SCHOOL DISTRICT OF THE CHATHAMS

AP Chemistry
Grades 11 & 12
Full Year

Course Overview

This is the second year chemistry course that provides students with a college-level foundation to support future advanced coursework in chemistry. Students cultivate their understanding of chemistry through labs, problem solving, and inquiry-based investigations, as they explore topics such as: atomic structure, intermolecular forces and bonding, chemical reactions, kinetics, thermodynamics, equilibrium, and electrochemistry. Created by the AP Chemistry Development Committee, the course curriculum is compatible with many Chemistry courses in colleges and universities. Strong math and first year chemistry skills are required.

New Jersey Student Learning Standards
The New Jersey Student Learning Standards (NJSLS) can be located at www.nj.gov/education/cccs/2020/.

Physical Science:
HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Technology Standards
9.4.12.IML.7: Develop an argument to support a claim regarding a current workplace or societal/ethical issue such as climate change (e.g., NJSLSA.W1, 7.1.AL.PRSNT.4).
9.4.12.TL.2: Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.
9.4.12.TL.3: Analyze the effectiveness of the process and quality of collaborative environments.

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9.4.12.IML.2: Evaluate digital sources for timeliness, accuracy, perspective, credibility of the source, and relevance of information, in media, data, or other resources (e.g., NJSLSA.W8, Social Studies Practice: Gathering and Evaluating Sources.
9.4.12.TL.2: Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.
9.4.12.TL.3: Analyze the effectiveness of the process and quality of collaborative environments.
9.4.12.TL.4: Collaborate in online learning communities or social networks or virtual worlds to analyze and propose a resolution to a real-world problem (e.g., 7.1.AL.IPERS.6).

Career Ready Practices

CRP2. Apply appropriate academic and technical skills
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.

Interdisciplinary Connections

English Language Arts:

Reading

- RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Writing

- WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
- WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

Speaking and Listening

- SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics:

- HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.
- HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSS-ID.A.1 Represent data with plots on the real number line.
- HSS-IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.
- HSS-IC.B.6 Evaluate reports based on data.
- HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- HSF-BF.A.1 Write a function that describes a relationship between two quantities.

Units of Study

Unit 1: Review of Primary Concepts/Stoichiometry *(~14 days)*
- How does the instrument we use affect the value we are measuring?
- How do we account for error in measurement?
- How does dimensional analysis help us solve chemical problems?
- How much do you remember from your first year chemistry course?

Unit 2: Chemical Reactions *(~ 14 days)*
- Why do certain substances react to form new substances?
- How can we predict the products of a reaction given the reactants?

Unit 3: Thermodynamics *(~10 days)*
- What is the first law of thermodynamics?
- What is the second law of thermodynamics?
- What is enthalpy?
- What is entropy?
- How can the Gibbs Free Energy equation be used to determine whether or not a reaction will occur spontaneously?
- What is specific heat?

Unit 4: Kinematics *(~9 days)*
- What factors affect the rate at which a chemical reaction will take place?
- How can rate laws be determined through experimentation?
- Why is an input of energy needed to start a reaction even though some reactions release energy once the reaction is initiated?

Unit 5: Chemical Equilibrium *(~9 days)*
- What does it mean for a chemical reaction to reach chemical equilibrium?
- What are equilibrium constants and how can they be useful?
- What happens when a chemical system at equilibrium is exposed to an external change in concentration, partial pressure, temperature, or volume?

Unit 6: Acids and Bases *(~20 days)*
- What makes a substance an acid? a base?

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- Why is pure water neutral in terms of pH?
- How does pH describe the relative strength of a particular acid or base?
- How can a solution be buffered to resist a change in pH?
- What factors affect solubility?

Unit 7: Electrochemistry *(~8 days)*
- What are voltaic cells and how do they function?
- What is free energy and how is it related to the voltage of a voltaic cell?
- What are electrolytic cells and how do they function?

Unit 8: States of Matter/ Gasses *(~12 days)*
- What causes matter to take on different states?
- What characteristics define these states?
- How does the kinetic molecular theory help us to better understand the behavior of gases?
- What are intermolecular forces and what role do they play in allowing matter to change phase?
- How are molecules or ions arranged in a crystalline solid?

Unit 9: Solutions/ Mixtures *(~6 days)*
- What is solubility?
- What factors affect solubility?

