Principles of Chemistry Common Learning Outcomes

University System of Georgia Principles of Chemistry (CHEM 1211 - CHEM 1212) Common Learning Outcomes

Common Student Learning Outcomes for the Core Curriculum

Quantitative Reasoning and Mathematics:

Quantitative reasoning and mathematics will be characterized by logic, critical evaluation, analysis, synthesis, generalization, modeling, and verbal, numeric, graphic, and symbolic problem solving.

Scientific Reasoning:

Scientific reasoning will be characterized by understanding and applying scientific method, laboratory techniques, mathematical principles, and experimental design to natural phenomena.

Content-based Learning Outcomes for Principles of Chemistry

As the result of instruction, we expect students successfully completing the Principles of Chemistry I and Principles of Chemistry II courses to understand and remember the following concepts and principles:

Properties of Matter

1. Chemistry is the study of the composition and properties of matter, and how those properties are affected by changes in composition and external conditions.
2. All matter has mass and takes up space, and is composed of particles interacting through forces. The properties of matter depend, in part, on the relative strength of interacting forces. This model of matter is useful for explaining the general properties of the three phases of matter (solid, liquid, gas) and the transitions between phases.

Atomic Theory

3. All matter is composed of just over 100 different types of particles, called atoms. Matter may be composed of a single type of atom (an element), or different types of atoms may bond to each other in fixed proportions to form compounds (molecules or crystals). A chemical reaction occurs when atoms rearrange their bonding structures, which may include adding or removing atoms to the basic chemical unit, resulting in new compounds.
4. Atoms combine chemically as whole units; therefore, a pure compound may be identified by its chemical formula. Different types of atoms have different relative masses; therefore, the number of particles in a fixed sample of a pure substance may be calculated by dividing by the relative mass of the atoms in the substance. The mole is a unit of measurement that has been defined to expedite the conversion between

the mass of a substance and the number of particles in a substance. One mole is the quantity of a substance such that the relative mass of all the atoms in the chemical formula is equal to that mass of the substance in grams.

5. It has proven useful in the study of chemistry to recognize different types or classes of reactions; some examples are replacement, combination, combustion, and acid-base reactions.

Thermochemistry: Temperature, Heat and Energy

6. Energy is stored in chemical bonds. Therefore, energy may be absorbed or released as chemical bonds are broken and formed in a chemical reaction. Exothermic reactions release heat as a result of a reaction, resulting in warmer surroundings; endothermic absorb heat in a reaction, resulting in colder surroundings. Enthalpy is a measure of the amount of heat absorbed or released in a chemical reaction.
7. Heat and work are two methods for transferring energy from one substance to another. Heat involves random motions of the particles of a substance; work results from non-random motions.
8. Temperature is a property of matter; it is proportional to the average kinetic energy of the particles of a substance. The addition or removal of heat usually (but not always) results in an increase or decrease in temperature, respectively. However, heat added to or removed from a substance may result in other changes in the energy of the substance besides an increase or decrease in random kinetic energy.

The Gaseous State

9. Four fundamental properties of all gases are pressure, volume, temperature, and quantity. These properties are related to each other mathematically in a relatively simple way. Observing two properties at a time while holding the other two constant results in the empirical gas laws; an equation relating all four properties simultaneously is called the ideal gas law. The ideal gas law is a very useful but approximate result; variations have been added to the ideal gas law to make it more closely reflects the behavior of real gasses.
10. Kinetic-molecular theory assumes that an ideal gas consists of point-like particles that only interact when they collide, and conserve kinetic energy before and after a collision. The pressure of gaseous systems is described as collisions of the point-like particles with the walls of the container. The ideal gas law may be derived from the assumptions of the theory and the application of classical mechanics to a large aggregate of point-like particles.
11. Measurements made on gaseous systems have lead to the identification of an absolute temperature scale. The lowest possible temperature in this scale is zero, designated as absolute zero. An ideal gas (in theory) would possess no energy at absolute zero, and therefore exhibits no pressure and have no volume.

Atomic Structure

12. Experimental evidence supports the concept of a nuclear atom: a positively charged core which occupies less than 1% of the volume of the atom surrounded point-like negatively charged electrons. The positively charged core, or nucleus, is very massive compared to the electrons surrounding it. The motion of the electrons is unspecified: they do not travel around the nucleus in regular or predictable paths, but out best

mathematical model suggest they are most likely to be found in specific regions of space known as orbitals.

