-polar. Like dissolves like.

Concentration - the measure of the strength of a solution, how much solute per given volume. Several ways to do this exist in chemistry.

Molarity - one way to measure concentration of a solution; molarity = the number of moles of solute divided by the liters of solution. (no substitutions here, if you have grams you must convert them into moles. If you have milliliters, or even quarts, you must convert to liters. Do the math, use your units.

Parts per million - a different way to measure concentration, usually when it's very, very low (but important). PPM = grams of solute divided by grams of solution multiplied by one million. Sometimes very low concentrations of substances can be harmful, such as lead in drinking water. Tiny amounts, which might have crazy small decimal molarity are “easier” to deal with in PPM.

Dilution - by adding more solvent to a solution, you make it weaker, have a lower molarity or a smaller PPM. This is called dilution.

Dilution formula - to determine how much stock solution you will need to create a secondary solution you'd use the dilution formula. The variable is always volume of stock solution. Once calculated, put that amount of stock solution in a beaker, fill to the volume of new solution you desire, and your work is done. The formula is $M_1V_1 = M_2V_2$ where M stands for molarity, V for volume. The number 1 refers to the stock solution, 2 is the new solution you wish to form. New solutions (in high school) are always more dilute than the stock solution.

Boiling point elevation - how much the BP of water (or any solution) goes up due to the addition of solute. For water, the BP elevation is 0.50 K per liter per mole of particles.

Freezing point depression - how much the FP of water (or any solution) drops, due to the addition of solute. For water, the FP depression is 1.86 K per liter per mole of particles.

Vapor pressure adjustment - the more solute that dissolves into water (or any solution) the lower the vapor pressure will be. Vapor pressure is a measure of evaporation rate. Evaporation is diminished when the water is now also attracted to the particles dissolved in it, in addition to all of the hydrogen bonds it already has. In our class we will do no math on this, but the more particles dissolved, the lower the vapor pressure becomes.

Electrolyte - when an ionic compound dissolves into water, the water ends up with loose ions dissolved into it. These loose ions allow the solution to conduct electricity. An electrolyte is an ionic solution, and it conducts electricity. An electrolyte is also an ionic compound that would dissolve in water and therefore would conduct electricity that way. Solid ionic compounds cannot conduct electricity, but might still be electrolytes if they are soluble in water.

Stock solution - the original solution you have on hand (literally, in stock) that you could use to dilute into a weaker solution, if you wanted to

Miscible - vocabulary word that means that two liquids can dissolve into each other (like dissolves like)

Immiscible - vocabulary word that means that 2 liquids cannot dissolve into each other, like oil and water, because like dissolves like!

Rate of solvation - how fast solute dissolves into solvent, affected by temperature (hotter usually means dissolves faster), particle surface area (more surface area means more collisions between solute and solvent, which means faster dissolving), and agitation (or stirring, again, stirring means more particle movement, so faster dissolving).

Kinetics - the part of chemistry that is about the rate of chemical reactions

Equilibrium - when a system is in balance, not stopped, but rather the rate of the forward reaction is equal to the rate of the reverse reaction. Sometimes this is called dynamic equilibrium (same thing)

Reactants - the stuff in a chemical reaction that you start out with

Products - the stuff in a chemical reaction that you end up with

Rate of a chemical reaction - how fast a chemical reaction happens (most are really quick, but measurable)

4 Factors that affect rate of reactions - Three different ways will affect collisions between particles (more collisions = faster reactions), they are temperature (hotter = faster), particle size or surface area (more surface area = more collisions possible between reactants = faster) and increasing concentration of reactants (higher concentration means more particles dissolved per liter = more collisions = faster). The fourth way to speed up reactions is to use a catalyst, but that does NOT impact collisions, rather it lowers the activation energy and/or opens a different pathway for the reaction to proceed that will be quicker because it's less energy required.

Potential energy diagram - shows the energy of the reactants, the energy required to start this reaction, and the energy of the products. It also shows the difference in energy between reactants and products, which is the ΔH for the reaction. There are only 2 kinds, exothermic and endothermic.

Activation energy - the energy required to start a chemical reaction. On a PE diagram (just above) it's the amount of kilo-Joules from the starting point of the reactants to the top of the curve.

Activated complex - the vocabulary word that describes the “in-between” point of a chemical reaction; once sufficient energy is provided to the reactants, they come apart, but the products have not quite formed. This lasts micro-seconds, but what exists in this moment are not reactants or products, rather the “activated-complex exists. On a PE diagram, this sits atop the top of the curve.

PE of reactants - all reactants have potential energy, based upon what they are, this is the starting energy point of a potential energy diagram (PE diagram)

PE of products - the energy that the products have at the end of the reaction, or on the right side of the PE diagram curve. If the products have less energy than the reactants started with, the “missing” energy was released and the reaction was exothermic. If the graph goes “uphill” and the products have more PE than the reactants, this energy gain was garnered through an endothermic process (absorbing energy from immediate surroundings)

ΔH - the difference between the PE of reactants and the PE of products. On a graph the + or - of ΔH is clear.

Catalyst - any substance that when added to a chemical reaction allows this reaction to proceed faster, but without changing it in ANY OTHER way. Same energy absorbed or released (ΔH constant), same products, same amounts, etc. It does this in either of 2 ways: lowering the activation energy required, or by opening up a different pathway for the reaction to proceed that is quicker because it takes less energy that way.

Dynamic equilibrium - when the rate of the forward reaction equals the rate of the reverse. Constantly changing while constantly staying the same.

