Science
Curriculum Unit Overview
Chemistry with Lab

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Unit 1 - Introduction to Chemistry

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:**
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Introduction to Chemistry	**Unit Number:** One	**Created:** 2022-2023	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.
2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.
3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.
4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.
2. Identify information presented graphically to solve a problem.
3. Identify a testable scientific question based on an observation, data or a model.
4. Identify quantities needed to solve a problem from given information (e.g. text, mathematical expressions, graphs, or tables).
5. Describe the components of and quantitative information from models and representations that illustrate particulate-level properties only.
6. Explain whether a model is consistent with chemical theories.
7. Explain chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations.
8. Explain the connection between particulate-level and macroscopic properties of a substance using models and representations.

Meaning

UNDERSTANDINGS

Students will understand that…

1. The mole allows different units to be compared.
2. Chemical formulas identify substances by their unique combination of atoms.
3. Atoms and molecules can be identified by their electron distribution and energy.
4. The periodic table shows patterns in electronic structure and trends in atomic properties.

ESSENTIAL QUESTIONS

1. Why are eggs sold as a dozen?
2. How can the same element be used in nuclear fuel rods and fake diamonds?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. One cannot count particles directly while performing laboratory work. Thus, there must be a connection between the masses of substances reacting and the actual number of particles undergoing chemical changes.
2. Avogadro's number (NA = 6.022 × 1023 mol-1) provides the connection between the number of moles in a pure sample of a substance and the number of constituent particles (or formula units) of that substance.
3. Expressing the mass of an individual atom or molecule in atomic mass units (amu) is useful because the average mass in amu of one particle (atom or molecule) or formula unit of a substance will always be numerically equal to the molar mass of that substance in grams. Thus, there is a quantitative connection between the mass of a substance and the number of particles that the substance contains. EQN: $n = m/M$
4. The mass spectrum of a sample containing a single element can be used to determine the identity of the isotopes of that element and the relative abundance of each isotope in nature.
5. The mass spectrum of a sample containing a single element can be used to determine the identity of the isotopes of that element and the relative abundance of each isotope in nature.
6. Some pure substances are composed of individual molecules, while others consist of atoms or ions held together in fixed proportions as described by a formula unit.
7. According to the law of definite proportions, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same.

8. The chemical formula that lists the lowest whole number ratio of atoms of the elements in a compound is the empirical formula.
9. While pure substances contain molecules or formula units of a single type, mixtures contain molecules or formula units of two or more types, whose relative proportions can vary.
10. Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.
11. The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.
12. Coulomb's law is used to calculate the force between two charged particles. EQN: F coulombic ∝ q1q2 SAP-1.A.3 r2
13. In atoms and ions, the electrons can be thought of as being in "shells (energy levels)" and "subshells (sublevels)," as described by the electron configuration. Inner electrons are called core electrons, and outer electrons are called valence electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements.
14. The relative energy required to remove an electron from different subshells of an atom or ion or from the same subshell in different atoms or ions (ionization energy) can be estimated through a qualitative application of Coulomb's law. This energy is related to the distance from the nucleus and the effective (shield) charge of the nucleus.
15. The energies of the electrons in a given shell can be measured experimentally with photoelectron spectroscopy (PES). The position of each peak in the PES spectrum is related to the energy required to remove an electron from the corresponding subshell, and the height of each peak is (ideally) proportional to the number of electrons in that subshell.
16. The organization of the periodic table is based on the recurring properties of the elements and explained by the pattern of electron configurations and the presence of completely or partially filled shells (and subshells) of electrons in atoms.
17. Trends in atomic properties within the periodic table (periodicity) can be qualitatively understood through the position of the element in the periodic table, Coulomb's law, the shell model, and the concept of shielding/effective nuclear charge. These properties include:Ionization energy, Atomic and ionic radii, Electron affinity, Electronegativity.
18. The periodicity (in SAP-2.A.2) is useful to predict /estimate values of properties in the absence of data.
19. The likelihood that two elements will form a chemical bond is determined by the interactions between the valence electrons and nuclei of elements.
20. Elements in the same column of the periodic table tend to form analogous compounds.
21. Typical charges of atoms in ionic compounds are governed by their location on the periodic table and the number of valence electrons.

SKILLS

Students will be skilled at (be able to do)...

1. Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept.
2. Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes.
3. Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance.
4. Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
5. Represent the electron configuration of an element or ions of an element using the Aufbau principle.
6. Explain the relationship between the photoelectron spectrum of an atom or ion both the electron configuration of the species and the interactions between the electrons.
7. Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.
8. Explain the relationship between trends in the reactivity of elements and periodicity.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept on homework, quizzes, tests and labs. 2. Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes on homework, quizzes, tests and labs. 3. Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance on homework, quizzes, tests and labs. 4. Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture of homework, quizzes, tests and labs. 5. Represent the electron configuration of an element or ions of an element using the Aufbau principle on homework, quizzes, tests and labs. 6. Explain the relationship between the photoelectron spectrum of an atom or ion both the electron configuration of the species and the interactions between the electrons on homework, quizzes, tests and labs. 7. Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity on homework, quizzes, tests and labs. 8. Explain the relationship between trends in the reactivity of elements and

	periodicity on homework, quizzes, tests and labs.
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapter 2 will address Moles and Molar Mass, Mass Spectroscopy of Elements, and Elemental Composition of Pure Substances.

Chapter 4 will address Composition of Mixtures.

Chapters 6,7,21, and PES will address Atomic Structure and Electron Configuration, Photoelectron Spectroscopy, and Periodic Trends.

Chapters 8,9 and more will address Valence Electrons and Ionic Compounds.

Multiple labs including titration, colorimetry and gravimetric analysis will include moles and molar mass, the composition of mixtures, and ionic compounds.

Unit 2 Matter and Change

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** 12 - 13 class pds
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Molecular and Ionic Compound Structure and Properties	**Unit Number:** Two	**Created:** 2021-2022	**Revised:** TBD
Standards Addressed: Standards - 3.2.10.A1; 3.2.10.A2; 3.2.10.A6; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.2; CHEM.B.1 Anchor Descriptors - CHEM.A.2.3; CHEM.B.1.3; CHEM.B.1.4			

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Transfer

Students will be able to independently use their learning to...

1. Make a scientific claim.
2. Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.
3. Explain the connection between particulate-level and macroscopic properties of a substance using models and representations.
4. Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).
5. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.

Meaning

UNDERSTANDINGS

Students will understand that…

1. Atoms or ions bond due to interactions between them, forming molecules.

2. Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair (VSEPR) Theory.

ESSENTIAL QUESTIONS

1. How has the discovery of DNA changed the world?
2. How are molecular compounds arranged?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. Electronegativity values for the representative elements increase going from left to right across a period and decrease going down a group. These trends can be understood qualitatively through the electronic structure of the atoms, the shell model and Coulomb's Law.
2. Valence electrons shared between atoms of similar electronegativity constitute a nonpolar covalent bond. For example, bonds between carbon and hydrogen are effectively nonpolar even though carbon is slightly more electronegative than hydrogen.
3. Valence electrons shared between atoms of unequal electronegativity constitute a polar covalent bond.
    a. The atom with a higher electronegativity will develop a partial negative charge relative to the other atom in the bond.
    b. In single bonds, greater differences in electronegativity lead to greater bond dipoles.
    c. All polar bonds have some ionic character, and the difference between ionic and covalent bonding is not distinct but rather a continuum.
4. The difference in electronegativity is not the only factor in determining if a bond should be designated as ionic or covalent. Generally, bonds between a metal and nonmetal are ionic, and bonds between two nonmetals are covalent. Examination of the properties of a compound is the best way to characterize the type of bonding.
5. In a metallic solid, the valence electrons from the metal atoms are considered to be delocalized and not associated with any individual atom.
6. A graph of potential energy versus the distance between atoms is a useful representation for describing the interactions between atoms. Such graphs

illustrate both the equilibrium bond length (the separation between atoms at which the potential energy is lowest) and the bond energy (the energy required to separate the atoms.

7. In a covalent bond, the bond length is influenced by both the size of the atom's core and the bond order (i.e., single, double, triple). Bonds with a higher order are shorter and have larger bond energies.
8. Coulomb’s law can be used to understand the strength of interactions between cations and anions.
    a. Because the interaction strength is proportional to the charge on each ion, larger charges lead to stronger interactions.
    b. Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.
9. The cations and anions in an ionic crystal are arranged in a systematic, periodic 3-D array that maximizes the attractive forces among cations and anions while minimizing the repulsive forces.
10. Metallic bonding can be represented as an array of positive metal ions surrounded by delocalized valence electrons (i.e., a “sea of electrons”).
11. Interstitial alloys form between atoms of different radii, where the smaller atoms fill the interstitial spaces between the larger atoms (e.g., with steel in which carbon occupies the interstices in iron).
12. Substitutional alloys form between atoms of comparable radius, where one atom substitutes for th either in the lattice. (In certain brass alloys, other elements, usually zing, substitute for copper.)
13. Lewis diagrams can be constructed according to an established set of principles.
14. In cases where more than one equivalent Lewis structure can be constructed, resonance must be included as a refinement to the Lewis structure. In many such cases, this refinement is needed to provide qualitatively accurate predictions of molecular structure and properties.
15. The octet rule and formal charge can be used as criteria for determining which of several possible valid Lewis diagrams provides the best model for predicting molecular structure and properties.
16. As with any model, there are limitations to the use of the Lewis structure model, particularly in cases with an odd number of valence electrons.
17. VSEPR theory uses the Coulombic repulsion between electrons as a basis for predicting the arrangement of electron pairs around a central atom.
18. Both Lewis diagrams and VSEPR theory must be used for predicting electronic and structural properties of many covalently bonded molecules and polyatomic ions, including the following:
    a. Molecular geometry
    b. Bond angles
    c. Relative bond energies based on bond order
    d. Relative bond lengths (multiple bonds, effects of atomic radius)
    e. Presence of a dipole moment
    f. Hybridization of valence orbitals of the molecule
19. The terms “hybridization” and “hybrid atomic orbital” are used to describe the arrangement of electrons around a central atom. When the central atom is sp hybridized, its ideal bond angles are 180°; for sp^2 hybridized atoms the bond angles are 120°; and for sp^3 hybridized atoms the bond angles are 109.5°.
20. Bond formation is associated with overlap between atomic orbitals. In multiple bonds, such overlap leads to the formation of both sigma and pi bonds. The overlap is stronger in sigma than pi bonds, which is reflected in sigma bonds having greater energy than pi bonds. The presence of a pi bond also prevents the rotation of the bond and leads to structural isomers.

