



Concept maps as a teaching and learning strategy: classification of matter ^(*)^(**)^(***)

Dr. Patrick Blessinger

Lecturer of education at SUNY (Old Westbury)
STEM teacher with NYSED
Chief research scientist for the International Higher Education
Teaching and Learning Association or HETL

Abstract

Chemistry forms the basis for all natural sciences. It is referred to as "the central science" as it links physical sciences (like physics and geology) with life sciences (such as biology and medicine). Its study of matter has a crucial role in grasping scientific phenomena.

The Classification of Matter concept map (graphic organizer) visually shows how matter is grouped by its physical and chemical traits. Concept maps help students understand and remember the subject better.

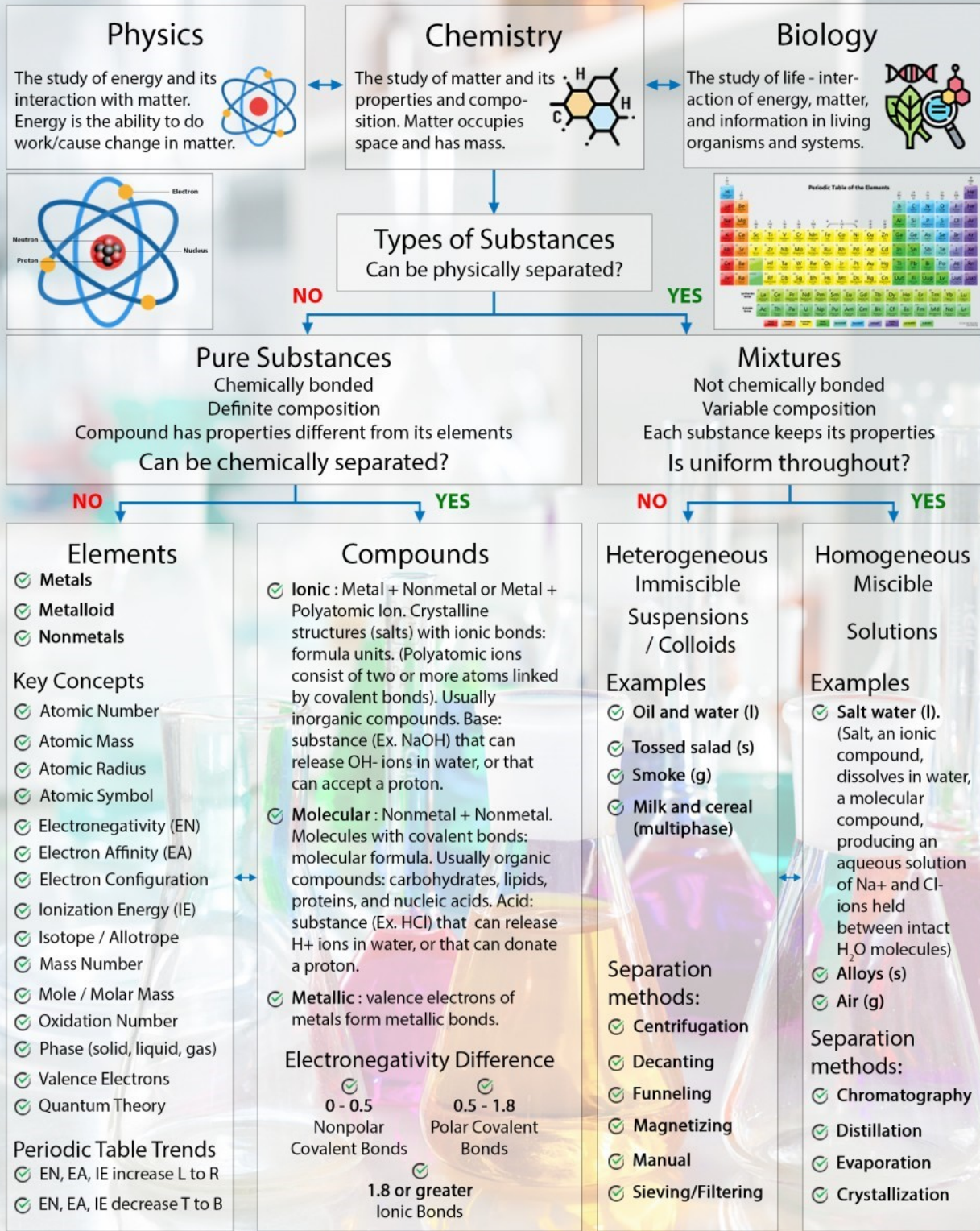
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Classification of Matter



Central organizing principles of chemistry: conservation of energy and mass, kinetic molecular theory, and thermodynamics.

Key formula: Gibbs Free Energy: $\Delta G = \Delta H - T\Delta S$ where ΔH is change in enthalpy, T is temperature, and ΔS is change in entropy.

Matter

Matter can broadly be classified into two categories: substances and mixtures. Grasping this concept of subdivision is very important for understanding chemistry.