LeChatleier's Principle - a famous adage: a system in dynamic equilibrium will stay in dynamic equilibrium, but when chemically stressed, this equilibrium will shift to create a new dynamic equilibrium. You can stress a chemical system by adding or removing reactants, or products, or energy, or by changing pressure on gases in the reaction.

Shift forward - a system in dynamic equilibrium might “shift” forward to accommodate a specific chemical stress placed upon this system. This would mean that once shifted there would be more “products” and “less reactants” but that a new dynamic equilibrium would form.

Shift reverse - same as shift forward, but some stresses “favor” the reverse reaction, creating a new equilibrium with different amounts of products and reactants, until a new balance is created. These shifts are in reaction to a chemical stress, and are temporary. The rate of the forward and the rate of the reverse reactions always gets back into a balance, not necessarily the original one, but a new one.

Entropy - in our course, the measure of chaos in a system. It's a vocabulary word here, without units.

Chaos - disorder. For example, solids are more orderly than liquids, gases are most disordered and have the most “chaos”. Cooler solutions have less chaos than hotter ones, as cooler solutions have lower KE and the particles are not moving as fast.

Clock reaction - in kinetics chemistry, a reaction that is slow enough to time with a stopwatch, and by changing conditions (say temperature or concentration) you could measure the impact of these on the rate of reaction. We do a Clock Lab in our course and it's great!

Collision theory - theory that says that chemical reactions occur when sufficient collisions between the reactant particles occurs. Faster collisions leads to faster reactions. Fewer collisions slow reactions down.

Acid - a compound in chemistry that creates a solution that would have an excess of H^{+1} ions in solution (for most acids, some other acids exist). Generally the more H^{+1} ions in solution the stronger the acid.

Base - a compound in chemistry that creates a solution with an excess of OH^{-1} ions in solution (for most bases, but some others exist). Generally, the more OH^{-1} ions in solution, the stronger the base

Arrhenius - Svante Arrhenius was a Swedish chemist who won the Nobel Prize for his work in acids and bases

Arrhenius acid - an acid with excess H^{+1} ions in solution

Arrhenius base - an base with excess OH^{-1} ions in solution

Dissociates - when ionic compounds, or a molecular compound with hydrogen, dissolves into water, it will also come apart into ions. If a compound creates ions in solution, it is said to have dissociated apart.

Ionizes - another word for dissociation, since the compounds break up into ions, this is an easy word to “get”

Hydrogen ion - hydrogen bonds to chlorine in a covalent way, but once in water this will ionize into the H^{+1} cation and a Cl^{-1} anion. Hydrogen is weird, it bonds covalently, it's nonmetal, but in water it “unbonds” like a group one metal, into a +1 cation. A whole branch of chemistry is arranged around this odd circumstance, it's called acid/base chemistry.

Concentration of hydrogen ions - the molarity of hydrogen ions in solution can be measured to tell the strength of an acid. Acids can have molarity, or can be measured on the pH scale

pH scale - a way to measure the strength of a solution as acid or base, or not either. A pH of 7 is neutral, neither acidic or basic. A pH below 7 is an acid, and a pH above 7 is a base. The scale runs 0-14.

$pH = -\log[H^{+1}]$ in math the pH scale is a negative logarithm scale of the number of moles of hydrogen ions per liter in a solution. We don't do the math with this, but you should be able to look at this formula without tearing up and being nervous.

Alternate theory - there are several other acid base theories that are not Arrhenius' theory. In our class we'll learn one, which is usually called just an alternate theory but is really the Bronsted-Lowry theory, named for 2 different scientists who developed it independently of each other. It's either a vocabulary word, or it's about why ammonia is a base even though it apparently has no hydroxide ions present.

Bronsted-Lowry theory - a theory that states if a compound can accept a H^{+1} ion into itself, it's a base.

In addition, if a compound can donate this H^{+1} ion, then it's an acid. See below, ammonia is a base.

Ammonia as a base - when ammonia NH_3 is put into water, it forms the ammonium ion NH_4^{+1} , the ammonia accepted a H^{+1} ion. Therefore ammonia is a base. Strangely, this H^{+1} ion came from a molecule of water, the H_2O is able to come apart into an H^{+1} ion and an OH^{-1} ion. Since water donated this H^{+1} ion to the ammonia, water (in this case) is an acid. Of course the “reason” that ammonia acts like a base in solution is because of that left over OH^{-1} floating in the water.

$NH_{3(G)} + HOH_{(L)} \rightarrow NH_{4^{+1}(AQ)} + OH^{-1}(AQ)$ in this reaction ammonia accepts an H^{+1} ion, it's a base. Since water donated this H^{+1} ion, water is an acid. That last part, the OH^{-1} ion provides the real reason that aqueous ammonia is a base.

HOH - a different way to write H_2O , which is sometimes easier to see in acid base chemical reactions

Neutral - solutions that are not acidic or basic are said to be neutral. Neutral solutions can have NO ions, or equal numbers of H^{+1} and OH^{-1} ions. There are two different ways for solutions to be neutral.

Neutralization - the process of combining exactly enough acid to base to balance out the ions, making for a neutral solution. This requires either a fair amount of math before mixing, or a titration process

Titration - a lab process where you carefully measure in an exact quantity of base to acid to neutralize it, or the exact amount of acid into a base to neutralize it. We'll do a titration lab, we use burettes - long thin tubes with lots of mL lines, and also use an acid base indicator to show us with color when we "get to neutral" and stop dripping solutions together (so we can measure and do math with our measurements) to figure out the strength of solution we were given as an unknown. It's fun too.

