2023 Polymer Science

Program CIP: 15.0607 — Plastics and Polymer Engineering Technology/Technician

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The Research and Curriculum Unit (RCU), located in Starkville, as part of Mississippi State University (MSU), was established to foster educational enhancements and innovations. In keeping with the land-grant mission of MSU, the RCU is dedicated to improving the quality of life for Mississippians. The RCU enhances intellectual and professional development of Mississippi students and educators while applying knowledge and educational research to the lives of the people of the state. The RCU works within the contexts of curriculum development and revision, research, assessment, professional development, and industrial training.

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Mrs. Rosemary G. Aultman, chair
Mr. Glen V. East, vice-chair
Ms. Mary Werner
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Standards

Standards and alignment crosswalks are referenced in the appendices. Depending on the curriculum, these crosswalks should identify alignment to the standards mentioned below, as well as possible related academic topics as required in the Subject Area Testing Program in Algebra I, Biology I, English II, and U.S. History from 1877, which could be integrated into the content of the units. Mississippi's CTE polymer science curriculum is aligned to the following standards:

Society of the Plastics Industry (SPI) Standards
Founded in 1937, SPI is the plastics industry trade association representing the third-largest manufacturing industry in the United States. SPI's member companies represent the entire plastics industry supply chain, including processors, machinery and equipment manufacturers, and raw materials suppliers.
plasticsindustry.org

Applied Academic Credit Benchmarks
The *Mississippi Polymer Science Curriculum Framework* is aligned to the Chemistry course in the 2018 *Mississippi College- and Career-Readiness Standards for Science*. An alignment crosswalk can be viewed at the end of this document.

National Educational Technology Standards for Students
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Next Generation Science Standards (NGSS)
NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press. The NGSS were developed by educators, content experts and policymakers, using as a guiding document *A Framework for K-12 Science Education* from the National Research Council. The K-12 academic standards in science were developed by and for educators and school leaders. An alignment crosswalk can be viewed at the end of this document.

Preface

Secondary CTE programs in Mississippi face many challenges resulting from sweeping educational reforms at the national and state levels. Schools and teachers are increasingly being held accountable for providing applied learning activities to every student in the classroom. This accountability is measured through increased requirements for mastery and attainment of competency as documented through both formative and summative assessments. This document provides information, tools, and solutions that will aid students, teachers, and schools in creating and implementing applied, interactive, and innovative lessons. Through best practices, alignment with national standards and certifications, community partnerships, and a hands-on, student-centered concept, educators will be able to truly engage students in meaningful and collaborative learning opportunities.

The courses in this document reflect the statutory requirements as found in Section 37-3-49, *Mississippi Code of 1972*, as amended (Section 37-3-46). In addition, this curriculum reflects guidelines imposed by federal and state mandates (Laws, 1988, Ch. 487, §14; Laws, 1991, Ch. 423, §1; Laws, 1992, Ch. 519, §4 eff. from and after July 1, 1992; Strengthening Career and Technical Education for the 21st Century Act, 2019 [Perkins V]; and Every Student Succeeds Act, 2015).

Mississippi Teacher Professional Resources

The following are resources for Mississippi teachers:

Curriculum, Assessment, Professional Learning

Program resources can be found at the RCU's website, rcu.msstate.edu.

Learning Management System: An Online Resource

Learning management system information can be found at the RCU's website, under Professional Learning.

Should you need additional instructions, contact the RCU at 662.325.2510 or helpdesk@rcu.msstate.edu.

Executive Summary

Pathway Description

Polymer Science is a pathway in the polymer materials manufacturing career cluster. This program is designed for students who wish to prepare for employment or continued education in the occupations of polymer materials manufacturing. The pathway is designed to provide students with hands-on experiences related to the application of polymer science concepts in the workplace. Students will develop academic and technical skills, 21st century skills, and human relations competencies that accompany technical skills for job success and lifelong learning. Students who complete the pathway will be better prepared to enter and succeed in related programs offered by Mississippi community colleges and institutions of higher education.

College, Career, and Certifications

Two national certifications are associated with the polymer science industry, the Certified Composites Technician (CCT) and the National Certification in Plastics (NCP).

Grade Level and Class Size Recommendations

It is recommended that students enter this program as a 10th grader. Exceptions to this are a district-level decision based on class size, enrollment numbers, student maturity, and CTE delivery method. This is a hands-on, lab- or shop-based course. Therefore, a maximum of 15 students is recommended per class with only one class with the teacher at a time.