Substances are characterized by their uniform and definite composition: elements or compounds. The classification of substances as elements and compounds is essential in the study of chemical reactions.

Elements are the simplest forms of matter and are represented in the periodic table of elements. They consist of atoms of only one type, defined by the atomic number, which refers to the number of protons in the nucleus. Elements are arranged in the periodic table as metals, metalloids, or nonmetals (Brown et al., 2014).

Compounds contain two or more elements joined by chemical bonds in a fixed ratio and have properties different from their constitutive elements. The classification of compounds occurs according to the type of chemical bond: ionic, covalent, and metallic. Ionic compounds are held together by electrostatic forces between ions due to the transfer of valence electrons. Covalent compounds are formed due to the sharing of valence electron pairs between atoms. Metallic compounds possess a "sea" of delocalized electrons shared among a lattice of metal ions (Silberberg, 2017).

Mixtures are either homogeneous or heterogeneous. They are composed of two or more substances combined physically but not chemically bonded. Thus, in a mixture, the different ingredients will maintain their properties, and the different ingredients will be separable through physical means.

Homogeneous mixtures, otherwise known as solutions, are uniform throughout—the solutes are distributed equally in the solvent—and only one phase appears. Saltwater, for example, may be separated by distillation, boiling, or evaporation (Atkins & de Paula, 2013).

Heterogeneous mixtures are nonuniform, and the mixture ingredients, for instance, oil and water, remain separated in the mix. Separation may be attained through filtration, centrifugation, or other means (Hill & Kolb, 2011).

Physical and Chemical Properties

Classifying matter is mainly based on the physical and chemical properties of the substance to determine how it will combine with other substances. Physical properties include qualities like melting point, boiling point, density, color, conductivity, and solubility that can be measured without affecting the substance's identity. Examples of chemical properties include flammability, reactivity, and heat of combustion.

A phase of matter—solid, liquid, or gas—is matter in a state determined by temperature and pressure. Thermodynamics describes the transition from one state of a substance to another, such as melting or freezing, evaporation or condensation. Density denotes the concentration of a substance relative to a fixed unit of volume. This helps explain substances and their buoyancy.

Chemical properties describe how a substance can change into other substances. Reactivity refers to a substance's tendency to undergo a chemical reaction. This property allows us to predict the products in a chemical reaction. Oxidation is a chemical process where a molecule, atom, or ion loses electrons. Both properties are critical factors in electrochemistry.

Interdisciplinary Knowledge

The classification of matter connects with principles from physics and biology, underscoring its interdisciplinary character within the natural sciences.

Knowledge of thermodynamics is beneficial in explaining the physical properties of matter, like phase transitions. This concept also helps clarify the energy conservation principle associated with chemical reactions.

Biological processes, from photosynthesis to respiration, involve changes in matter and energy. The nature of the classification of matter and chemical bonds is a prerequisite for understanding the composition of biological molecules, such as proteins and nucleic acids.

Central Organizing Principles

The Classification of Matter concept map focuses on some core principles in chemistry: the law of conservation of mass, the law of conservation of energy, and the periodic law. These principles provide the foundation for the study of matter and the key to more specialized areas of chemistry.

The Law of Conservation of Mass states that mass cannot be created or destroyed in a chemical reaction. It is critical to explaining chemical equations and stoichiometry. It describes the combination of elements into compounds and their separation without losing mass.

The Law of Conservation of Energy states that energy cannot be created or destroyed but only changed from one form to another and only transferred from one particle, object, or system to another. It is a basic tenet to be applied in all studies on energy changes during reactions, phase transitions, or other types of changes.

The periodic law states that the properties of elements are a periodic function of their atomic number. This law explains the behavior of elements and how compounds are formed. The rows in the periodic table represent the electron energy level, while columns represent the number of valence electrons.

These concepts provide an appropriate foundation for advanced topics on thermodynamics, kinetics, and quantum chemistry.

Chemical Bonding

Valence electrons are the most external electrons of every atom, which are concerned with chemical bonding and reactivity. The valence electrons determine how an element should react with other elements to form compounds and what kind of bonds can be formed. Valence electrons also permit the grouping of elements and compounds by describing the bonding behavior that enables predicting chemical reactions. The three main ones include ionic, covalent, and metallic.

Ionic bonds are formed when an atom donates an electron to another, causing oppositely charged ions to attract each other. These bonds are found in compounds between metals and nonmetals, like common salt (sodium chloride, NaCl).

Covalent bonds are formed by sharing electron pairs between atoms. This typically takes place between two nonmetal atoms. Bonds can either be polar or non-polar.

Metallic bonds are found in metals; atoms share a "sea" of delocalized electrons. As seen in elements like copper and iron, these bonds give metals properties such as conductivity and malleability.

Kinetic Molecular Theory

Understanding the behavior of matter and energy interactions depends on certain core principles, such as the Kinetic Molecular Theory (KMT) and the laws of thermodynamics. KMT describes how particles in matter, particularly gases, are in constant random motion.