Acid base indicators - there are literally hundreds of chemicals and naturally occurring substances that will change color, depending upon the pH of a solution. Different indicators indicate what pH a solution is close to. They are not always exact, more often they show ranges of pH. Cabbage juice (gross as it sounds, it smells worse) is a great naturally occurring acid base indicator, and sometimes we can get 14 different colors for 14 different pH solutions.

Hydronium ion (the dumbest thing all year in my opinion) - in some theories an excess of H^{+1} ions in solution makes for an acid. Some people don't like to "think" about hydrogen ions in solution, they like to think that the H^{+1} ions combine with a water molecule this way: $H^{+1} + H_2O \rightarrow H_3O^{+1}$ ions. I think that this is by far the craziest thing I ever heard of. I don't know why you have to learn this, but here it is, memorize it.

Organic chemistry - a long time ago, in a galaxy far, far away, chemists thought some compounds could only be formed by living organisms because they (the chemists) were not smart enough to do it yet. Then one day someone figured out how to synthesize urea (go figure!). Now we lump compounds that center on carbon as "organic" compounds, but scientists can make all of them without living organisms helping them.

Carbon - the central atom in all organic compounds. In high school, if the first atom is carbon in the formula, it's organic. An easy rule to remember.

Hydrocarbon - a compound made up of carbon and hydrogen only

Alkane - a simple hydrocarbon where the carbon atoms are only single bonded to each other (except for methane, CH_4 , which only has one carbon atom in total)

Alkene - a simple hydrocarbon but has at least one $C=C$ double bond in the chain. In our course these chained hydrocarbons will only have ONE $C=C$ bond, although multiple double bonds are possible.

Alkyne - a simple hydrocarbon but has at least one $C\equiv C$ triple bond in the chain. In our course these chained hydrocarbons will only have ONE $C\equiv C$ bond, although multiple triple bonds are possible.

Functional group - organic molecules that are made up of more than just carbon and hydrogen can have oxygen atoms, halogen atoms, nitrogen atoms, and other "funky" little groups of atoms bonded to the chains of hydrocarbon. This extra fun stuff are called the functional groups, as they add extra "function" or properties to the compounds. They're in table "R" on your reference tables.

Organic prefixes for carbon - hydrocarbon chains in our class can be single links (one carbon) up to 10 carbons linked together. We use prefixes to name the lengths of these chains, on Table P, they are: meth, eth, prop, but, pent, hex, hept, oct, non, and dec.

Condensed structural formulas - sometimes with chained hydrocarbons, with or without functional groups, a simple chemical formula, say C_5H_{10} does not indicate "where" the double bond would be. It could be between carbon atoms 1 + 2, or 2 + 3. A condensed structural formula shows how the atoms bond together, so you can determine where this bond is. For a 1-pentene it would be $CH_2CHCH_2CH_2CH_3$, but for a 2-pentene the formula would be $CH_3CHCHCH_2CH_3$. Both have five carbon atoms and ten hydrogen atoms, but these are two slightly different compounds with different names. A condensed structural formula allows you to "build" it in a drawing quickly to "see" where the special bonds, or functional groups really are.

Halocarbons (halide) - a functional group that would include one or more of the group 17 halide atoms into an organic compound.

Alcohols - these can be a bit tricky as the alcohol functional group is the $-OH$ group. That has an oxygen atom bonded to one hydrogen atom, and that group is bonded to a carbon. It might appear to some neophyte chemists as a "hydroxide" which is a polyatomic anion (OH^{-1}), also made up of one oxygen and one hydrogen but also an extra electron and it's an ion. Alcohol groups are not ionic, and are in organic MOLECULES, not in ionic compounds. Don't get tricked by this. There are 1000's of organic alcohol molecules, but only one is in drinks you can buy in stores when you are 21, these contain ethanol. Other alcohols will likely destroy your liver and cause you to die a miserable death.

Ethers - really cool molecules that have a single oxygen atom sort of "inside" a chain of hydrocarbons. It is sometimes referred to as "an oxygen bridge" between 2 hydrocarbon chains.

Ketones - this has a single oxygen atom that is bonded to one carbon atom in a chain, but it is in the middle of a chain, not at the end of a chain of carbon atoms bonded together. If this oxygen atom were ever at the END OF THE CHAIN, it would be an aldehyde!

Aldehydes - similar to ketones (and easy to mix up) but this molecule has a single oxygen atom bonded to a chain of hydrocarbons, but is ALWAYS AT THE END of the chain, never in the middle. If it were in the middle of the chain, it would be a ketone!

Organic acids - acids in organic chem have a group that is called the $-COOH$ group, and has one carbon atom double bonded to an oxygen atom PLUS that carbon is also bonded to $-OH$. The carbon makes it's 4th bond to the chain. Acid groups in our course are always at the END of a chain. Don't get fooled ever to think that an alcohol group plus an aldehyde are bunched up together. The general rule is go big, two functional groups will NOT bunch up for you in high school chem ever.

Esters - are my favorites, and smell the best (or worst!). Look for a $-COO$ group in the middle of a chain, with that carbon atom double bonded to one oxygen atom, and single bonded to the next one. Both the original carbon, and the second oxygen atom bond to other carbons in the chain to make the molecule. To make an ester, an alcohol molecule reacts with an organic acid, both "open up" and when HOH (water) comes out, it makes room for the rest of these two molecules to bond together. Esterification is sometimes called "dehydration synthesis" as the removal of water allows the ester to bond.