Student Prerequisites

For students to experience success in the program, the following student prerequisites are suggested:

1. C or higher in English (the previous year)
2. C or higher in high school-level math (last course taken or the instructor can specify the level of math instruction needed)
3. Instructor approval and TABE reading score (eighth grade or higher)

or

1. TABE reading and math score (eighth grade or higher)
2. Instructor approval

or

1. Instructor approval

Assessment

The latest assessment blueprint for the curriculum can be found at rcu.msstate.edu/curriculum/curriculumdownload.

Applied Academic Credit

The latest academic credit information can be found at mdek12.org/ese/approved-course-for-the-secondary-schools.

Teacher Licensure

The latest teacher licensure information can be found at mdek12.org/oel/apply-for-an-educator-license.

Professional Learning

If you have specific questions about the content of any training sessions provided, please contact the RCU at 662.325.2510 or helpdesk@rcu.msstate.edu.

Course Outlines

Option 1— Four 1-Carnegie Unit Courses

This curriculum consists of four one-credit courses that should be completed in the following sequence:

1. **Introduction to Polymer Science I—Course Code: 994502**
2. **Introduction to Polymer Science II—Course Code: 994503**
3. **Advanced Topics in Polymer Science—Course Code: 994504**
4. **Careers in Polymer Science—Course Code: 994505**

Course Description: Introduction to Polymer Science I
This course orients the students to the polymer science program and lab. During this course, students learn computer applications relevant to polymer science. They are also introduced to chemistry concepts.

Course Description: Introduction to Polymer Science II
This course emphasizes polymer synthesis and selection, the manufacturing and processing techniques associated with polymers, and the methods and benefits of plastics recycling.

Course Description: Advanced Topics in Polymer Science
This course allows students to explore an industry problem through the scientific design process and investigate advanced polymer manufacturing processes.

Course Description: Careers in Polymer Science
This course focuses on metals, ceramics, surface coatings, and composite materials.

Introduction to Polymer Science I—Course Code: 994502

Unit	Unit Title	Hours
1	Orientation to Industrial Employability and Safety	40
2	Chemistry of Solids and Solutions	70
3	Foundational Organic Chemistry	30
Total		**140**

Introduction to Polymer Science II—Course Code: 994503

Unit	Unit Title	Hours
4	Polymers	80
5	Thermoplastic Polymer Processing	60
Total		**140**

Advanced Topics in Polymer Science—Course Code: 994504

Unit	Unit Title	Hours
6	Polymer Safety and Concepts Review	30
7	Industry Guided Work-Based Learning	60
8	Advanced Polymer Manufacturing	50
Total		**140**

Careers in Polymer Science—Course Code: 994505

Unit	Unit Title	Hours
9	Metals	30
10	Ceramics and Glass	30
11	Surface Coatings	30
12	Composite Materials, Manufacturing, and Applications	50
Total		**140**

Option 2—Two 2-Carnegie Unit Courses
This curriculum consists of two 2-credit courses that should be completed in the following sequence:

1. **Polymer Science I—Course Code: 994500**
2. **Polymer Science II—Course Code: 994501**

Course Description: Polymer Science I
This course encompasses the course and lab. During the course, students learn computer applications relevant to polymer science, and they are also introduced to chemistry concepts and the structures and properties of polymers. Students are also taught the processing techniques associated with thermoplastic polymers and the methods and benefits of plastics recycling.

Course Description: Polymer Science II
This course allows students to explore an industry problem through the scientific design process and investigate advanced polymer manufacturing processes. Instruction focuses on metals, ceramics, surface coatings, and composite materials.

Polymer Science I—Course Code: 994500

Unit	Unit Title	Hours
1	Orientation to Industrial Employability and Safety	40
2	Chemistry of Solids and Solutions	70
3	Foundational Organic Chemistry	30
4	Polymers	80
5	Thermoplastic Polymer Processing	60
Total		**280**

Polymer Science II—Course Code: 994501

Unit	Unit Title	Hours
6	Polymer Safety and Concepts Review	30
7	Industry Guided Work-Based Learning	60
8	Advanced Polymer Manufacturing	50
9	Metals	30
10	Ceramics and Glass	30
11	Surface Coatings	30
12	Composite Materials, Manufacturing, and Applications	50
Total		**280**

Career Pathway Outlook

Overview

The Polymer Science pathway will target careers at the professional and technical levels in polymer science. Students enrolled in these courses should be better prepared to pursue degrees at the community college and four-year college level.

Needs of the Future Workforce

Data for this synopsis were compiled from the Mississippi Department of Employment Security (2021). Employment opportunities for each of the occupations are listed below.