13. A useful model of the nucleus suggests it is composed of positively charged protons and neutral neutrons, held together by a 'strong force'. The number of protons determines the type of atom; the sum of protons and neutrons determines the relative mass of the atom.
14. Chemical bonding involves a balance of attractive and repulsive forces between the electrons and nuclei. Most descriptions of bonding characterize chemical bonds in terms of the electrons only. Electrons can be described by quantum numbers, which identify the mostly likely locations of the electrons in space and also their relative energies. Quantum numbers are very helpful in explaining the number and types of bonds that an atom may form with other atoms.

Periodicity and Chemical Bonding

15. The structure of the periodic chart is the result of electron quantum numbers. The outermost electrons (valence electrons) in a column have certain quantum numbers that are the same, and therefore those elements generally bond and behave chemically in similar ways. An orbital may hold either 0, 1, or 2 electrons, but never more than two electrons. Elements in a row, or period, of the Chart are generally adding electrons to a set pf orbitals with the same 'principal' quantum numbers. The start of a new period represents a significant increase in the energy of an electron compared to the previous period.
16. Experimental evidence has shown that the last column of the periodic table contains a set of mainly unreactive atoms: the noble gases. They share the common property of having completely filled orbitals in their valence shell. This configuration results in an energetically stable atom. One guiding principle of chemical bonding is that attaining the same 'electron configuration' as the noble gasses is desirable, and is often a consequence for atoms in a compound after a chemical reaction.
17. Chemical bonds that result in the transfer of electrons from one atom to another are called ionic bonds; chemical bonds that result from the sharing of electrons are called covalent bonds. The transfer of electrons results in the formation of charged chemical species, called ions. Most chemical bonds are neither purely ionic nor purely covalent in nature. Covalent bonds are often imagined to be the end result of the overlap of atomic orbitals, leading to a new set of 'molecular' orbitals.
18. A method of accounting for valence electrons and their known properties has been developed which is able to help predict bonding patterns in many small molecules and ions (Lewis structures).

Geometry, Molecular Structure, and Properties

19. Application of the basics of electrostatic repulsion leads to a systematic method for determining the equilibrium geometry of a molecule. Geometry, bond strength, the distribution of charge (dipoles), and the resulting intermolecular forces determine the properties of pure substances in the liquid and solid states.

Solutions

20. Intermolecular forces determine the extent to which two or more pure substances will mix. A homogenous mixture of two substances (a solution) consisting of one major component (a solvent) and one minor

component (a solute) will have physical properties that are similar to those of the pure solvent, but vary from them in a regular, mathematical way (the colligative properties). Concentration is a measure of the amount of a dissolved substance in a solvent.

Electrochemistry

21. A certain class of chemical reactions in which electrons are transferred from one species to another is called oxidation-reduction (or redox) reactions. Procedures have been developed to correctly account for the transfer of electrons (balance) in redox reactions. Oxidation-reduction is the basis of electrochemical cells.

Acid - Base Reactions

22. A certain class of chemical reactions in which a proton (or hydrogen ion) is transferred from one molecule to another is called acid-base reactions. The proton donor is the acid and the proton acceptor is the base. An alternative and more general theory of acid-base reactions describes the process in terms of donating an electron pair. The electron pair donor is the base and the electron pair acceptor is the acid. One common base in water chemistry is the hydroxide ion. Often, the neutralization of an acid and a base in an aqueous solution results in the formation of a water molecule and a 'salt'.
23. The relative concentration of an acid or base in a solution can be measured on a logarithmic scale known as 'pH'. Solutions with lower pH are more acidic; solutions with higher pH are more basic; solutions at 25 □C with a pH of 7 are neutral. Although the pH scale is the most well-known scale used in the study of acid-base chemistry, there are other useful measures based on logarithmic measures, including pOH and pKa.

Reaction Rate

24. The length of time it takes for a reaction to proceed can vary; a measure of the speed of a reaction is the reaction rate. Reaction rate usually changes over time. Mathematical equations may be written (a rate equation) that describe how the reaction rate varies with the concentrations of reactants and temperature. Different reactants may have different 'orders' in the rate equation. Methods employing experimental data are available to determine the order of a reaction with respect to a reactant.
25. Reactions can be imagined as collisions between reacting species. In a mixture, collisions occur randomly and often. For a collision to be effective, resulting in the creation or destruction of chemical bonds, the collision must have sufficient energy and the correct orientation of reacting species.
26. Increasing the temperature at which a reaction is run will increase the rate at which the reaction proceeds. A theory is in place to describe this effect by considering the energy flow of a reaction.
27. Reactions are written in terms of the initial and final states of the system. Most reactions, though, are the accumulation of many 'elementary' reactions or steps, called a mechanism. The sum of these steps must add to the overall process being investigated. In addition, each elementary step must occur exactly as written, thus describing the collision process between reacting species. The mechanism must also yield a theoretical rate equation that is consistent with the experimental rate equation.