Amines - amines have 1 atom of nitrogen plus 2 hydrogen atoms ($-\text{NH}_2$) attached to the hydrocarbon chain anywhere you feel like omitting a hydrogen atom. It makes a single bond to any carbon in the chain.

Amides - also have a single nitrogen atom and two hydrogen atoms, but these are ALWAYS bonded to a carbon atom that has an oxygen atom double bonded to it. That put this ($-\text{CONH}_2$) group on the END of a chain.

Methyl group - sometimes you add in what looks like methane (CH_4) as a functional group, but since that compound already makes all the bonds it needs, you can't attach it. Only by removing ONE HYDROGEN ATOM would you be able to bond it in. Methane is CH_4 , a METHYL group is $-\text{CH}_3$, allowing the carbon one more bond which it makes to another carbon in a hydrocarbon chain.

Ethyl group - when a 2 carbon group (like a methyl group but 2 carbons long) acts like a function group, the group is $-\text{CH}_2\text{CH}_3$ that first carbon only makes 3 bonds, so it can readily make a bond to another carbon in a hydrocarbon chain.

Propyl group - when a 3 carbon group (like an ethyl group but 3 carbons long) acts like a function group, the group is $-\text{CH}_2\text{CH}_2\text{CH}_3$ that first carbon only makes 3 bonds, so it can readily make a bond to another carbon in a hydrocarbon chain.

Other "alkyl" groups - a smaller chain of any length can be added to a longer chain. In size order, they'd be methyl, ethyl, propyl (all above), then butyl, pentyl, hexyl, heptyl, octyl, nonyl, and decyl. In our course the longest chain you need to name is a 10 carbon chain, so you will not see a decyl group.

Substitution reaction - when you might attempt to bond a halogen atom to an alkane chain hydrocarbon, that hydrocarbon is "full" and has no room to squeeze in an atom of F, Cl, Br, or I. What happens is ONE hydrogen atom gets bumped out, and one of the diatomic halogen atoms takes its place. The "extra" halogen atom bonds to the newly "loose" hydrogen atom. This let a halogen "SUBSTITUTE" itself into the molecule, you did NOT ADD IT to the molecule.

There are two products (halocarbon plus something like HCl, or HF)

Addition reaction - when you attempt to bond a halogen atom to an alkene or to an alkyne, the double or triple bond will open up 2 spots, letting you ADD IN both atoms of a diatomic halogen, or hydrogen molecule. For example: ethene and H_2 becomes ethane, ethene and Cl_2 become CH_2CHCl_2 (1,2 dichloroethane). Two reactants are ADDED together to become ONE PRODUCT. If you start with ethyne plus Br_2 , you end up with CHBrCHBr or 1,2 dibromoethene (here the triple bond becomes a double bond, allowing both atoms of bromine to be added into the product).

Esterification reaction - esters form when an alcohol molecule bonds with an organic acid. There are no openings in either molecule, all have bonded to the fullest, so the way they make this opening to bond together is weird. From the acid, part of the $-\text{COOH}$ group comes off, the $-\text{OH}$ part, and that opening in the acid would allow the alcohol to bond it had an opening. The alcohol pops off a hydrogen atom, and this $-\text{H}$ bonds to the $-\text{OH}$ from the acid to make water. The two open spots then bond together, creating a $-\text{COO}$ functional group. This is sometimes called dehydration synthesis as water must be removed to allow the 2 molecules to form one new ester. STRANGELY, the acid loses what might appear to be a base ion - hydroxide, but it does not! The $-\text{OH}$ that comes off of the acid group are 2 atoms but NOT an ion. The $-\text{H}$ atom that pops off of the alcohol IS NOT a H^{+1} ion, and this is NOT IONIC in any way.

Polymerization - plastics are called polymers; poly means many, while “mer” stands for body or unit. A plastic molecule, or polymer, is made up of long strands of hydrocarbon, or hydrocarbons with functional groups. They have no actual formulas as the chains they form are of various lengths. The “mers” have a formula, and they string together in multiples, of all different lengths. Maybe you can understand this as pasta ziti macaroni. If you have a bowlful of ziti tubes, they could represent the “mer” units. Each is the same size, each would have the “same formula”. A catalyst will be able to open these molecules up, by removing some atoms, so that each molecule can bond to the next, forming a chain. You’d end up with really long tubes of ziti’s, some 2 feet long, some three feet, some in between. The polymers are strands of the original molecules chained together, and then often tangled up into solids. There are 1000’s of kinds of polymers, soft, crackly, hard, clear, colored, brittle, flexible, etc. I even have a rectangular chunk of polymer that lets me buy food at Wegmans, it’s called a credit card, and it’s made up of one type of polymer (the best kind too!)

Fermentation - man has known this chemical reaction for thousands of years, it’s the process that allows sugars (or chains of sugars called carbohydrates) to be processed by yeast cells into waste products called ethanol alcohol and carbon dioxide. Imagine (if you can) grape juice and yeast into a corked bottle, and stored in the basement under reasonable conditions. After a while the juice is gone, and you have champagne - carbonated wine. Using different sugars or carbohydrates, and different conditions, you can make beer, wine, vodka, whiskey, etc. All different flavors, all fermented by people using yeast. Some of these adult beverages have the bubbles (CO_2 is a waste product of the yeast’s anaerobic life), some beverages allow this gas to go into the air (most liquors have no carbonation). Do not drink alcoholic beverages until you are old enough to do so, and then only in moderation. Morals, and health aside, this is an organic chemical reaction.