Table 1.1: Current and Projected Occupation Report

Description	Jobs, 2018	Projected Jobs, 2028	Change (Number)	Change (Percent)	Average Hourly Earnings, Year
Chemical Engineers	250	260	10	4%	$52.15, 2021
Chemical Technicians	490	490	0	0%	$25.13, 2021
Chemists	250	260	10	4%	$40.12, 2021
Materials Engineers	160	160	0	0%	$41.03, 2021

Source: Mississippi Department of Employment Security; mdes.ms.gov (2021).

Perkins V Requirements and Academic Infusion

The Polymer Science curriculum meets Perkins V requirements of introducing students to and preparing them for high-skill, high-wage occupations in polymer science fields. It also offers students a program of study, including secondary, postsecondary, and institutions of higher learning courses, that will further prepare them for polymer science careers. Additionally, this curriculum is integrated with academic college- and career-readiness standards. Lastly, it focuses on ongoing and meaningful professional development for teachers as well as relationships with industry.

Transition to Postsecondary Education

The latest articulation information for secondary to postsecondary can be found at the Mississippi Community College Board website, mccb.edu.

Best Practices

Innovative Instructional Technologies

Classrooms should be equipped with tools that will teach today's digital learners through applicable and modern practices. The Polymer Science educator's goal should be to include teaching strategies that incorporate current technology. To make use of the latest online communication tools—wikis, blogs, podcasts, and social media platforms, for example—the classroom teacher is encouraged to use a learning management system that introduces students to education in an online environment and places more of the responsibility of learning on the student.

Differentiated Instruction
Students learn in a variety of ways, and numerous factors—students' background, emotional health, and circumstances, for example—create unique learners. By providing various teaching and assessment strategies, students with various learning preferences can have more opportunity to succeed.

CTE Student Organizations
Teachers should investigate opportunities to sponsor a student organization. There are several here in Mississippi that will foster the types of learning expected from the Polymer Science curriculum. Technology Student Association (TSA) and Skills USA are examples of student organizations with many outlets for polymer science students. Student organizations provide participants and members with growth opportunities and competitive events. They also open the doors to the world of industry careers and scholarship opportunities. In addition, The University of Southern Mississippi (USM) has partnered with the secondary polymer science programs to host an annual student competition. For more information, please refer to the University of Southern Mississippi Polymer Science department, usm.edu/polymer.

Cooperative Learning
Cooperative learning can help students understand topics when independent learning cannot. Therefore, you will see several opportunities in the Polymer Science curriculum for group work. To function in today's workforce, students need to be able to work collaboratively with others and solve problems without excessive conflict. The Polymer Science curriculum provides opportunities for students to work together and help each other complete complex tasks. There are many field experiences within the Polymer Science curriculum that will allow and encourage collaboration with professionals currently in the polymer science field.

Work-Based Learning
Work-based learning (WBL) is an extension of understanding competencies taught in the Polymer Science classroom. This program may require students to obtain a minimum of 35 hours, which may include but are not limited to clinicals or worksite field experiences, entrepreneurships, internships, pre-apprenticeships, school-based enterprises, job placements, and simulated worksites. These real-world connections and applications provide a link to all types of students regarding knowledge, skills, and professional dispositions. Thus, supervised collaboration and immersion into the agricultural industry are keys to students' success, knowledge, and skills development. For more information on embedded WBL, visit the Mississippi Work-Based Learning Manual on the RCU website, rcu.msstate.edu.

Professional Organizations

American Chemical Society
acs.org

Society of Plastics Engineers
4spe.org

SPI: The Plastics Industry Trade Association
plasticsindustry.org

Using This Document

Competencies and Suggested Objectives
A competency represents a general concept or performance that students are expected to master as a requirement for satisfactorily completing a unit. Students will be expected to receive instruction on all competencies. The suggested objectives represent the enabling and supporting knowledge and performances that will indicate mastery of the competency at the course level.

Teacher Resources
All teachers should request to be added to the Canvas Resource Guide for their course. For questions or to be added to the guide, send a Help Desk ticket to the RCU by emailing helpdesk@rcu.msstate.edu.

Perkins V Quality Indicators and Enrichment Material
Some of the units may include an enrichment section at the end. This material will greatly enhance the learning experiences of students. If the Polymer Science program is using a national certification, work-based learning, or another measure of accountability that aligns with Perkins V as a quality indicator, this material could very well be assessed on that quality indicator. It is the responsibility of the teacher to ensure all competencies for the selected quality indicator are covered throughout the year.