Gas particles collide with other particles or against the walls of their containers, assuming the collision is perfectly elastic. A substance's temperature is the function of the average kinetic energies of its particles. This relation influences the interdependence of pressure, volume, and temperature of gases.

In ideal gases, the interactions between the particles are negligible. In real gases, at high enough pressures and low enough temperatures, one can have intermolecular forces that yield departures from ideal behavior.

KMT gives the microscopic basis for understanding such macroscopic properties as pressure, temperature, and phase transformations.

Thermodynamics

Understanding energy-matter interactions is based on some basic scientific formulae quantifying the relationship between energy and matter and their changes through physical and chemical processes.

First Law of Thermodynamics: $\Delta U = Q - W$. This law of energy conservation states that the change of the internal energy of a system is equal to the added heat minus the work done—an essential relationship in applications from engines to biological systems.

Second Law of Thermodynamics: The entropy of a closed system increases with time, showing why certain processes are irreversible and how energy spreads out—a very important concept in understanding heat flow and the efficiency of engines (Atkins and de Paula, 2013).

Third Law of Thermodynamics: The entropy of a system approaches a minimum value as the temperature reaches absolute zero (Silberberg, 2017).

Ideal Gas Equation: $PV = nRT$. This is the equation of the behavior of an ideal gas with regard to its pressure, volume, and temperature. This equation forms a basis for explaining the behavior of gases in varied conditions.

Heat Capacity and Specific Heat: $q = mc\Delta T$. This formula helps find the heat absorbed or released when the temperature of a substance changes. This equation is crucial in heating and cooling applications.

These formulae set the stage for the study of energy-matter interactions, a key concern for physics, chemistry, and biology students.

Gibbs Free Energy Law

Gibbs Free Energy is a thermodynamic view of whether or not a chemical reaction will run spontaneously at the constant temperature and pressure condition. Therefore, it gives the maximum work done in a thermodynamic system at constant temperature and pressure.

Gibbs-Free Energy Equation: $\Delta G = \Delta H - T\Delta S$

Where ΔG is the change in Gibbs free energy, ΔH is the enthalpy change, T is the temperature in Kelvin, and ΔS is the entropy change.

$\Delta G < 0$: the reaction is spontaneous

$\Delta G = 0$: system is at equilibrium

$\Delta G > 0$: the reaction is non-spontaneous and requires the input of energy.

Gibbs free energy is involved in most facets of chemical equilibria, phase transitions, and metabolic processes such as cellular respiration. It is also of paramount importance in engineering to enable the design of efficient power plants or refrigeration systems (Silberberg, 2017).

Teaching Strategies

The Classification of Matter concept map is also an instructional tool with several purposes in a classroom. It furthers student learning through direct instruction and active learning methods.

Direction instruction explicitly teaches complex topics through coherent explanations and well-organized teaching methods to understand the core material (Blessinger, 2018).

First, the teacher introduces the concept map to the learners, indicating its structure and purpose. This map represents the relationships among the different categories of matter, such as pure substances (elements, compounds) and mixtures (homogeneous, heterogeneous), and how they relate to one another.

Second, with the help of the map, it is easy to introduce each concept to the learners step-by-step. In this way, learners will clearly realize how these ideas fit together within the context of chemistry as a whole.

Third, concepts should be presented, and then students should be given guided practice to deepen their knowledge. They can be guided in using the concept map to classify different substances. For example, they can sort or classify different materials, such as salt water, iron, or air, into different groups based on the one they resemble on the map.

Since assessment is an integral part of teaching and learning, the teacher can use the concept map to probe students for understanding by checking whether they can correctly group the substances and explain why they did so. For instance, these may be in the form of quizzes, assignments, and projects.

Active learning strategies complement direct instruction, where engaged learning activities concretize concepts within the brain for better comprehension, retention, and recall. Active learning strategies refer to techniques or methods that get students involved in hands-on learning, usually with collaboration, critical thinking, and problem-solving (Prince, 2004).

Concept maps are very effective in problem-based learning since students are working on materials to be presented actively. For instance, within a problem-based learning approach, students can be given a real-world challenge concerning the classification of matter—a mystery substance where students have to determine its composition using physical and chemical properties.

Concept maps can also help with inquiry-based learning. It is a method of stimulus for students to formulate questions, plan research, and prepare and solve qualitative and quantitative problems on their own.

Concept maps enhance students' understanding of the material and make the learning environment more engaging because they allow students to participate in the learning process and take responsibility for their results.

The concept map on the classification of matter is an ideal educational tool in both direct instruction and active learning contexts. Whether structured as teacher-led or student-led, the map offers a versatile tool that aids students at the very basics in understanding the core chemistry concepts that will later set a base for success in more advanced studies.

Conclusion

The Classification of Matter concept map is not just a tool for organizing chemical concepts but an educational resource integrating central organizing principles and interdisciplinary knowledge. Educators can enhance student engagement and understanding by employing direct instruction and active learning strategies, making chemistry study accessible and relevant. This approach prepares students for more advanced scientific topics and fosters a deeper appreciation for the interconnectedness of the natural sciences.

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