SKILLS

Students will be skilled at (be able to do)...

1. Make a scientific claim.
2. Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.
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Summary of Key Learning Events and Instruction

Chapters 8, 9 and more will address Types of Chemical Bonds, Lewis Diagrams, Resonance and Formal Charge, and Bond Hybridization.

Chapters 11 and 13 will address Intramolecular Force and Potential Energy, Structure of Ionic Solids, and Structure of Metals and Alloys.

Curriculum Development Hub

Unit 3 Measurement

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Unit Name: Intermolecular Forces and Properties	**Unit Number:** 3	**Created:** 2021-2022	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

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Transfer

Students will be able to independently use their learning to...

1. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
2. Explain the connection between particulate-level and macroscopic properties of a substance using models and representations.
3. Represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic).
4. Explain the relationship between variables within an equation when one variable changes.
5. Explain chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations.
6. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
7. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures).
8. Identify experimental procedures that are aligned to the question (which may include a sketch of a lab setup).
9. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
10. Identify or describe potential sources of experimental error.

Meaning
UNDERSTANDINGS *Students will understand that…* 1. Intermolecular forces can explain the physical properties of a material. 2. Matter exists in three states: solid, liquid, and gas, and their differences are influenced by variances in spacing and motion of the molecules. 3. Gas properties are explained macroscopically - using the relationships among pressure, volume, temperature, moes, gas constant - and molecularly by the motion of the gas. 4. Interactions between intermolecular forces influence the solubility and separation of mixtures. 5. Spectroscopy can determine the structure and concentration in a mixture of a chemical species.
ESSENTIAL QUESTIONS 1. How do interactions between particles influence mixtures? 2. Why does the smell of perfume only last a short time? 3. Why can you swim in water but cannot walk through a wall? 4. How are the properties of gases described? 5. How can you determine the structure and concentration of a chemical species in a mixture?

Stage 1: Essential Content, Concepts & Skills ***What do we want students to know and be able to do?*** [Jump to Table of Contents]
Acquisition
KNOWLEDGE

Students will know…

1. London dispersion forces are a result of the Coulombic interactions between temporary, fluctuating dipoles. London dispersion forces are often the strongest net intermolecular force between large molecules. a. Dispersion forces increase with increasing contact area between molecules and with increasing polarizability of the molecules. b. The polarizability of a molecule increases with an increasing number of electrons in the molecule; and the size of the electron cloud. It is enhanced by the presence of pi bonding. c. The term “London dispersion forces” should not be used synonymously with the term “van der Waals forces.”
2. The dipole moment of a polar molecule leads to additional interactions with other chemical species. a. Dipole-induced dipole interactions are present between a polar and nonpolar molecule. These forces are always attractive. The strength of these forces increases with the magnitude of the dipole of the polar molecule and with the polarizability of the nonpolar molecule.b. Dipole-dipole interactions are present between polar molecules. The interaction strength depends on the magnitudes of the dipoles and their relative orientation. Interactions between polar molecules are typically greater than those between nonpolar molecules of comparable size because these interactions act in addition to London dispersion forces. c. Ion-dipole forces of attraction are present between ions and polar molecules. These tend to be stronger than dipole- dipole forces.
3. The relative strength and orientation dependence of dipole-dipole and ion-dipole forces can be understood qualitatively by considering the sign of the partial charges responsible for the molecular dipole moment, and how these partial charges interact with an ion or with an adjacent dipole.
4. Hydrogen bonding is a strong type of intermolecular interaction that exists when hydrogen atoms covalently bonded to the highly electronegative atoms (N, O, and F) are attracted to the negative end of a dipole formed by the electronegative atom (N, O, and F) in a different molecule, or a different part of the same molecule.
5. In large biomolecules, noncovalent interactions may occur between different molecules or between different regions of the same large biomolecule.
6. Many properties of liquids and solids are determined by the strengths and types of intermolecular forces present. Because intermolecular interactions are broken when a substance vaporizes, the vapor pressure and boiling point are directly related to the strength of those interactions. Melting points also tend to correlate with interaction strength, but because the interactions are only rearranged, in melting, the relations can be more subtle.
7. Particulate-level representations, showing multiple interacting chemical species, are a useful means to communicate or understand how intermolecular interactions help to establish macroscopic properties.
8. Due to strong interactions between ions, ionic solids tend to have low vapor pressures, high melting points, and high boiling points. They tend to be brittle due to the repulsion of like charges caused when one layer slides across another layer. They conduct electricity only when the ions are mobile, as when the ionic solid is melted or dissolved in water or another solvent.
9. In covalent network solids, the atoms are covalently bonded together into a three dimensional network (e.g., diamond) or layers of two-dimensional networks (e.g., graphite). These are only formed from nonmetals: elemental (e.g., diamond, graphite) or binary compounds of two nonmetals (e.g., silicon dioxide and silicon carbide). Due to the strong covalent interactions, covalent solids have high melting points. Three-dimensional network solids are also rigid and hard, because the covalent bond angles are fixed. However, graphite is soft because adjacent layers can slide past each other relatively easily.
10. Molecular solids are composed of distinct, individual units of covalently-bonded molecules attracted to each other through relatively weak intermolecular forces. Molecular solids generally have a low melting point because of the relatively weak intermolecular forces present between the molecules. They do not conduct electricity because their valence electrons are tightly held within the covalent bonds and the lone pairs of each constituent molecule. Molecular solids are sometimes composed of very large molecules or polymers.
11. Metallic solids are good conductors of electricity and heat, due to the presence of free valence electrons. They also tend to be malleable and ductile, due to the ease with which the metal cores can rearrange their structure. In an interstitial alloy, interstitial atoms tend to make the lattice more rigid, decreasing malleability and ductility. Alloys typically retain a sea of mobile electrons and so remain conducting.
12. In large biomolecules or polymers, noncovalent interactions may occur between different molecules or between different regions of the same large

biomolecule. The functionality and properties of such molecules depend strongly on the shape of the molecule, which is largely dictated by noncovalent interactions.

13. Solids can be crystalline, where the particles are arranged in a regular three-dimensional structure, or they can be amorphous, where the particles do not have a regular, orderly arrangement. In both cases, the motion of the individual particles is limited, and the particles do not undergo overall translation with respect to each other. The structure of the solid is influenced by interparticle interactions and the ability of the particles to pack together.
14. The constituent particles in liquids are in close contact with each other, and they are continually moving and colliding. The arrangement and movement of particles are influenced by the nature and strength of the forces (e.g., polarity, hydrogen bonding, and temperature) between the particles.
15. The solid and liquid phases for a particular substance typically have similar molar volume because, in both phases, the constituent particles are in close contact at all times.
16. In the gas phase, the particles are in constant motion. Their frequencies of collision and the average spacing between them are dependent on temperature, pressure, and volume. Because of this constant motion, and minimal effects of forces between particles, a gas has neither a definite volume nor a definite shape.
17. The macroscopic properties of ideal gases are related through the ideal gas law: EQN: $PV = nRT$.
18. In a sample containing a mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the total pressure of the sample is the sum of the partial pressures. EQN: $PA = Ptotal \times XA$, where XA = moles A/total moles; EQN: $Ptotal = PA + PB + PC + \dots$In a sample containing a mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the total pressure of the sample is the sum of the partial pressures. EQN: $PA = Ptotal \times XA$, where XA = moles A/total moles; EQN: $Ptotal = PA + PB + PC + \dots$
19. Graphical representations of the relationships between P, V, T, and n are useful to describe gas behavior.
20. The kinetic molecular theory (KMT) relates the macroscopic properties of gases to motions of the particles in the gas. The Maxwell-Boltzmann distribution describes the distribution of the kinetic energies of particles at a given temperature.
21. All the particles in a sample of matter are in continuous, random motion. The average kinetic energy of a particle is related to its average velocity by the equation: EQN: $KE = \frac{1}{2} mv2$.
22. The Kelvin temperature of a sample of matter is proportional to the average kinetic energy of the particles in the sample.
23. The Maxwell-Boltzmann distribution provides a graphical representation of the energies/ velocities of particles at a given temperature.
24. The ideal gas law does not explain the actual behavior of real gases. Deviations from the ideal gas law may result from interparticle attractions among gas molecules, particularly at conditions that are close to those resulting in condensation. Deviations may also arise from particle volumes, particularly at extremely high pressures.
25. Solutions, also sometimes called homogeneous mixtures, can be solids, liquids, or gases. In a solution, the macroscopic properties do not vary throughout the sample. In a heterogeneous mixture, the macroscopic properties depend on location in the mixture.
26. Solution composition can be expressed in a variety of ways; molarity is the most common method used in the laboratory. EQN: $M = nsolute /Lsolution$
27. Particulate representations of solutions communicate the structure and properties of solutions, by illustration of the relative concentrations of the components in the solution and drawings that show interactions among the components.
28. The components of a liquid solution cannot be separated by filtration. They can, however, be separated using processes that take advantage of differences in the intermolecular interactions of the components. a. Chromatography (paper, thin-layer, and column) separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components of the solution (the mobile phase) and with the surface components of the stationary phase. b. Distillation separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components and the effects these interactions have on the vapor pressures of the components in

the mixture.