Saponification - if you ever misspell this one, and put the first 4 letters in a new order, say: SOAP, it will remind you that this reaction produces soap. There are many kinds of soap, some for your face, some for your car, some for taking grease off of a mechanic’s hands, some for clothes, some even says it will make you look younger! Soap is made by adding together fats to bases, and you end up with a triple alcohol and a “soap” which is the weirdest molecule in our class. It’s organic with carbon, it’s molecular too, but it has a ion in it as well. That, plus you’ll have a remarkably hard time naming any of the reactants or products because they are too big and we only cover simple organic molecule naming. That makes this “reaction” the easiest to recognize. If you can’t name any molecule you see, it’s likely saponification. Additions of scent make soap a wonderful experience. I suggest you try it at least 2x per day if you are not already doing so.

Amino acids - this is not part of our class, but when an amine group is attached to the same molecule with an organic acid, an amino acid forms. Of course thousands of combinations are possible, there are a limited number of them in any type of organism. You won’t have to name them, but this is not hard to grasp, nor hard to recognize. It’s the only organic molecule you might see with 2 functional groups in one molecule.

Isomers - the third funky vocab word (add to allotrope and isotope) this means that for many middle sized to big sized organic molecules you can “take them apart” and bond them together in a different way, they have the same chemical formula, but with a different organization they will be different molecules or even different types of molecules. For example, dimethyl ether, CH_3OCH_3 has a chemical formula of $\text{C}_2\text{H}_6\text{O}$. If you rearranged these atoms into $\text{CH}_3\text{CH}_2\text{OH}$ you get ethanol alcohol, but with the same $\text{C}_2\text{H}_6\text{O}$ combination of atoms. These 2 compounds are isomers of each other. They have the SAME MOLAR MASS, and the SAME percent comp by mass, but they are NOT THE SAME. It’s almost like making a Lego toy plane, then taking it apart and forming those pieces into a boat. The same number of pieces, but bonded together differently. Same mass, different properties. It’s because of these isomers that we bother with condensed structural formulas. The simple chemical formulas do not tell us “HOW” the molecules are built, therefore what they might be.

Ring hydrocarbons - chains of hydrocarbons end, and at the end are hydrogen atoms. If a chain is physically long enough, and you remove a hydrogen atom from each end, the ends can connect together, forming a ring of some size. Three carbon atom chain rings exist, as do larger ones. They get a “cyclo” name in front of them and always have fewer hydrogen atoms than the “non-cyclo” hydrocarbon molecules. For example. Pentane is C_5H_{12} . Cyclopentane has 5 carbon atoms, single bonded together, but in a ring. The only way the end carbon atoms can bond together is if they each lose one hydrogen atom. This lets a ring form, with the formula C_5H_{10} . It’s called cyclopentane, five carbon atom hydrocarbon, single bonds only, in a ring form. But C_5H_{10} is the formula for pentene (1-pentene or 2-pentene, not just pentene) and “should” have a double bond. This cyclopentane has no double bond, but because it bonds to itself in a ring, it has 2 less hydrogen atoms than pentane normally has. Tricky business. (again, another reason that condensed structural formulas are important, C_5H_{10} can be bonded together in different ways - isomers)

Redox - this is part of chemistry that pertains to electrochemistry, the study of batteries and electroplating. It sounds better than Oxred, but that name could work too!

Oxidation - the chemical process that means to lose electrons (it used to mean gaining an oxygen atom which could only occur if a molecule lost an electron to let this oxygen bond in). Old names die slow deaths, it’s not really about oxygen anymore, but it’s a name.

Reduction - the opposite of oxidation, the process of gaining electrons. Oxidation and reduction must exactly match for a reaction to occur. The number of electrons lost (transferred) must equal the number of electrons gained. Controlling where these electrons go in between could let a chemist have moving electrons, which is electricity and how batteries actually make electricity. The electricity is produced by the loss of electrons, running these electrons through a flashlight bulb, before allowing something else in the battery to gain the electrons to complete the redox. The electrons can “do some work” on their way to being gained.

Half reaction - oxidation cannot occur without reduction. Each is considered to be a half reaction. The oxidation half reaction is balanced by the reduction half reaction. In the oxidation half reaction the electrons are oxidized or released. In the reduction half reaction, these exact electrons are gained. Together the two half reactions combine into a whole redox reaction.

Oxidation numbers - selected oxidation states, or ion charges, all on the periodic tables. When the numbers change in a chemical reaction, you can determine what species was oxidized, what was reduced. For example: when sodium and chlorine make sodium chloride, it looks like this: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$ if we added in the oxidation numbers it would appear this way: $2\text{Na}^{\circ} + \text{Cl}_2^{\circ} \rightarrow 2\text{Na}^{+1}\text{Cl}^{-1}$ this shows neutral sodium atoms combine to neutral chlorine, and form ionic sodium ions that are bonded to chloride ions. The sodium goes from neutral to positive (it lost electrons, the Na was oxidized) while the chlorine goes from neutral to negative (it gained electrons, it was reduced). The oxidation half reaction is $2\text{Na}^{\circ} \rightarrow 2\text{Na}^{+1} + 2\text{e}^{-}$ the reduction half reaction is this: $\text{Cl}_2^{\circ} + 2\text{e}^{-} \rightarrow 2\text{Cl}^{-1}$ two electrons “lost” and two are gained. The half reactions are equal and opposite.

Voltaic cell - a chemical set up that allows one to separate the oxidation and reduction half reactions, and the electrons flow in a wire between these 2 half reactions, able to do work on the way. It's a chemistry vocab word for battery. Batteries are technologically fancy little packages that hold separate redox reaction apart, until you flip the switch, and let this spontaneous reaction to proceed (and make your light or toy go). Here chemistry makes electricity.