Unit 10: Atomic Structure *(~6 days)*
- What is all matter composed of?
- How is the number and arrangement of electrons in an atom related to its placement within the Periodic Table of Elements?
- What other trends can be found by the arrangement of atoms on the Periodic Table of Elements?
- How does the number and placement of electrons within electron orbitals influence the types and numbers of bonds an element can make?
- How can each individual electron's position be defined?
- How do the chemical and physical properties of metals and non-metals differ?
- How can we predict whether two atoms will interact to produce an ionic bond, a covalent bond, or no bond at all?

Unit 11: Bonding *(~8 days)*
- How does the octet rule help chemists to predict what kind (and sometimes how many) of a bond an atom will make?
- How can the strength of a covalent bond be used to predict how much energy will be given off during a chemical reaction?
- How can the VESPR model help us predict the shape of molecules?
- What causes some covalent bonds to be polar, whereas others are non-polar?
- What is organic chemistry?

Unit 12: Independent Work *(~20 days)*
- How can the concepts learned this year be used in an authentic and meaningful way?

Learning Objectives/Discipline Standards of Practice

<u>Learning Objectives:</u>
Unit 1: Prior Knowledge/Stoichiometry

- Identify evidence of chemical and physical changes in matter.
- 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.
- 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.
- Explain the relationship between macroscopic characteristics and bond interactions for:
    - Chemical processes.
    - Physical processes.
- 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.
- Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept.
- Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance.
- Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
- Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.
- Calculate the number of solute particles, volume, or molarity of solutions.
- Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity.

Unit 2: Chemical Reactions

- Represent changes in matter with a balanced chemical or net ionic equation:
    1. For physical changes.
    2. For given information about the identity of the reactants and/or product.
    3. For ions in a given chemical reaction.
- Represent a given chemical reaction or physical process with a consistent particulate model.
- Identify a reaction as acid- base, oxidation-reduction, or precipitation.

Unit 3:Thermodynamics

- Explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation.
- Represent a chemical or physical transformation with an energy diagram.
- Explain the relationship between the transfer of thermal energy and molecular collisions.
- 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.
- 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.
- 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.
- Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction.
- Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation.
- Represent a chemical or physical process as a sequence of steps.
- Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpies of the individual steps.

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- Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
- Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
- Explain whether a physical or chemical process is thermo-dynamically favored based on an evaluation of ΔG^o.
- Explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process.
- Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
- Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o, and T.
- Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.

Unit 4: Kinetics

- Explain the relationship between the rate of a chemical reaction and experimental parameters.
- Represent experimental data with a consistent rate law expression
- Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time. (The integrated rate law)
- Represent an elementary reaction as a rate law expression using stoichiometry.
- Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions.
- Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile.
- Identify the components of a reaction mechanism.
- Identify the rate law for a reaction from a mechanism in which the first step is rate limiting.
- Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting.
- Represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile.
- Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism.

Unit 5: Chemical Equilibrium

- Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations.
- Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions.
- Represent the reaction quotient Qc or Qp, for a reversible reaction, and the corresponding equilibrium expressions $K_c = Q_c$ or $K_p = Q_p$.
- Calculate Kc or Kp based on experimental observations of concentrations or pressures at equilibrium.
- Explain the relationship between very large or very small values of K and the relative concentrations
- of chemical species at equilibrium.
- Represent a multistep process with an overall equilibrium expression, using the constituent K expressions for each individual reaction.
- Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant.
- Represent a system undergoing a reversible reaction with a particulate model.
- Identify the response of a system at equilibrium to an external stress, using Le Chatelier's principle.

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- Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium.
- Calculate the solubility of a salt based on the value of Ksp for the salt.
- 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.
- Identify the qualitative effect of changes in pH on the solubility of a salt.

Unit 6: Acids and Bases

- Identify species as Brønsted- Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.
- Calculate the values of pH and pOH, based on Kw and the concentration of all species present in a neutral solution of water.
- Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base.
- Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.
- Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.
- Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases.
- Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.
- 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.
- Explain the relationship between the strength of an acid or base and the structure of the molecule or ion.
- 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.
- 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.
- Identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer.
- 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.

Unit 7: Electrochemistry

- Represent a balanced redox reaction equation using half-reactions.
- Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
- Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
- Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
- Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell

Unit 8: States of Matter/ Gasses

- Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when:
    1. The molecules are of the same chemical species.
    2. The molecules are of two different chemical species.
- Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles.