29. Substances with similar intermolecular interactions tend to be miscible or soluble in one another.
30. Differences in absorption or emission of photons in different spectral regions are related to the different types of molecular motion or electronic transition: a. Microwave radiation is associated with transitions in molecular rotational levels. b. Infrared radiation is associated with transitions in molecular vibrational levels. c. Ultraviolet/visible radiation is associated with transitions in electronic energy levels.
31. When a photon is absorbed (or emitted) by an atom or molecule, the energy of the species is increased (or decreased) by an amount equal to the energy of the photon.
32. The wavelength of the electromagnetic wave is related to its frequency and the speed of light by the equation: EQN: $c = \lambda v$. The energy of a photon is related to the frequency of the electromagnetic wave through Planck's equation ($E = \hbar \nu$).
33. The Beer-Lambert law relates the absorption of light by a solution to three variables according to the equation: EQN: $A = Ebc$. and molar absorptivity. The molar absorptivity E describes how intensely a sample of molecules or ions absorbs light of a specific wavelength. The path length b and concentration c are proportional to the number of absorbing species.
34. In most experiments the path length and wavelength of light are held constant. In such cases, the absorbance is proportional only to the concentration of absorbing molecules or ions.

SKILLS

Students will be skilled at (be able to do)...

1. Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when: a. The molecules are of the same chemical species. b. The molecules are of two different chemical species.
2. Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles.
3. Represent the differences between solid, liquid, and gas phases using a particulate level model.
4. Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.
5. Explain the relationship between the motion of particles and the macroscopic properties of gases with: a. The kinetic molecular theory (KMT). b. A particulate model. c.A graphical representation.
6. Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.
7. Calculate the number of solute particles, volume, or molarity of solutions.
8. Using particulate models for mixtures: a. Represent interactions between components. b. Represent concentrations of components.
9. Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.
10. Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.
11. Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region.
12. Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.
13. Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when: a. The molecules are of the same chemical species. b. The molecules are of two different chemical species. 2. Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles. 3. Represent the differences between solid, liquid, and gas phases using a particulate level model. 4. Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law. 5. Explain the relationship between the motion of particles and the macroscopic properties of gases with: a. The kinetic molecular theory (KMT). b. A particulate model. c.A graphical representation. 6. Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes. 7. Calculate the number of solute particles, volume, or molarity of solutions. 8. Using particulate models for mixtures: a. Represent interactions between components. b. Represent concentrations of components. 9. Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles. 10. Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles. 11. Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region. 12. Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.

	13. Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapter One will introduce solids, liquids and gases.
Chapter Two will introduce the foundation for bonding.
Chapter Four will discuss solutions and molarity.
Chapters Eight and Nine plus will cover ionic and covalent bonding.
Chapter Ten will cover the gas laws.
Chapters Eleven and Thirteen will deepen the understanding of solids, liquids, gases, and solutions.

Unit 4 Atomic Structure

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]

Curriculum Development Hub

Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Chemical Reactions	**Unit Number:** 4	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:
1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.
2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.
3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Formulate a hypothesis or predict the results of an experiment.
2. Determine a balanced chemical equation for a given chemical phenomena.
3. Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).
4. Support a claim with evidence from experimental data.
5. Explain the relationship between variables within an equation when one variable changes.
6. Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.
7. Describe the components of and quantitative information from models and representations that illustrate both particulate-level properties and macroscopic-level properties.

Meaning

UNDERSTANDINGS

Students will understand that…

1. A substance that changes its properties, or that changes into a different substance can be represented by chemical equations.
2. When a substance changes into a new substance, or when its properties change, no mass is lost or gained.
3. A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

ESSENTIAL QUESTIONS

1. What makes fireworks explode?
2. Why is the mass of a raw egg different than a boiled egg?
3. What are the processes related to changes in a substance?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. A physical change occurs when a substance undergoes a change in properties but not a change in composition. Changes in the phase of a substance (solid, liquid gas) or formation/separation of mixtures of substances are common physical changes.
2. A chemical change occurs when substances are transformed into new substances, typically with different compositions. Production of heat or light, formation of a gas, formation of a precipitate, and/or color change provide possible evidence that a chemical change has occurred.
3. All physical and chemical processes can be represented symbolically by balanced equations.
4. Chemical equations represent chemical changes.These changes are the result of a rearrangement of atoms into new combinations; thus, and=y representation of a chemical change must contain equal numbers of atoms of every element before and after the change occurred. Equations thus demonstrate that mass is conserved in chemical reactions.
5. Balanced molecular, complete ionic, and net ionic equations are differing symbolic forms used to represent a chemical reaction. The form used to represent the reaction depends on the context in which it is to be used.
6. Balanced chemical equations in their various forms can be translated into symbolic particulate representations.
7. Processes that involve the breaking and/or formation of chemical bonds are typically classified as chemical processes. Processes that involve only changes in intermolecular interactions, such as phase changes, are typically classified as physical processes.
8. Sometimes physical processes involve the breaking of chemical bonds. For example, plausible arguments could be made for the dissolution of a salt in water, as either a physical or chemical process, involves breaking of ionic bonds, and the formation of ion- dipole interactions between ions and solvent.
9. Because atoms must be conserved during a chemical process, it is possible to calculate product amounts by using known reactant amounts, or to calculate reactant amounts given known product amounts.
10. Coefficients of balanced chemical equations contain information regarding the proportionality of the amounts of substances involved in the reaction. These values can be used in chemical calculations involving the mole concept.
11. Stoichiometric calculations can be combined with the ideal gas law and calculations involving molarity to quantitatively study gases and solutions.
12. Titrations may be used to determine the concentration of an analyte in solution. The titrant has a known concentration of a species that reacts specifically and quantitatively with the analyte. The equivalence point of the titration occurs when the analyte is totally consumed by the reacting species in the titrant. The equivalence point is often indicated by a change in a property (such as color) that occurs when the equivalence point is reached. This observable event is called the endpoint of the titration.
13. Acid-base reactions involve transfer of one or more protons between chemical species.

14. Oxidation-reduction reactions involve transfer of one or more electrons between chemical species, as indicated by changes in oxidation numbers of the involved species. Combustion is an important subclass of oxidation-reduction reactions, in which a species reacts with oxygen gas. In the case of hydrocarbons, carbon dioxide and water are products of complete combustion.
15. In a redox reaction, electrons are transferred from the species that is oxidized to the species that is reduced.
16. Oxidation numbers may be assigned to each of the atoms in the reactants and products; this is often an effective way to identify the oxidized and reduced species in a redox reaction.
17. Precipitation reactions frequently involve mixing ions in aqueous solution to produce an insoluble or sparingly soluble ionic compound. All sodium, potassium, ammonium, and nitrate salts are soluble in water.
18. By definition, a Bronsted-Lowry acid is a proton donor and a Bronsted-Lowry base is a proton acceptor.
19. Only in aqueous solutions, water plays an important role in many acid-base reactions, as its molecular structure allows it to accept protons from and donate protons to dissolved species.
20. When an acid or base ionizes in water, the conjugate acid-base pairs can be identified in the relative strengths compared.
21. Balanced chemical equations for redox reactions can be constructed from half-reactions.

SKILLS

Students will be skilled at (be able to do)...

1. Identify evidence of chemical and physical changes in matter.
2. Represent changes in matter with a balanced chemical or net ionic equation:
    a. For physical changes.
    b. For given information about the identity of the reactants and/or products.
    c. For ions in a given chemical reaction.
3. Represent a given chemical reaction or physical process with a consistent particulate model.
4. Explain the relationship between macroscopic characteristics and bond interactions for:
    a. Chemical processes.
    b. physical processes.
5. Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.
6. Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.
7. Identify a reaction as acid-base, oxidation-reduction, or precipitation.
8. Identify species as Bronsted- Lowry acids, bases, and/or conjugate acid-base pairs, based on proton transfer involving those species.
9. Represent a balanced redox reaction equation using half-reactions.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?
How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Identify evidence of chemical and physical changes in matter. 2. Represent changes in matter with a balanced chemical or net ionic equation: a. For physical changes. b. For given information about the identity of the reactants and/or products. c. For ions in a given chemical reaction. 3. Represent a given chemical reaction or physical process with a consistent particulate model. 4. Explain the relationship between macroscopic characteristics and bond interactions for: a. Chemical processes. b. physical processes. 5. Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process. 6. Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion. 7. Identify a reaction as acid-base, oxidation-reduction, or precipitation. 8. Identify species as Bronsted- Lowry acids, bases, and/or conjugate acid-base pairs, based on proton transfer involving those species. 9. Represent a balanced redox reaction equation using half-reactions.
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?

Curriculum Development Hub

This section provides a summary of the Key Learning Events and Instruction *Teachers may summarize the topics within lessons or may utilize [Laurel UbD Lesson Plan Template](#)* [Jump to Table of Contents](#)
Summary of Key Learning Events and Instruction Chapter 1 will introduce physical and chemical change. Chapter 3 will introduce chemical equations and stoichiometry. Chapter 4 will introduce chemical reactions in solution and their stoichiometry. Chapter 16 will deepen the understanding of acid-base reactions. Chapter 17 will deepen the understanding of precipitate reactions. Chapter 20 will deepen the understanding of redox reactions.

Unit 5 Electrons in Atoms

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Kinetics	**Unit Number:** 5	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

[Curriculum Development Hub](#)

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
2. Explain the relationship between variables within an equation when one variable changes.
3. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.
4. Determine a balanced chemical equation for a given chemical phenomena.
5. Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).
6. Describe the components of and quantitative information from models and representations that illustrate both particulate-level properties and macroscopic-level properties.

Meaning

UNDERSTANDINGS

Students will understand that…

1. Some reactions happen quickly, while others happen more slowly and depend on reactant concentrations and temperature.
2. There is a relationship between the speed of a reaction and the collision frequency of particle collisions.
3. Many chemical reactions occur through a series of elementary reactions. These elementary reactions when combined form a chemical equation.
4. The speed at which a reaction occurs can be influenced by a catalyst.

ESSENTIAL QUESTIONS

1. Why are some reactions faster than other reactions?
2. How long will a marble statue last?
3. How can a sports drink cure a headache?
4. Why does bread rise?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. The kinetics of a chemical reaction is defined as the rate at which an amount of reactants is converted to products per unit of time.