Electrolytic cell - a nonspontaneous redox reaction that uses electricity to make a chemical reaction occur that would not otherwise happen from an energy point of view. Here, electricity makes chemistry.

LEO the Lion goes GER - an acronym to help you remember that Loss of Electrons is Oxidation, but that the Gain of Electrons is Reduction

Leo is a RED CAT - another acronym to remind you that REDUCTION only happens at the CATHODE in electrochemistry. Anodes oxidize electrons, reduction happens on the cathode side of the diagram or in the battery.

Relative oxidation numbers - also called selected oxidation states. We can assign these to all compounds and elements. Elements are all zero/neutral. Ionic compounds all have ion charges. Molecular compounds all have oxidation numbers as well. As we view the relative oxidation numbers across the arrow in a chemical reaction, if these numbers change, this reaction is also REDOX. If these numbers don't change, it's not a redox reaction.

Net ionic equation - in redox, if you combine the two half reactions, and cancel out the electrons on both sides of the arrow, you can form a single “net” reaction. It does not show the electrons, which science hopes you are smart enough to keep in your mind. From above the half reactions for the formation of sodium chloride are: $2\text{Na}^{\circ} \rightarrow 2\text{Na}^{+1} + 2\text{e}^{-}$ and $\text{Cl}_2^{\circ} + 2\text{e}^{-} \rightarrow 2\text{Cl}^{-1}$ combine them into this net ionic equation: $2\text{Na}^{\circ} + \text{Cl}_2^{\circ} \rightarrow 2\text{Na}^{+1} + 2\text{Cl}^{-1}$

Spontaneous reactions - reactions that occur without being forced to by the addition of energy. Most chemical reactions that you are familiar with are spontaneous. Nonspontaneous reactions are seen in electroplating redox. Or they are reactions that have a “too high” activation energy to be easily reversed. All reactions can be reversed, some just take a lot more energy to do that.

3 reasons that all batteries die - all voltaic cells, or batteries die for the same three reasons. They run out of anode (which stops the electrons that make the electricity), they run out of “cathode side cations” which get reduced by gaining the electrons that were oxidized, or they run out of the salt solution, which provides ions to keep the oxidation side and the reduction side of this battery (voltaic cell) electrically neutral while losing and gaining electrons all the while it runs. It can't run out of cathode!

Electroplating - using electricity to make a nonspontaneous redox reaction to occur. This relatively simple process allows scientists and artists to reduce ions of precious metals like gold, silver, etc. to be reduced into atoms, and cover what are called “base metals” which are strong but not “pretty”. No one wants an iron fork, but if you could plate silver on top of the iron: the iron would not rust and be too ugly for your mouth, the iron is super strong, so your fork would work on meat, the silver is pretty and very unreactive, so your fork would be pretty for a long time, and the amount of silver makes plated silver less expensive than solid silver. Solid silver would be too soft anyway, you’d end up with pretty but bent forks! To do this, you use an electrochemical cell to make the reaction happen.

Nonspontaneous reactions - reactions that require energy (electricity) to happen. Often seen in electrochemical cells for electroplating.

Nuclear chemistry - the part of chemistry that is especially unusual as it’s NOT about electrons, it’s about the nucleus (hence the name, nuclear!)

Radioisotope - isotopes are chemically identical atoms with a varied number of neutrons, and therefore a different mass. Most isotopes (about 1200 of 1500 in total) are stable and you’d probably never notice them. About 300 of all isotopes have such a weird ratio of neutrons to protons that they are unstable as they exist, so they emit parts of themselves (parts of their nucleus). This emission is radiation. An unstable isotope that emits radiation is called a radio-isotope. Stable isotopes are just called isotopes.

Stable nucleus - most isotopes have a stable ratio of neutrons to protons in the nucleus, they have stable nuclei. There is a pattern of what is stable in a nucleus, and what ratios fall outside this stable proportion. Smaller atoms have close to a 1:1 neutron to proton ratio, as atoms get larger, the stable ratio changes to 1.2 neutrons to 1 proton. As atoms get bigger still, the stable ratio is closer to 1.5 neutrons to 1 proton. Any atoms that have ratios outside this “band of stability” are radioisotopes and unstable.

Band of stability - on the neutron to proton graph, the area of atoms that are not radioisotopes (and unstable) are outside this “band of stability”. This is just a graph that shows which ratios of neutrons to protons are stable or not stable.

Radiation - any emission by a radioisotope, be it energy or particles or both, that it emits in an attempt to change it’s ratio of neutrons to protons to be more stable. All radiation is very unhealthy for humans and most animals and plants. Some natural radiation, and some very low exposure is normal, but less is much better than some.

Radioactive particles - table O showcases some radiation particles, which include alpha particles, or beta particles, and positron particles. Sometimes atoms can emit protons or neutrons directly as well. Any particle that is emitted by a nucleus is radioactive.

Radioactive energy - sometimes pure energy is released with or without radioactive particles, gamma radiation is one listed for you on table O. It’s highly energized and will disrupt your cells, killing them outright, or possibly damaging them, which can lead to them changing into cancer cells.

Alpha particles - the weakest radiation, made up of 2 protons and 2 neutrons (like a helium atom nucleus). Mass of 4 amu, and weakest penetrating power of all. Your skin can block it, but your wet parts (mouth, eyes) can let it in. If you eat it, or get it via eyes or mouth, you can die a terribly painful death.