28. Catalysts are substances that change the rate of a reaction but are not consumed in the overall reaction. The addition of a catalyst to a reaction opens an alternative mechanism to go from reactants to products.

Equilibrium

29. Many reactions are reversible: while reactants are forming products, products may simultaneously be forming reactants. Dynamic equilibrium occurs when the rate of the forward reaction matches the rate of the reverse reaction. Under those conditions, the relative concentrations of reactants and products remain constant. A mathematical expression may be written that describes the relative concentrations or reactants and products at equilibrium.
30. The addition or removal of reactants or products may affect the equilibrium conditions. The equilibrium reaction must adjust to reestablish the equilibrium dictated by the 'equilibrium constant'. Altering the temperature requires the system to adjust to a new equilibrium, based on the temperature dependence of both the forward and reverse rate equations. Le Chatelier's Principle is a statement of how to determine the qualitative effects of changes to a system on equilibrium concentrations.

Thermodynamics

31. A spontaneous process is one that occurs without an ongoing outside intervention. Usually, a reaction is spontaneous if the process is exothermic (lowers its energy) or if the reaction is associated with an increase in entropy, a measure of the randomness of the system.
32. Equations have been developed relating these two 'thermodynamic' quantities under the conditions of constant temperature and pressure, resulting in a new thermodynamic quantity, Gibb's free energy that is a definite predictor of spontaneity. Equilibrium conditions are also related to Gibb's free energy.

Process-based Learning Outcomes for Principles of Chemistry

As the result of instruction, we expect students successfully completing the Principles of Chemistry I and Principles of Chemistry II courses to be able to successfully complete the following tasks:

1. Write correct formulas for compounds from their names, and vice versa. Identify the meaning of a chemical formula.
2. Balance simple chemical reactions. Explain or interpret the meaning of the coefficients of a balanced chemical reaction and any subscripts.
3. Report numerical answers to word problems using the correct number of significant figures, and evaluate the error in a measurement or calculation.
4. Solve word problems based on realistic chemistry situations, using appropriate mathematical equations associated with the subject at hand and correctly substituting data found in the word problem in the equation(s) in order to solve for an unknown quantity.
5. Use dimensional analysis to perform mathematical operations, such as converting between the mass and moles of substances using data obtained from the periodic chart, chemical formulas, and balanced equations.
6. Communicate ideas and concepts using appropriate grammatical forms in both oral and written formats.

Furthermore, as a laboratory science, we expect all students who have completed the Principles of Chemistry sequence to:

Recognize the importance of safety in a chemistry laboratory and practice appropriate safety rules and policies whenever conduction an experimental investigation.

We also expect all students to have had personal experience with the following tasks:

1. Measure and transfer liquids using a beaker, graduated cylinder, volumetric flask, and pipette.
2. Determine the mass of a substance on a balance.
3. Use a burette to perform a titration.
4. Create a solution of known concentration.
5. Observe the effects of a chemical reaction.
6. Classify materials as acids or bases.
7. Use spectrometry to find the concentration of an absorbing species in solution.
8. Measure colligative properties.
9. Observe factors affecting reaction rates.
10. Graph and interpret measured data.

NOTE:

The Principles of Chemistry course sequence (CHEM 1211 / 1212) is designed for students majoring in science, mathematics, and engineering. Many institutions in the University System of Georgia have other general chemistry courses designed for non-science majors, or for students interested in certain health sciences.

The Chemistry Academic Advisor Committee asserts that the most significant difference between the 'majors' course and other, lower-level courses is not in content-based or process-based learning outcomes but in the depth of the material covered and in the level of the mathematics used. Therefore, the learning outcomes presented in this document may also be considered a reasonable guide for lower-level chemistry courses as well, recognizing that certain learning outcomes may not be included in those courses and other outcomes (such as chemistry principles relating to the study of organic chemistry) may be added as important outcomes.

For specific information about other general chemistry courses or a particular Principles of Chemistry course, please contact the chemistry department as the appropriate University System institution.

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