2. The rates of change of reactant and product concentrations are determined by the stoichiometry in the balanced chemical equation.
3. The rate of reaction is influenced by reactant concentrations, temperature, surface area, catalysts, and other environmental factors.
4. Experimental methods can be used to monitor the amounts of reactants and/or products of a reaction and to determine the rate of the reaction.
5. The rate law expresses the rate of a reaction as proportional to the concentration of each reactant raised to a power.
6. The power of each reactant in the rate law is the order of the reactions with respect to that reactant. The sum of the powers of the reactant concentrations in the rate law is the overall order of the reaction.
7. The proportionality constant in the rate law is called the rate constant. The value of this constant is temperature dependent and the units reflect the overall reaction order.
8. Comparing initial rates of a reaction is a method to determine the order with respect to each reactant.
9. The order of a reaction can be inferred from a graph of concentration of reactant versus time.
10. If a reaction is first order with respect to a reactant being monitored, a plot of the natural log (ln) of the reactant concentration as a function of time will be linear.
11. If a reaction is second order with respect to a reactant being monitored, a plot of the reciprocal of the concentration of that reactant as a function of time will be linear.
12. The slopes of the concentration versus time data for zeroth, first and second order reactions can be used to determine the rate constant for the reaction.
13. Half-life is a critical parameter for the first order reactions because the half-life is constant and related to the rate constant for the reaction by the equation: $t1/2 = 0.693/k$.
14. Radioactive decay processes provide an important illustration of first order kinetics.
15. The rate law of an elementary reaction can be inferred from the stoichiometry of the molecules participating in a collision.
16. Elementary reactions involving the simultaneous collision of three or more particles are rare.
17. For an elementary reaction to successfully produce products, reactants must successfully collide to initiate bond-breaking and bond-making events.
18. In most reactions, only a small fraction of the collisions leads to a reaction. Successful collisions have both sufficient energy to overcome energy barriers and orientations that allow the bonds to rearrange in the required manner.
19. The Maxwell-Boltzmann distribution curve describes the distribution of particle energies; this distribution can be used to gain a qualitative estimate of the fraction of collisions with sufficient energy to lead to a reaction, and also how that fraction depends on temperature.
20. Elementary reactions typically involve the breaking of some bonds and the forming of new ones.
21. The reaction coordinate is the axis along which the complex set of motions involved in rearranging reactants to form products can be plotted.
22. The energy profile gives the energy along the reaction coordinate, which typically proceeds from reactants, through a transition state, to products. The energy difference between the reactants and the transition state is the activation energy for the forward reaction.
23. The Arrhenius equation relates the temperature dependence of the rate of an elementary reaction to the activation energy needed by molecular collisions to reach the transition state.
24. A reaction mechanism consists of a series of elementary reactions, or steps, that occur in a sequence. The components may include reactants, intermediates, products, and catalysts.
25. The elementary steps when combined should align with the overall balanced equation of a chemical reaction.
26. A reaction intermediate is produced by some elementary steps and consumed by others, such that it is present only while a reaction is occurring.
27. Experimental detection of a reaction intermediate is a common way to build evidence in support of one reaction mechanism over an alternative mechanism.
28. For reaction mechanisms in which each elementary step is irreversible, or in which the first step is rate limiting, the rate law of the reaction is set by

the molecularity of the slowest elementary step (i.e., the rate limiting step).

29. If the first elementary reaction is not really limiting, approximations (such as steady state) must be made to determine a rate law expression.
30. Knowledge of energetics of each elementary reaction in a mechanism allows for the construction of an energy profile for a multi-step reaction.
31. In order for a catalyst to increase the rate of a reaction, the addition of the catalyst must increase the number of effective collisions and or provide a reaction path with a lower activation energy relative to the original reaction coordinate.
32. In a reaction mechanism containing a catalyst, the net concentration of the catalyst is constant. However, the catalyst will frequently be consumed in the rate-determining step of the reaction, only to be regenerated in a subsequent step in the mechanism.
33. Some catalysts accelerate a reaction by binding to the reactant(s). The reactants are either oriented more favorably or react with lower activation energy. There is often a new reaction intermediate in which the catalyst is bound to the reactant(s). Many enzymes function in this manner.
34. Some catalysts involved covalent bonding between the catalyst and the reactant. An example is acid-base catalysis, in which a reactant or intermediate either gains or loses a proton. This introduces a new reaction intermediate and new elementary reactions involving that intermediate.
35. In surface catalysis, a reactant or intermediate binds to, or forms a covalent bond with, the surface. This introduces elementary reactions involving these new bound reaction intermediate(s).

SKILLS

Students will be skilled at (be able to do)...

1. Explain the relationship between the rate of a chemical reaction and experimental parameters.
2. Represent experimental data with a consistent rate law expression.
3. Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time.
4. Represent an elementary reaction as a rate law expression using stoichiometry.
5. Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions.
6. Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile.
7. Identify the components of a reaction mechanism.
8. Identify the rate law for a reaction from a mechanism in which the first step is rate limiting.
9. Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting.
10. .Represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile.
11. Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	Assessment Evidence

1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Explain the relationship between the rate of a chemical reaction and experimental parameters. 2. Represent experimental data with a consistent rate law expression. 3. Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time. 4. Represent an elementary reaction as a rate law expression using stoichiometry. 5. Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions. 6. Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile. 7. Identify the components of a reaction mechanism. 8. Identify the rate law for a reaction from a mechanism in which the first step is rate limiting. 9. Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting. 10. .Represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile.
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize [Laurel UbD Lesson Plan Template]

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Summary of Key Learning Events and Instruction

Chapter 14 will cover kinetics and reaction mechanisms.

Unit 6 Periodic Table Jump to Table of Contents			
Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Thermodynamics	**Unit Number:** 6	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions ***What are the overarching takeaways and big ideas for students?*** Jump to Table of Contents
Big Ideas:

Curriculum Development Hub

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
2. Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.
3. Make observation or collect data from representations of laboratory setups or results, while attending to precision where appropriate.
4. Describe the components of and quantitative information from models and representations that illustrate both particulate-level properties and macroscopic-level properties.
5. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
6. Identify quantities needed to solve a problem from given information (e.g. text, mathematical expressions, graphs, or tables).

Meaning

UNDERSTANDINGS

Students will understand that…

1. Changes in a substance’s properties or change into a different substance requires an exchange of energy.
2. The energy exchanged in a chemical transformation is required to break and form bonds.

ESSENTIAL QUESTIONS

1. Why is energy released when water becomes an ice cube?

2. How are chemical transformations that require bonds to break and form influenced by energy?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. Temperature changes in a system indicate energy changes.
2. Energy changes in a system can be described as endothermic and exothermic processes such as the heating or cooling of a substance, phase changes, or chemical transformations.
3. When a chemical reaction occurs, the energy of the system either decreases (exothermic reaction), increases (endothermic reaction), or remains the same. For exothermic reactions, the energy lost by the reacting species (system) is gained by the surroundings, as heat transfer from or work done by the system. Likewise, for endothermic reactions, the system gains energy from the surroundings by heat transfer to or work done by the system.
4. The formation of a solution may be an exothermic or endothermic process, depending on the relative strengths of intermolecular/ interparticle interactions before and after the dissolution process.
5. A physical or chemical process can be described with an energy diagram that shows the endothermic or exothermic nature of that process.
6. The particles in a warmer body have a greater average kinetic energy than those in a cooler body.
7. Collisions between particles and thermal contacts can result in the transfer of energy. This process is called heat transfer, heat exchange, or transfer of energy as heat.
8. Eventually, thermal equilibrium is reached as the particles continue to collide. At thermal equilibrium, the average kinetic energy of both bodies is the same, and hence, their temperatures are the same.
9. The heating of a cool body by a warmer body is an important form of energy transfer between two systems. The amount of heat transferred between two bodies may be quantified by the heat transfer equation: $q = mc\Delta T$. Calorimetry experiments are used to measure the transfer heat.
10. The first law of thermodynamics states that energy is conserved in chemical and physical processes.

11. The transfer of a given amount of thermal energy will not produce the same temperature change in equal masses of matter with differing specific heat capacities.
12. Heating system increases the energy of the system, while cooling a system decreases the energy of the system.
13. The specific heat capacity of a substance and the molar heat capacity are both used in energy calculations.
14. Chemical systems change their energy through three main processes: heating/cooling, phase transitions, and chemical reactions.
15. Energy must be transferred to a system to cause a substance to melt (or boil). The energy of the system therefore increases as the system undergoes a solid-to-liquid (or liquid-to-gas) phase transition. Likewise, a system releases energy when it freezes (or condenses). The energy of the system decreases as the system undergoes a liquid-to-solid (or gas-to-liquid) phase transition. The temperature of a pure substance remains constant during a phase change.
16. The energy absorbed during a phase change is equal to the energy released during a complementary phase change in the opposite direction. For example, the molar heat of condensation of a substance is equal to the negative of its molar heat of vaporization.
17. The enthalpy change of a reaction gives the amount of heat energy released (for negative values) or absorbed (for positive values) by a chemical reaction to constant pressure.
18. During a chemical reaction, bonds are broken and/or formed, and these events change the potential energy of the system.
19. The average energy required to break all of the bonds in the reactant molecules can be estimated by adding up the average bond energies of all the bonds in the reactant molecules. Likewise, the average energy released in forming the bonds in the product molecules can be estimated. If the energy released is greater than the energy required, the reaction is exothermic. If the energy required is greater than the energy released, the reaction is endothermic.
20. Tables of standard enthalpies of formation can be used to calculate the standard enthalpies of reactions. Although the concept of State function is not required for the course, two principles of hess's law should be understood. first, when a reaction is reversed, the enthalpy change stays constant in magnitude but becomes reversed in mathematical sign. second, when two or more reactions are added to obtain an overall reaction, the individual anthropy changes of each reaction are added to obtain the net enthalpy of the overall reaction.
21. When the products of a reaction are at different temperature than their surroundings, they exchange energy with the surroundings to reach thermal equilibrium. thermal energy is transferred to the surroundings from the products of an exothermic reaction. thermal energy is transferred from the surroundings to the products of an endothermic reaction.

SKILLS

Students will be skilled at (be able to do)...

1. Explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation.
2. Represent a chemical or physical transformation with an energy diagram.
3. Explain the relationship between the transfer of thermal energy and molecular collisions.
4. Calculate the heat q absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature.
5. Explain changes in the heat q absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition.
6. Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction.
7. Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction

8. Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation.
9. Represent a chemical or physical process as a sequence of steps.
10. Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpies of the individual steps.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation. 2. Represent a chemical or physical transformation with an energy diagram. 3. Explain the relationship between the transfer of thermal energy and molecular collisions. 4. Calculate the heat q absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature. 5. Explain changes in the heat q absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition. 6. Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction. 7. Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction 8. Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation. 9. Represent a chemical or physical process as a sequence of steps. 10. Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpies of the individual steps.

1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapters 5 and 19 will introduce and cover thermodynamics.

Unit 7 Ionic Bonding

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Equilibrium	**Unit Number:** 7	**Created: 2022 - 2023**	**Revised:** TBD

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Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6

Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2

Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.

2. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
3. Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.
4. Explain the relationship between variables within an equation when one variable changes.
5. Identify quantities needed to solve a problem from given information (e.g. text, mathematical expressions, graphs, or tables).
6. Represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic).
7. Explain the connection between the experimental results and chemical concepts, processes, or theories.
8. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).

Meaning

UNDERSTANDINGS

Students will understand that…

1. Some reactions can occur in both forward and reverse directions, sometimes proceeding in each direction simultaneously.
2. A system at equilibrium depends on the relationships between concentrations, partial pressures of chemical species, and equilibrium constant K.
3. Systems at equilibrium respond to external stresses to offset the effect of the stress.
4. The dissolution of a salt is a reversible process that can be influenced by environmental factors such as pH or other dissolved ions.

ESSENTIAL QUESTIONS

1. Why is a waterfall considered a spontaneous reaction?
2. How can reactions occur in more than one direction?
3. How is caffeine removed from coffee?
4. Why is food stored in a refrigerator?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. Many observable processes are reversible. Examples include evaporation and condensation of water, absorption and desorption of a gas, or dissolution and precipitation of a salt. Some important reversible chemical processes include that transfer of protons in acid-base reactions and the transfer of electrons in redox reactions.
2. When equilibrium is reached, no observable changes occur in the system. Reactants and products are simultaneously present, and the concentrations for partial pressures of all species remain constant.
3. The equilibrium state is dynamic. The forward and reverse processes continue to occur at equal rates, resulting in no net observable change.
4. Graphs of concentration, partial pressure, or rate of reaction versus time for simple chemical reactions can be used to understand the establishment of chemical equilibrium.
5. If the rate of the forward reaction is greater than the reverse reaction, then there is a net conversion of reactants to products. If the rate of reverse reaction is greater than the forward reaction, then there is a net conversion of products to reactants. An equilibrium state is reached when these rates are equal.
6. The reaction quotient, Q_c, describes the relative concentrations of reaction species at any time. For gas phase reactions, the reaction quotient may instead be written in terms of pressures as Q_p. The reaction quotient tends toward the equilibrium constant such that at equilibrium, K_c equals $Q_c$and K_p equals Q_p.
7. The reaction quotient does not include the substances whose concentrations (or partial pressures) are independent of the amounts, such as for solids and pure liquids.
8. Equilibrium constants can be determined from experimental measurements of the concentrations or partial pressures of the reactants and products at equilibrium.
9. Some equilibrium reactions have very large K values and proceed essentially to completion. Others have very small K values and barely proceed at all.
10. When a reaction is reversed, K is inverted.
11. When the stoichiometric coefficients of a reaction are multiplied by a factor c, K is raised to the power c.
12. When reactions are added together, the K of the resulting overall reaction is the product of the K's for the reactions that were summed.
13. Since the expressions for K and Q have identical mathematical forms, all valid algebraic manipulations of K also apply to Q.
14. Concentrations or partial pressures of species that equilibrium can be predicted given the balanced reaction, initial concentrations, and the appropriate K.
15. Particulate representations can be used to describe the relative numbers of reactant and product particles present prior to and at equilibrium, and the value of the equilibrium constant.
16. LeChatlier's principle can be used to predict the response of a system to stresses such as addition or removal of a chemical species, change in temperature, change in volume / pressure of a gas-phase system, or dilution of a reaction system.
17. LeChatlier's principle can be used to predict the effect that a stress hat will have on experimentally measurable properties such as pH, temperature, and color of a solution.

18. A disturbance to assist him in equilibrium causes Q to differ from K, thereby taking the system out of equilibrium. The system responds by bringing Q back into agreement with K, thereby establishing a new equilibrium state.
19. Some stresses, such as changes in concentration, cause a change in Q only. A change in temperature causes a change in K. In either case, the concentrations of partial pressures of species redistribute to bring Q and K back into equality.
20. The disillusion of assault is a reversible process whose extent can be described by Ksp, the solubility product constant.
21. The solubility of a substance can be calculated from the Ksp for the dissolution process. This relationship can also be used to predict the relative solubility of different substances.
22. The solubility rules can be quantitatively related to Ksp, in which Ksp values greater than 1 correspond to soluble salts.
23. The solubility of a salt is reduced to when it is dissolved into a solution that already contains one of the ions present in the salt. The impact of this common ion effect on the solubility can be understood quantitatively using LeChatlier's principle or calculated from the Ksp for the dissolution process.
24. Solubility of assault is pH sensitive when one of the constituent ions is a weak acid or base. These effects can be understood quantitatively using Le Chatelier's principle.
25. The free energy change ΔG° for dissolution of a substance reflects a number of factors: the breaking of the intermolecular interactions that hold the solid together, the reorganization of the solvent around the dissolved species, and the interaction of the dissolved species with the solvent. It is possible to estimate the sign and relative magnitude of the enthalpic and entropic contributions to each of these factors. However, making predictions for the total change in free energy of dissolution can be challenging due to the cancellations among the free energies associated with the three factors cited.

SKILLS

Students will be skilled at (be able to do)...

1. Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations.
2. Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions.
3. Represent the reaction quotient Qcp or Q, for a reversible reaction, and the corresponding equilibrium expressionsKc = Qc or Kp = Qp .
4. Calculate Kc or Kp based on experimental observations of concentrations or pressures at equilibrium.
5. Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium.
6. Represent a multistep process with an overall equilibrium expression, using the constituent K expressions for each individual reaction.
7. Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant.
8. Represent a system undergoing a reversible reaction with a particulate model.
9. Identify the response of a system at equilibrium to an external stress, using Le Châtelier's principle.
10. Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium.
11. Calculate the solubility of a salt based on the value of Ksp for the salt.
12. Identify the solubility of a salt, and/or the value of Ksp for the salt, based on the concentration of a common ion already present in solution.
13. Identify the qualitative effect of changes in pH on the solubility of a salt.
14. Explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?
How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations. 2. Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions. 3. Represent the reaction quotient Qcp or Q, for a reversible reaction, and the corresponding equilibrium expressionsKc = Qc or Kp = Qp . 4. Calculate Kc or Kp based on experimental observations of concentrations or pressures at equilibrium. 5. Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium. 6. Represent a multistep process with an overall equilibrium expression, using the constituent K expressions for each individual reaction. 7. Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant. 8. Represent a system undergoing a reversible reaction with a particulate model. 9. Identify the response of a system at equilibrium to an external stress, using Le Châtelier's principle. 10. Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium. 11. Calculate the solubility of a salt based on the value of Ksp for the salt. 12. Identify the solubility of a salt, and/or the value of Ksp for the salt, based on the concentration of a common ion already present in solution. 13. Identify the qualitative effect of changes in pH on the solubility of a salt. 14. Explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process.
1. Accuracy	OTHER EVIDENCE:

2. Significant Figures 3. Evidence 4. Detailed	1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapter 15 will introduce equilibrium and LeChatelier’s principle.
Chapter 17 will introduce Ksp and solubility calculations.

Unit 8 Covalent Bonding

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Course Title:Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don’t get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Acids and Bases	**Unit Number:** 8	**Created: 2022 - 2023**	**Revised:** TBD

Curriculum Development Hub

Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6

Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2

Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

2. Explain the relationship between variables within an equation when one variable changes.
3. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
4. Identify information presented graphically to solve a problem.
5. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
6. Make observation or collect data from representations of laboratory setups or results, while attending to precision where appropriate.
7. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
8. Explain how potential sources of experimental error may affect the experimental results.

Meaning

UNDERSTANDINGS

Students will understand that…

1. The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved.
2. A buffered solution resists changes to its pH when small amounts of acids or bases are added.