Beta particles - this radiation is similar to an electron, near massless with a negative charge (but not a “normal” electron, it arises from a nucleus) it has much stronger penetrating power and can either harm you terribly, or is used in radiation therapies to kill tumors (aim carefully, kill the tumor cells, try to kill as few other healthy cells in the process). Sort of a crazy plan medically but very effective at times.

Gamma radiation - most powerful penetration, hard to ever hide from, will kill you outright or will potentially cause cancer in smaller doses. Avoid at all costs. This is pure energy, no particles here.

Positron particles - super odd, like an electron (near massless) but with a positive charge. Bad for you too.

Penetrating power - the ability to get through stuff, especially if you’re radiation. In strength order (and order of the Greek alphabet) alpha particles are weakest, then beta, then gamma is the strongest.

Half life - another super odd thing; radioisotopes all emit radiation at a specific rate, all are different from each other. All are uncontrolled by humans, and occur like clocks on a very specific schedule. The time it takes for one half of a sample to emit radiation (and change into some other isotope) is called it’s half life. A half life can be milliseconds long (happens super fast), or it can take billions of years. These half lives have been measured accurately, and cannot be speeded up or slowed down in any way. If you could speed it up, you’d certainly win a Nobel Prize and become as rich as Bill Gates. Get busy learning or get busy getting old. Your choice.

Decay - when a radioisotope emits radiation from it’s nucleus to attempt to become more stable, it changes into a different isotope as it changes the ratio of neutrons to protons in its nucleus. This process has several names, it can be said that radioisotopes decay, or undergo radioactive decay by emitting radiation.

Spontaneous decay - this decay, or radioactive emission, happens spontaneously. If it happens that way, it’s called spontaneous decay. Sometimes scientists can shoot beams of neutrons or other particles at various isotopes to encourage it to decay in a different way, that would be nonspontaneous.

Transmutation - when an isotope emits radiation, it decays into some other isotope. This is also called transmutation. An atom starts out as one atom, then emits radiation and “transmutes” into a different type of atom. This can be called transmutation.

Decay mode - various isotopes emit different kinds of radiation in their process to get stable. If they emit alpha particles it therefore has an alpha decay mode. If it were to emit beta particles instead, that isotope would have a beta decay mode. Decay mode means what sort of radioactive decay does this isotope undergo. Many isotopes must go through several steps, or several decay modes before they get stable. These modes are clearly outlined and known.

Natural transmutation - when isotopes undergo their particular decay mode and become different isotopes in their quest towards stability, this occurs without assistance by humans. This is called natural transmutation as it occurs “naturally”.

Artificial transmutation - if scientists shoot beams of energy or particles at isotopes to force them to undergo a transmutation that they would not have done, this is called artificial transmutation. It occurs often in nuclear bombs and in nuclear reactors too. The unstable isotopes end up transmuting, but not in the way that they might have done so without this “encouragement” by scientists.

Fission reaction - a type of nuclear reaction that scientists created that “splits” atoms. A larger isotope is shot with (usually) neutrons. When these neutrons are absorbed into the nucleus they crash into, this new nucleus is made unstable, and it will soon split into two or more smaller atoms, releasing more neutrons and energy. This small energy emission and small number of neutrons then crash into more isotopes, doubling or tripling the effect, and then it multiplies again and again. A single split atom can encourage more and more atoms to split, releasing more and more energy. A chain reaction starts, one that grows and grows, and keeps going until there is no more isotope to split. These reactions can sometimes be controlled in a nuclear reactor, and make enough energy to electrify a city, or be totally out of control as with a nuclear bomb exploding. In this reaction there is a slight loss of mass (break the law of conservation of matter!) and this small amount of mass converted into huge amount of energy. (huge!)

Fusion reaction - this reaction is another nuclear reaction, but smaller isotopes are crushed together and form larger atoms. There is also a small loss of mass in this type of nuclear reaction (not chemical reaction, nuclear reaction!) and crazy amounts of energy is released. These can be 1000's of times stronger reactions than fission. These cannot be controlled in anyway. The Sun undergoes fusion, and humans have made fusion bombs, which are many times stronger (worse?) than fission bombs.

Chain reaction - a reaction that starts small but grows as it proceeds. Nuclear reactions are chain reactions

$E = mc^2$ - this small equation, which you have all seen before, is one of the craziest places in our class for me.

Here I will try to explain to you what only a few people in the world can actually understand in a way that is true. Albert Einstein wrote this a long time ago, and the letters stand for Energy equals the Mass of matter times a constant called the SPEED OF LIGHT squared. Thus, a very small mass, multiplied by a huge, constant number (squared) equals a lot of energy. Matter can be converted into energy during a nuclear reaction. The Law of Conservation of Matter applies only to chemical reaction, not nuclear reactions. Energy = matter is the most important part of this, think hard now, a small bit of stuff can be converted into huge amounts of energy, the mass transmutes into pure energy. How? How the heck do I know?! This stuff will keep you up at night! But it does.

Simple fusion - humans have been able to make fusion happen by crushing radioactive hydrogen isotopes tighter (H-2 deuterium, and H-3 tritium) together, by putting them inside a nuclear fission bomb, and they crushed form into helium. On the Sun, because the pressure and temperatures in the middle of the Sun, “normal” hydrogen atoms can be squashed into helium, releasing crazy amounts of energy.

Fusion on the Sun - due to much great pressure and temperature, normal isotopes of hydrogen can be fused into helium. On Earth, scientists must use larger isotopes of hydrogen to fuse into helium.