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- Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles.
- Represent the differences between solid, liquid, and gas phases using a particulate- level model.
- Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.
- Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.
- 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.
- Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.

Unit 9: Solutions/ Mixtures

- Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.
- Using particulate models for mixtures:
    1. Represent interactions between components.
    2. Represent concentrations of components
- Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.

Unit 10: Atomic Structure

- Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes.
- Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region.
- Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.
- Represent the electron configuration of an element or ions of an element using the Aufbau principle.
- Explain the relationship between the photoelectron spectrum of an atom or ion and:
  A. The electron configuration of the species.
  B. The interactions between the electrons and the nucleus.
- Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.
- Explain the relationship between trends in the reactivity of elements and periodicity.

Unit 11: Bonding

- Explain the relationship between trends in the reactivity of elements and periodicity.
- Explain the relationship between the type of bonding and the properties of the elements participating in the bond.
- Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.
- Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions.
- Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.
- Represent a molecule with a Lewis diagram.
- Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures.

<u>Discipline Standards of Practice</u>

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AP Chemistry Practices

- Models and Representations
    - Describe models and representations, including across scales.
- Question and Method
    - Determine scientific questions and methods.
- Representing Data and Phenomena
    - Create representations or models of chemical phenomena.
- Model Analysis
    - Analyze and interpret models and representations on a single scale or across multiple scales.
- Mathematical Routines
    - Solve problems using mathematical relationships.
- Argumentation
    - Develop an explanation or scientific argument.

Science and Engineering Practices

- Plan and Carryout and Investigation
    - Identify or pose a testable question based on observations, data or a model
- Constructing Explanations and Designing Solutions
- Using Mathematics and Computational Thinking
    - Using data to evaluate a hypothesis
    - Perform mathematical equations in the curriculum
- Analyzing and Interpreting Data
- Developing and Using Models
    - Describe characteristics of a biological concept, process or model represented visually
- Engaging in Argument from Evidence
    - Making a scientific claim
    - Provide reasoning to justify a claim by connecting evidence to biological theories
- Asking Questions and Defining Problems
- Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts

- Structure and Function
- Stability and Change
- Systems and System Models
- Energy and Matter
- Scale, Proportion, and Quantity
- Cause and effect

Instructional Resources and Materials

Resources

Chemistry: The Central Science by Brown, LeMay & Bursten 9th ed. (Prentice Hall, 2003)

Materials & Benchmark Tasks

- Unit 1 & 2 Labs
    - Empirical Formula of a Hydrate
    - Qualitative analysis
    - Standardization of NaOH solution with a primary standard (acid-base titration)
    - An Activity Series of Metals

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    - Standardization of $KMnO_4$ solution with $K_2C_2O_4$ and determination of % of H_2O_2 in commercial hydrogen peroxide (redox titration)
    -
- Unit 3 Labs:
    - Fuel Combustion and Calorimetry
- Unit 4 Labs:
    - Rate of a reaction
    - Kinetics of Crystal Violet reaction
- Unit 5 Labs:
    - Determine the value of the equilibrium constant, K_{eq}, of a chemical reaction
    - Equilibrium and LeChatelier Principle
- Unit 6 Labs
    - Hydrolysis of Salts
    - Properties of Buffers
    - Acid-Base Titration Curves
    - Determine the Solubility Product of an Ionic Compound
- Unit 7 Labs
    - Electrochemical Cells
    - Electrolysis of Water
- Unit 8 Labs
    - Determine the Value of the Gas Constant
    - Determine the Molar Mass of a Volatile Liquid
- Unit 9 Labs
    -
- Unit 10 Labs
    - Photoelectron spectroscopy (dry lab)
- Unit 11 Labs
    - Molecular geometry
    - Molecular Polarity
    - Molecules and Light

Assessment Strategies
Assessment is designed to measure a student's mastery of a course standard and learning objective. Assessment can be used for both instructional purposes (formative assessment) and for evaluative purposes (summative assessment).

The following is a general list of the many forms assessment may take in learning.

- Tests
- Quizzes
- Lab Design
- Lab Notebooks
- Lab Reports
- Case Studies
- Data Analysis
- Presentations
- Projects
- Lab-based FRQ's

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