ESSENTIAL QUESTIONS

1. How are reactions involving acids and bases related to pH?
2. How does your body maintain pH balance?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. The concentrations of hydronium ion and hydroxide ion are often reported as pH and pOH, respectively.
2. Water autoionizes with an equilibrium constant Kw.
3. In pure water, pH equals pOH is called a neutral solution. At 25° celsius, pKw equals 14.0 and thus pH = pOH = 7.0.
4. The value of Kw is temperature dependent, so the pH of pure, neutral water will deviate from 7.0 at temperatures other than 25° C.
5. Molecules of a strong acid will completely ionize an aqueous solution to produce hydronium ions. As such, the concentration of hydronium in a strong acid solution is equal to the initial concentration of the strong acid and thus the pH of the strong acid solution is easily calculated.
6. When dissolved in solution, strong bases completely dissociate to produce hydroxide ions. As such, the concentration of OH^- in a strong base solution is equal to the initial concentration of the strong base, and thus the pOH (and pH) of the strong base solution is easily calculated.
7. Weak acids react with water to produce hydronium ions. However, molecules of a weak acid will only partially ionize in this way. In other words, only a small percentage of molecules of a weak acid are ionized in a solution. Thus, the concentration of hydronium is much less than the initial concentration of the molecular acid, and the vast majority of the acid molecules remain un-ionized.
8. A solution of a weak acid involves equilibrium between an un-ionized ion acid and its conjugate base. The equilibrium constant for the reaction is Ka often reported as pKa. The pH of a weak acid solution can be determined from the initial acid concentration and the pKa.
9. Weak bases react with water to produce hydroxide ions in solution. However, ordinarily just a small percentage of the molecules of a weak base in solution will ionize in this way. Thus, the concentration of OH^- in the solution does not equal the initial concentration of the base, and the vast majority of the base molecules remain un-ionized.
10. A solution of a weak base involves equilibrium between an un-ionized base and its conjugate acid. The equilibrium constant for this reaction is Kb, often reported as pKb,. The pH of a weak base solution can be determined from the initial base concentration and the pKb.
11. When a strong acid and a strong base are mixed, they react quantitatively in a reaction represented by the equation: H^+ (aq) + OH^- (aq) ⟶ H_2O (l). The pH of the resulting solution may be determined from the concentration of the excess reactant.
12. When a weak acid and a strong base are mixed, they react quantitatively in a reaction represented by the equation: HA (aq) + OH^- (aq) ⟶ A^- (aq) + H_2O (l). If the weak acid is in excess, then a buffer solution is formed, and the pH can be determined from the Henderson-Hasselbalch equation. If the strong base is in excess, then the pH can be determined from the moles of excess hydroxide ion and the total volume of solution. If they are equimolar, then the (slightly basic) pH can be determined from the equilibrium represented by the equation: A^- (aq) + H_2O (l) ⟶ HA (aq) + OH^- (aq).
13. When a weak base and a strong acid are mixed, they react quantitatively in a reaction represented by the equation: B (aq) + H_3O^+ (aq) ⟶ HB^+ (aq) + H_2O (l). If the weak base is in excess, then a buffer solution is formed, and the pH can be determined from the Henderson-Hasselbalch equation. If the strong acid is in excess, then the pH can be determined from the moles of excess hydronium ion and the total volume of solution. If they are equimolar, then the (slightly acidic) pH can be determined from the equilibrium represented by the equation: HB^+ (aq) + H_2O (l) ⟶ B (aq) + H_3O^+ (aq) .
14. When a weak acid and a weak base are mixed, they will react to an equilibrium state whose reaction may be represented by the equation: HA (aq) + B (aq) ⇆ A^- (aq) + HB^+ (aq).
15. An acid-base reaction can be carried out under controlled conditions in a titration. A titration curve, plotting pH against the volume of titrant added, is useful for summarizing results from a titration.
16. At the equivalence point, the number of moles of titrant added is equal to the number of moles of analyte originally present. This relationship can be used to obtain the concentration of the analyte. This is the case for titrations of strong acids/bases and weak acids/bases.

17. For titrations of weak acids/bases, it is useful to consider the point halfway to the equivalence point, that is, the half-equivalence point. At this point, there are equal concentrations of each species in the conjugate acid-base pair, for example, for a weak acid [HA] = [A−]. Because pH = pK and basa when the conjugate acid e have equal concentrations, the pKa can be determined from the pH at the halfequivalence point in a titration.
18. For polyprotic acids, titration curves can be used to determine the number of acidic protons. In doing so, the major species present at any point along the curve can be identified, along with the pKa associated with each proton in a weak polyprotic acid.
19. The protons on a molecule that will participate in acid-base reactions, and the relative strength of these protons, can be inferred from the molecular structure. a.Strong acids (such as HCl, HBr, HI, HClO4 , H2 SO4 , and HNO3) have very weak conjugate bases that are stabilized by electronegativity, inductive effects, resonance, or some combination thereof. b.Carboxylic acids are one common class of weak acid. c.Strong bases (such as group I and II hydroxides) have very weak conjugate acids. d.Common weak bases include nitrogenous bases such as ammonia as well as carboxylate ions. e.Electronegative elements tend to stabilize the conjugate base relative to the conjugate acid, and so increase acid strength.
20. The protonation state of an acid or base (i.e., the relative concentrations of HA and A−) can be predicted by comparing the pH of a solution to the pKa of the acid in that solution. When solution pH < acid pKa , the acid form has a higher concentration than the base form. When solution pH > acid pKa , the base form has a higher concentration than the acid form.
21. The protonation state of an acid or base (i.e., the relative concentrations of HA and A−) can be predicted by comparing the pH of a solution to the pKa of the acid in that solution. When solution pH < acid pKa , the acid form has a higher concentration than the base form. When solution pH > acid pKa , the base form has a higher concentration than the acid form.
22. A buffer solution contains a large concentration of both members in a conjugate acid-base pair. The conjugate acid reacts with added base and the conjugate base reacts with added acid. These reactions are responsible for the ability of a buffer to stabilize pH.
23. The pH of the buffer is related to the pKa of the acid and the concentration ratio of the conjugate acid-base pair. This relation is a consequence of the equilibrium expression associated with the dissociation of a weak acid, and is described by the HendersonHasselbalch equation. Adding small amounts of acid or base to a buffered solution does not significantly change the ratio of [A−]/[HA] and thus does not significantly change the solution pH. The change in pH on addition of acid or base to a buffered solution is therefore much less than it would have been in the absence of the buffer.
24. Increasing the concentration of the buffer components (while keeping the ratio of these concentrations constant) keeps the pH of the buffer the same but increases the capacity of the buffer to neutralize added acid or base.
25. When a buffer has more conjugate acid than base, it has a greater buffer capacity for addition of added base than acid. When a buffer has more conjugate base than acid, it has a greater buffer capacity for addition of added acid than base.

SKILLS

Students will be skilled at (be able to do)...

1. Calculate the values of pH andpOH,based on Kw and the concentration of all species present in a neutral solution of water.
2. Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base.
3. Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.
4. Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases.
5. Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.
6. Explain the relationship between the strength of an acid or base and the structure of the molecule or ion.
7. Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pKa of the conjugate acid or the pKb of the conjugate base.
8. Explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered

solution.

9. Identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer.
10. Explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Calculate the values of pH andpOH,based on Kw and the concentration of all species present in a neutral solution of water. 2. Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base. 3. Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base. 4. Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases. 5. Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components. 6. Explain the relationship between the strength of an acid or base and the structure of the molecule or ion. 7. Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pKa of the conjugate acid or the pKb of the conjugate base. 8. Explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered solution. 9. Identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer. 10. Explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution.

1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?

This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapter 16 will deepen the students understanding of acids and bases.

Unit 9 Naming Ionic and Covalent Compounds

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			

Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

1. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
2. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
3. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
4. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
5. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
6. Explain how modifications to an experimental procedure will alter results.
7. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

1. Some chemical or physical processes cannot occur without intervention.
2. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
3. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

1. How does water flow uphill?
2. How is the favorability of a chemical or physical transformation determined?
3. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

1. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
2. Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.
3. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
4. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
5. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which ΔGo < 0. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When ΔGo<0 for the process, it is said to be thermodynamically favored.
6. The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of formation of the reactants and products.
7. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.
8. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.
9. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).
10. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.
11. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under “kinetic control.” High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.
12. The phrase “thermodynamically favored” (ΔGo < 0) means that the products are favored at equilibrium (K > 1).
13. The equilibrium constant is related to free energy by the equations
14. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1.

When $\Delta G°$ is much larger or much smaller than RT, the value of K deviates strongly from 1.

15. Processes with $\Delta G° < 0$ favor products (i.e., $K > 1$) and those with $\Delta G° > 0$ favor reactants (i.e., $K < 1$).
16. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.
17. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has $\Delta G° < 0$.
18. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.
19. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.
20. For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.
21. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).
22. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials
23. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.
24. In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.
25. Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.
26. The standard cell potential Eo corresponds to the standard conditions of $Q = 1$. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when $Q = K$). Deviations from standard conditions that take the cell further from equilibrium than $Q = 1$ will increase the magnitude of the cell potential relative to Eo. Deviations from standard conditions that take the cell closer to equilibrium than $Q = 1$ will decrease the magnitude of the cell potential relative to Eo. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.
27. Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = Eo - (RT/nF) \ln Q$ to solve problems.
28. Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: a.Number of electrons transferred b.Mass of material deposited on or removed from an electrode c.Current d.Time elapsed e.Charge of ionic species EQN: $I = q/t$

SKILLS

Students will be skilled at (be able to do)...

1. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
2. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
3. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo.
4. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
5. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T.
6. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
7. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
8. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
9. Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
10. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	Assessment Evidence
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 1. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes. 2. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process. 3. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo. 4. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate. 5. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T. 6. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes. 7. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.

	8. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell. 9. Explain the relationship between deviations from standard cell conditions and changes in the cell potential. 10. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.
1. Accuracy 2. Significant Figures 3. Evidence 4. Detailed	OTHER EVIDENCE: 1. Answers to questions in Class 2. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapters 5 and 19 will introduce entropy.
Chapter 20 will cover electrochemistry and its connection to energy.

Unit 10 Introduction to Stoichiometery

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to be the equivalent of a first-year college chemistry course and to prepare students for the Chemistry Exam. The depth, speed, and rigor of the class will not be the same as first year chemistry. The Tim Shelenberger has set the curriculum for the course, and topics will fall into one of six "Big Ideas." There will be nine 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate considerable time outside of school hours in order to be successful. Please don't get behind. Students will also complete a minimum of sixteen hands-on lab activities and prepare a report for each lab. At least 25% of class time will be spent on lab activities. The emphases of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:
1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.
2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.
3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.
4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

8. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
9. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
10. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
11. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
12. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
13. Explain how modifications to an experimental procedure will alter results.
14. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

4. Some chemical or physical processes cannot occur without intervention.
5. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
6. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

4. How does water flow uphill?
5. How is the favorability of a chemical or physical transformation determined?
6. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

29. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
30. Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.
31. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
32. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
33. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which $\Delta Go < 0$. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When $\Delta Go<0$ for the process, it is said to be

thermodynamically favored.

34. The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of formation of the reactants and products.
35. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.
36. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.
37. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).
38. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.
39. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under "kinetic control." High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.
40. The phrase "thermodynamically favored" (ΔGo < 0) means that the products are favored at equilibrium (K > 1).
41. The equilibrium constant is related to free energy by the equations
42. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.
43. Processes with ΔG° < 0 favor products (i.e., K > 1) and those with ΔG° > 0 favor reactants (i.e., K < 1).
44. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.
45. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has ΔG° < 0.
46. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.
47. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.
48. For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.
49. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).
50. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials
51. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus,

a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.