Nuclear power plant - a controlled nuclear reaction, in that the chain reaction mechanism is not allowed to get out of control, scientists can absorb neutrons, so that the reaction can proceed, but not get too big. This allows scientists to release a controlled amount of heat at any time. This heat super boils water into steam, steam is pumped under high pressure through a turbine, to produce electricity, and then the steam is condensed, and reboiled and the process repeats. When working well, only excess heat and electricity are emitted from a power plant (plus the radioactive spent fuel, but not all of the time)

Power plant wastes - heat is a byproduct of a nuclear power plant. The super heated steam that turns a turbine must be condensed back to water so that it can absorb as much energy from the reactor core as possible, to make as much electricity as possible. This heat is conducted into clean water that is brought in via a large lake or an ocean, then is pumped into the lake or ocean. This disrupts the local ecosystems, but fish don't vote and this is relatively minor. Spent fuel is a bigger problem as there is no place to keep it safe, to make it less radioactive, or less radioactive faster (Noble prize right there!), or protect it from bad guys who'd like to use it to make a dirty bomb (below). It can't be safely transported or put anywhere, or shot into space, so for now, it sits in cooling tanks (think big swimming pools) waiting for you to figure this out (really). In the meantime, it's kind of okay, but was NOT in Fukushima, Japan a few years back. This is really a big problem with nuclear power plants that is completely not figured out yet.

Nuclear bomb - a device used by some people to explode in a very big way, to kill and destroy large areas all at once. These can be a deterrent to war, or can kill many people (mostly innocents) all at once. This is a moral situation that we will not figure out, and you should give it some thought. Remember to keep thinking in your life, you will likely change your mind several times about this.

Dirty bomb - spent nuclear fuel is radioactive but cannot be exploded in a "normal" nuclear bomb way. It can be exploded with a smaller conventional bomb, and splash the invisible but deadly radiation around. This won't kill many people, but is more a scary way to freak out cities. Imagine if a small explosion spreading a batch of radioactive material around outside the stock exchange might impact our economy. Few deaths, but terror and possible economic crisis are likely. Scary stuff, what shall we do with that spent fuel?

Carbon-14 - radioactive carbon, which exists in small proportion naturally occurring. It's formed by radiation from the Sun hitting the atmosphere, and is formed at a slow but steady rate. It also decays at a known rate. You eat plants that make food from CO₂ in the air, some proportion is radioactive carbon. Sometimes you eat animals that ate plants, so the amount of radioactive carbon in all living things is steady and measureable.

Radiocarbon dating - by measuring how much radioactive carbon is present in relatively young fossils (up to 120,000 years only) scientists can measure accurately how much is present. Since all living things have a constant rate. When they die, they stop eating, but the decay continues on. The difference between the amount present compared to what is in living things can be calculated, and you can tell how long ago something stopped eating (approximately how long ago it died). This is very accurate to 120,000 years, after than too little C-14 is left to measure. This is not wacky, this is simple to do in college chemistry and is accepted as completely correct and accurate without care to any religious perspectives.

Medical Radiation therapies - doctors can “shoot” beta particles from radioactive cobalt at tumors; the beta particles will kill the tumor cells, which might be in a location that makes them hard to cut out. On the way the beta particles will also kill the skin and other cells they penetrate on the way to kill the tumor. Doctors know that by harming you a little, and killing your tumor, you can recover once the tumor is killed. Also, doctors can give you small doses of radioactive iodine, which is supposed to be absorbed by your thyroid gland. After a period of time, a special image can be made. If your thyroid absorbs the proper amount of iodine, doctors can “see” that. If not, they can diagnose your thyroid problems. Radioactive iodine in small doses emits not too much radiation, and for not too long (short half life). The down side of ingesting radioactive stuff vs. the up side of a quick, non-invasive measure of your thyroid is sometimes worth it. (baby, I’m worth it)

Geiger counters - a device that measures radiation emitted nearby. Made first by a scientist named Geiger

Radiation exposure in humans - all radiation is bad for humans. Some naturally occurring radiation, say with radon from the ground, or from smoke detectors, or old fashioned glow in the dark paint, or even from the Sun, is normal. Less is always better, but zero is unlikely to hope for.

Tritium - an isotope of Hydrogen with 2 neutrons, with mass of 3 AMU

Deuterium - an isotope of Hydrogen with 1 neutron, with mass of 2 AMU

Turbine - a device that has many magnets surrounding copper wire. Many years ago scientists discovered that a moving magnetic field created electricity. By having a turbine turned by steam in a power plant, huge magnets turn around copper wire creating electricity from the motion of the magnets. Windmills turn turbines, as do coal power plants, or oil power plants. Nuclear plants do also. Some bicycles have tiny turbines that touch a wheel, creating electricity enough to light a couple of light bulbs on your ride, for safety and for you to see a bit better in the dark.

Iodine pills - people that live near nuclear power plants are provided with sodium iodide pills. In the event of a leak, radioactive iodine can be released, and it could be absorbed by humans. This radioactive iodine could get absorbed by your thyroid gland (if it works normally and it probably does). This would put lots of radiation into your neck, which is bad. By taking these pills as soon as a leak is detected, your body saturates it’s thyroid gland with “safe” iodine. Any extra iodine you absorb that is radioactive will likely be urinated away quickly, and make it less likely you get cancer. This is a bit scary, but actually pretty sensible from a biology perspective. It’s also practical in that leaks can happen and you don’t want cancer or any chance to get it. You are also unlikely to shut down any nuclear power plants nearby anyway.