52. In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.
53. Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.
54. The standard cell potential Eo corresponds to the standard conditions of Q = 1. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when Q = K). Deviations from standard conditions that take the cell further from equilibrium than Q = 1 will increase the magnitude of the cell potential relative to Eo. Deviations from standard conditions that take the cell closer to equilibrium than Q = 1 will decrease the magnitude of the cell potential relative to Eo. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.
55. Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = E^o - (RT/nF) \ln Q$ to solve problems.
56. Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: a.Number of electrons transferred b.Mass of material deposited on or removed from an electrode c.Current d.Time elapsed e.Charge of ionic species EQN: $I = q/t$

SKILLS

Students will be skilled at (be able to do)...

11. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
12. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
13. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^o.
14. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
15. Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o, and T.
16. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
17. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
18. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
19. Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
20. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?
How will you know that they did it?

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Evaluative Criteria	Assessment Evidence
5. Accuracy 6. Significant Figures 7. Evidence 8. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 11. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes. 12. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process. 13. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ∆Go. 14. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate. 15. Explain whether a process is thermodynamically favored using the relationships between K, ∆Go, and T. 16. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes. 17. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell. 18. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell. 19. Explain the relationship between deviations from standard cell conditions and changes in the cell potential. 20. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.
5. Accuracy 6. Significant Figures 7. Evidence 8. Detailed	OTHER EVIDENCE: 3. Answers to questions in Class 4. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?

This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction
Chapters 5 and 19 will introduce entropy. Chapter 20 will cover electrochemistry and its connection to energy.

Unit 11 Chemical Equations

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and

other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

15. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
16. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
17. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
18. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
19. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
20. Explain how modifications to an experimental procedure will alter results.
21. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

7. Some chemical or physical processes cannot occur without intervention.
8. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
9. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

7. How does water flow uphill?
8. How is the favorability of a chemical or physical transformation determined?
9. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

57. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
58. Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.
59. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
60. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
61. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which $\Delta Go < 0$. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When $\Delta Go<0$ for the process, it is said to be thermodynamically favored.
62. The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of formation of

the reactants and products.

63. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.
64. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.
65. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).
66. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.
67. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under “kinetic control.” High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.
68. The phrase “thermodynamically favored” (ΔGo < 0) means that the products are favored at equilibrium (K > 1).
69. The equilibrium constant is related to free energy by the equations
70. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.
71. Processes with ΔG° < 0 favor products (i.e., K > 1) and those with ΔG° > 0 favor reactants (i.e., K < 1).
72. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.
73. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has ΔG° < 0.
74. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.
75. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.
76. For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.
77. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).
78. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials
79. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.
80. In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a

driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.

81. Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.
82. The standard cell potential Eo corresponds to the standard conditions of $Q = 1$. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when $Q = K$). Deviations from standard conditions that take the cell further from equilibrium than $Q = 1$ will increase the magnitude of the cell potential relative to Eo. Deviations from standard conditions that take the cell closer to equilibrium than $Q = 1$ will decrease the magnitude of the cell potential relative to Eo. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.
83. Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = Eo - (RT/nF) \ln Q$ to solve problems.
84. Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: a.Number of electrons transferred b.Mass of material deposited on or removed from an electrode c.Current d.Time elapsed e.Charge of ionic species EQN: $I = q/t$

SKILLS

Students will be skilled at (be able to do)...

21. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
22. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
23. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo.
24. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
25. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T.
26. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
27. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
28. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
29. Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
30. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	**Assessment Evidence**

9. Accuracy 10. Significant Figures 11. Evidence 12. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 21. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes. 22. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process. 23. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo. 24. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate. 25. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T. 26. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes. 27. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell. 28. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell. 29. Explain the relationship between deviations from standard cell conditions and changes in the cell potential. 30. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.
9. Accuracy 10. Significant Figures 11. Evidence 12. Detailed	OTHER EVIDENCE: 5. Answers to questions in Class 6. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize [Laurel UbD Lesson Plan Template]

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Summary of Key Learning Events and Instruction

Chapters 5 and 19 will introduce entropy.
Chapter 20 will cover electrochemistry and its connection to energy.

Unit 12 Reaction Stoichiometry [Jump to Table of Contents]			
Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions *What are the overarching takeaways and big ideas for students?* Jump to Table of Contents
Big Ideas: 1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and

other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

22. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
23. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
24. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
25. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
26. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
27. Explain how modifications to an experimental procedure will alter results.
28. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

10. Some chemical or physical processes cannot occur without intervention.
11. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
12. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

10. How does water flow uphill?
11. How is the favorability of a chemical or physical transformation determined?
12. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

85. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
86. Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.
87. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
88. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
89. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which ΔGo < 0. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When ΔGo<0 for the process, it is said to be thermodynamically favored.
90. The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of formation of

the reactants and products.

91. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.
92. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.
93. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).
94. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.
95. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under “kinetic control.” High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.
96. The phrase “thermodynamically favored” (ΔGo < 0) means that the products are favored at equilibrium (K > 1).
97. The equilibrium constant is related to free energy by the equations
98. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.
99. Processes with ΔG° < 0 favor products (i.e., K > 1) and those with ΔG° > 0 favor reactants (i.e., K < 1).
100. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.
101. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has ΔG° < 0.
102. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.
103. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.
104. For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.
105. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).
106. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials
107. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.

108. In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.
109. Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.
110. The standard cell potential Eo corresponds to the standard conditions of Q = 1. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when Q = K). Deviations from standard conditions that take the cell further from equilibrium than Q = 1 will increase the magnitude of the cell potential relative to Eo. Deviations from standard conditions that take the cell closer to equilibrium than Q = 1 will decrease the magnitude of the cell potential relative to Eo. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.
111. Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = E^o - (RT/nF) \ln Q$ to solve problems.
112. Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: a.Number of electrons transferred b.Mass of material deposited on or removed from an electrode c.Current d.Time elapsed e.Charge of ionic species EQN: $I = q/t$

SKILLS

Students will be skilled at (be able to do)...

31. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
32. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
33. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo.
34. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
35. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T.
36. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
37. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
38. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
39. Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
40. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	Assessment Evidence
13. Accuracy 14. Significant Figures 15. Evidence 16. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 31. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes. 32. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process. 33. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo. 34. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate. 35. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T. 36. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes. 37. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell. 38. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell. 39. Explain the relationship between deviations from standard cell conditions and changes in the cell potential. 40. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.
13. Accuracy 14. Significant Figures 15. Evidence 16. Detailed	OTHER EVIDENCE: 7. Answers to questions in Class 8. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapters 5 and 19 will introduce entropy.

Chapter 20 will cover electrochemistry and its connection to energy.

Curriculum Development Hub

Unit 13 States of Matter Jump to Table of Contents			
Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions ***What are the overarching takeaways and big ideas for students?*** Jump to Table of Contents
Big Ideas: 1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and

other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.

2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.

3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.

4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

29. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
30. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
31. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
32. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
33. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
34. Explain how modifications to an experimental procedure will alter results.
35. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

13. Some chemical or physical processes cannot occur without intervention.
14. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
15. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

13. How does water flow uphill?
14. How is the favorability of a chemical or physical transformation determined?
15. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

113. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
114. Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.
115. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
116. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
117. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which ΔGo < 0. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When ΔGo<0 for the process, it is said to be thermodynamically favored.
118. The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of

formation of the reactants and products.

119. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.
120. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.
121. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).
122. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.
123. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under “kinetic control.” High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.
124. The phrase “thermodynamically favored” (ΔGo < 0) means that the products are favored at equilibrium (K > 1).
125. The equilibrium constant is related to free energy by the equations
126. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.
127. Processes with ΔG° < 0 favor products (i.e., K > 1) and those with ΔG° > 0 favor reactants (i.e., K < 1).
128. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.
129. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has ΔG° < 0.
130. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.
131. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.
132. For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.
133. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).
134. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials
135. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.

136. In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.

137. Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.

138. The standard cell potential Eo corresponds to the standard conditions of Q = 1. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when Q = K). Deviations from standard conditions that take the cell further from equilibrium than Q = 1 will increase the magnitude of the cell potential relative to Eo. Deviations from standard conditions that take the cell closer to equilibrium than Q = 1 will decrease the magnitude of the cell potential relative to Eo. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.

139. Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = E_o - (RT/nF) \ln Q$ to solve problems.

140. Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: a.Number of electrons transferred b.Mass of material deposited on or removed from an electrode c.Current d.Time elapsed e.Charge of ionic species EQN: $I = q/t$

SKILLS

Students will be skilled at (be able to do)...

41. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
42. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
43. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^o.
44. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
45. Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o, and T.
46. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
47. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
48. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
49. Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
50. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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Evaluative Criteria	Assessment Evidence
17. Accuracy 18. Significant Figures 19. Evidence 20. Detailed	PERFORMANCE TASK(S)/Think GRASPS: 41. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes. 42. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process. 43. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔGo. 44. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate. 45. Explain whether a process is thermodynamically favored using the relationships between K, ΔGo, and T. 46. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes. 47. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell. 48. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell. 49. Explain the relationship between deviations from standard cell conditions and changes in the cell potential. 50. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.
17. Accuracy 18. Significant Figures 19. Evidence 20. Detailed	OTHER EVIDENCE: 9. Answers to questions in Class 10. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?
This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapters 5 and 19 will introduce entropy.
Chapter 20 will cover electrochemistry and its connection to energy.

Curriculum Development Hub

Unit 14 Gas Laws

Jump to Table of Contents

Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and

other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.
2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.
3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.
4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

36. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
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40. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
41. Explain how modifications to an experimental procedure will alter results.
42. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

16. Some chemical or physical processes cannot occur without intervention.
17. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
18. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

16. How does water flow uphill?
17. How is the favorability of a chemical or physical transformation determined?
18. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

141. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
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143. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
144. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
145. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term "spontaneous" has been used to describe processes for which ΔGo < 0. The phrase "thermodynamically favored" is preferred instead so that common misunderstandings (equating "spontaneous" with "suddenly" or "without cause") can be avoided. When ΔGo<0 for the process, it is said to be thermodynamically favored.
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formation of the reactants and products.

147. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.
148. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.
149. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).
150. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.
151. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under “kinetic control.” High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.
152. The phrase “thermodynamically favored” (ΔGo < 0) means that the products are favored at equilibrium (K > 1).
153. The equilibrium constant is related to free energy by the equations
154. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.
155. Processes with ΔG° < 0 favor products (i.e., K > 1) and those with ΔG° > 0 favor reactants (i.e., K < 1).
156. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.
157. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has ΔG° < 0.
158. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.
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161. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).
162. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials
163. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.

164. In a real system under nonstandard conditions, the cell potential will vary depending on the concentrations of the active species. The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.
165. Equilibrium arguments such as Le Châtelier's principle do not apply to electrochemical systems, because the systems are not in equilibrium.
166. The standard cell potential Eo corresponds to the standard conditions of Q = 1. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when Q = K). Deviations from standard conditions that take the cell further from equilibrium than Q = 1 will increase the magnitude of the cell potential relative to Eo. Deviations from standard conditions that take the cell closer to equilibrium than Q = 1 will decrease the magnitude of the cell potential relative to Eo. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.
167. Algorithmic calculations using the Nernst equation are insufficient to demonstrate an understanding of electrochemical cells under nonstandard conditions. However, students should qualitatively understand the effects of concentration on cell potential and use conceptual reasoning, including the qualitative use of the Nernst equation: EQN: $E = E^o - (RT/nF) \ln Q$ to solve problems.
168. Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following: a.Number of electrons transferred b.Mass of material deposited on or removed from an electrode c.Current d.Time elapsed e.Charge of ionic species EQN: $I = q/t$

SKILLS

Students will be skilled at (be able to do)...

51. Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
52. Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
53. Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^o.
54. Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
55. Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o, and T.
56. Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
57. Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
58. Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
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60. Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

Stage 2: Assessments/Evidence of Learning

What are the formative (informal) and summative (formal) assessments used to measure learning and growth?

How will you know that they did it?

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21. Accuracy 22. Significant Figures 23. Evidence 24. Detailed	OTHER EVIDENCE: 11. Answers to questions in Class 12. Questions asked during class

Stage 3: Learning Plan

What are the differentiated instructional strategies, activities, lesson plans that support the enduring understandings and essential questions for all students?

This section provides a summary of the Key Learning Events and Instruction

Teachers may summarize the topics within lessons or may utilize Laurel UbD Lesson Plan Template

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Summary of Key Learning Events and Instruction

Chapters 5 and 19 will introduce entropy.
Chapter 20 will cover electrochemistry and its connection to energy.

Unit 15 Water and Solutions

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Course Title: Chemistry with Lab	**Course Author:** Tim Shelenberger	**Grade Level(s):** 10-12	**Time/Duration:** [Type Here]
Course Summary: The Chemistry class is designed to prepare students for a first-year college chemistry course with a lab. The depth, speed, and rigor of the class will not be the same as a college or AP Chemistry course. There will be eight 43-minute periods during a six-day cycle and every second of that time will be used to cover material and complete activities. Students will need to dedicate some time outside of school hours in order to be successful. Please don't get behind. At least 25% of class time will be spent on lab activities.The emphasis of the Chemistry class will be developing an understanding of the content and practicing good science habits.			
Unit Name: Applications of Thermodynamics	**Unit Number:** 9	**Created: 2022 - 2023**	**Revised:** TBD
Standards Addressed: 3.2.10.A1; 3.2.10.A2;3.2.10.A3; 3.2.10.A4; 3.2.10.A5; 3.2.10.A6; 3.2.12.A1; 3.2.12.A2;3.2.12.A3; 3.2.12.A4; 3.2.12.A5; 3.2.12.A6 Assessment Anchors - CHEM.A.1; CHEM.A.2; CHEM.B.1; CHEM.B.2 Anchor Descriptors - CHEM.A.1.1; CHEM.A.1.2; CHEM.A.2.1;CHEM.A.2.2; CHEM.A.2.3; CHEM.B.1.1; CHEM.B.1.2; CHEM.B.1.3; CHEM.B.1.4; CHEM.B.2.1; CHEM.B.2.2			

Stage 1 Desired Results: Enduring Understandings & Essential Questions

What are the overarching takeaways and big ideas for students?

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Big Ideas:

1 - Scale, Proportion, and Quantity (SPQ) Quantities in chemistry are expressed at both the macroscopic and atomic scale. Explanations, predictions and

other forms of argumentation in chemistry require understanding the meaning of these quantities and the relationship between quantities at the same scale and across scales.
2 - Structure and Properties (SAP) Properties of substances observable at the macroscopic scale emerge from the structure of atoms and molecules and the interactions between them. Chemical reasoning moves in both directions across these scales. Properties are predicted from known aspects of the structures and interactions at the atomic scale. Observed properties are used to infer aspects of the structures and interactions.
3 - Transformations (TRA) At its heart, chemistry is about the rearrangement of matter. Understanding the details of these transformations requires reasoning at many levels as one must quantify what is occurring both macroscopically and at the atomic level during the process. This reasoning can be as simple as monitoring amounts of products made or as complex as visualizing the intermolecular forces among the species in a mixture. The rate of transformation is also of interest, as particles must move and collide to initiate reaction events.
4 - Energy (ENE) Energy has two important roles in characterizing and controlling chemical systems. The first is accounting for the distribution of energy among the components of a system and the ways that heat exchanges, chemical reactions, and phase transitions redistribute this energy. The second is considering the enthlapic and entropic driving forces for a chemical process. These are closely related to the dynamic equilibrium present in many chemical systems and the ways in which changes in experimental conditions alter the positions of these equilibria.

Transfer

Students will be able to independently use their learning to...

43. Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules.
44. Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g./performing dimensional analysis and attending to significant figures).
45. Provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification.
46. Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels.
47. Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
48. Explain how modifications to an experimental procedure will alter results.
49. Identify an appropriate theory, definition, or mathematical relationship to solve a problem.

Meaning

UNDERSTANDINGS

Students will understand that…

19. Some chemical or physical processes cannot occur without intervention.
20. The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
21. Electrical energy can be generated by chemical reactions.

ESSENTIAL QUESTIONS

19. How does water flow uphill?
20. How is the favorability of a chemical or physical transformation determined?
21. How is electrical energy generated using chemical reactions?

Stage 1: Essential Content, Concepts & Skills

What do we want students to know and be able to do?

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Acquisition

KNOWLEDGE

Students will know…

169. Entropy increases when matter becomes more dispersed. For example, the phase change from solid to liquid or from liquid to gas results in a dispersal of matter as the individual particles become freer to move and generally occupy a larger volume. Similarly, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space. For reactions involving gas-phase reactants or products, the entropy generally increases when the total number of moles of gas-phase products is greater than the total number of moles of gas-phase reactants.
170. Entropy increases when energy is dispersed. According to kinetic molecular theory (KMT), the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. As a result, the entropy of the system increases with an increase in temperature.
171. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.
172. The Gibbs free energy change for a chemical process in which all the reactants and products are present in a standard state (as pure substances, as solutions of 1.0 M concentration, or as gases at a pressure of 1.0 atm (or 1.0 bar)) is given the symbol ΔGo.
173. The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. Historically, the term “spontaneous” has been used to describe processes for which $\Delta Go < 0$. The phrase “thermodynamically favored” is preferred instead so that common misunderstandings (equating “spontaneous” with “suddenly” or “without cause”) can be avoided. When $\Delta Go<0$ for the process, it is said to be thermodynamically favored.
174. The standard Gibbs free energy change for a physical or chemical process may also be determined from the standard Gibbs free energy of

formation of the reactants and products.

175. In some cases, it is necessary to consider both enthalpy and entropy to determine if a process will be thermodynamically favored. The freezing of water and the dissolution of sodium nitrate are examples of such phenomena.

176. Knowing the values of ΔHo and ΔSo for a process at a given temperature allows ΔGo to be calculated directly.

177. In general, the temperature conditions for a process to be thermodynamically favored (ΔGo < 0) can be predicted from the signs of ΔHo and ΔSoas shown in the table below: ΔHoΔSoSymbolsΔGo<0, favored at: <0>0<>all T >0<0><no T >0>0> >high T <0<0< <low T In cases where ΔHo < 0 and ΔSo > 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically favored (ΔGo < 0). In cases where ΔHo > 0 and ΔSo < 0, no calculation of ΔGo is necessary to determine that the process is thermodynamically unfavored (ΔGo > 0).

178. Many processes that are thermodynamically favored do not occur to any measurable extent, or they occur at extremely slow rates.

179. Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under “kinetic control.” High activation energy is a common reason for a process to be under kinetic control. The fact that a process does not proceed at a noticeable rate does not mean that the chemical system is at equilibrium. If a process is known to be thermodynamically favored, and yet does not occur at a measurable rate, it is reasonable to conclude that the process is under kinetic control.

180. The phrase “thermodynamically favored” (ΔGo < 0) means that the products are favored at equilibrium (K > 1).

181. The equilibrium constant is related to free energy by the equations

182. Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.

183. Processes with ΔG° < 0 favor products (i.e., K > 1) and those with ΔG° > 0 favor reactants (i.e., K < 1).

184. An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a.Electrical energy to drive an electrolytic cell or charge a battery. b.Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis.

185. A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). In the coupled system, the individual reactions share one or more common intermediates. The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has ΔG° < 0.

186. Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate levels.

187. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically unfavored reaction. Visual representations of galvanic and electrolytic cells are tools of analysis to identify where half-reactions occur and in what direction current flows.

188. For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode.

189. Electrochemistry encompasses the study of redox reactions that occur within electrochemical cells. The reactions are either thermodynamically favored (resulting in a positive voltage) or thermodynamically unfavored (resulting in a negative voltage and requiring an externally applied potential for the reaction to proceed).

190. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials

191. ΔGo (standard Gibbs free energy change) is proportional to the negative of the cell potential for the redox reaction from which it is constructed. Thus, a cell with a positive Eo involves a thermodynamically favored reaction, and a cell with a negative Eo involves a thermodynamically unfavored reaction.

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