Unit 1: Orientation to Industrial Employability and Safety

Competencies and Suggested Objectives
1. Evaluate the local program and explore how personality traits and learning styles can impact success in the classroom and workplace. DOK3 a. Examine the local student handbook and program, establishing rules and guidelines. b. Examine how understanding personality and learning styles can impact learning and workplace performance. • True Colors • Animal communications • Myers-Briggs • Learning style inventories • Multiple intelligence assessments c. Describe student organizations (including SkillsUSA and Technology Student Association) activities and participate in a polymer skills competition.
2. Explain and demonstrate employability skills over the course of the program. DOK4 a. Perform a self-evaluation and compare it to traits of a quality employee (e.g., integrity, loyalty, responsibility, etc.). b. Create an educational and/or career-track plan for a selected job in materials science. c. Prepare a résumé containing essential information for polymer specific careers. d. Complete a job application. e. Describe and demonstrate the procedures for a job interview. f. Explain personnel law, requirements of Title IX law, and employment procedures as related to plastics and polymer manufacturing.
3. Explain and demonstrate the roles human relations, teamwork, and leadership play in plastics and polymer manufacturing. DOK3, 4 a. Describe and practice the qualities of an effective leader (i.e., positive attitude, image, decisiveness, communication skills, and professional knowledge). b. Prepare a project-management methodology and use it consistently. c. Research and/or participate in personal-development seminars, leadership conferences, and national/international exchange programs, or research/participate in student organizations, competitions, and related activities.
4. Describe and demonstrate safe laboratory practices and environmental responsibility when working with laboratory equipment, chemicals, and processing equipment commonly encountered in polymer-related industries. DOK1, 2, 3 a. Apply safety rules/guidelines, colors, and symbols for the lab and workplace, and establish how to use safety equipment properly (e.g., Flinn safety test/contract). b. Investigate how industrial, governmental, and environmental organizations impact safe operations in polymer-related industries. • Occupational Safety and Health Administration (OSHA) • Environmental Protection Agency (EPA) • Chemical Safety Board (CSB) • American Chemical Society (ACS)

- American National Standards Institute (ANSI)
- Food and Drug Administration (FDA)

c. Identify basic laboratory equipment and functions while correctly and safely using selected pieces of equipment.

d. Detail safe practices related to the operation of equipment in laboratories and manufacturing facilities.
   - Lockout tags
   - Safety zones and floor markings
   - Emergency stop buttons

e. Evaluate the resources available for the safe handling and disposal of chemicals.
   - Department of Transportation (DOT) placards
   - National Fire Protection Agency (NFPA) safety diamond
   - Safety Data Sheets (SDS)

5. Demonstrate the ability to manage a computer operating system in relation to plastics and polymer applications. DOK1, 4
   a. Create files and transfer them between directories and subdirectories.
   b. Produce and utilize graphics in relation to research for plastics design and production.
   c. Produce quality word processing and multimedia documents related to polymer science topics.
   d. Create an e-portfolio to include all relevant materials.

Note: Safety is to be taught as an ongoing part of the program. Students are required to complete a written safety test with 100% accuracy before entering the workspace. Documentation should be kept on file.

Note: This unit will be ongoing throughout the year. Time allotted for this unit will be distributed over the entire year.

Unit 2: Chemistry of Solids and Solutions

Competencies and Suggested Objectives
1. Apply inquiry-based and problem-solving processes and skills to scientific investigations. DOK2, 3, 4 a. Use current technologies to explore current research related to a specific topic. • Peer review • Web technology • Authentic vs. hearsay • Primary vs. secondary sources b. Clarify research questions and design laboratory investigations. c. Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations. • Hypothesis • Experimental design • Observations • Data analyses • Interpretations • Theory development d. Organize data to construct graphs (e.g., plotting points, labeling the x- and y-axis, and creating appropriate titles and legends for circle, bar, and line graphs), draw conclusions, and make inferences. e. Evaluate the procedures, data, and conclusions to critique the scientific validity of research. f. Formulate and revise scientific explanations and models using logic and evidence (data analysis). g. Collect, analyze, and draw conclusions from data to create a formal presentation using available technology (e.g., computers, calculators, Smart Board, computer-based learning, lab interfaces, etc.).
2. Demonstrate an understanding of the atomic model of matter by explaining atomic structure. DOK2 a. Describe and classify matter based on physical and chemical properties and the interactions between molecules of atoms (e.g., classifying properties such as boiling point, melting point, density, mass, volume, flammability, etc. as being physical or chemical; describing each state of matter in terms of internal energy, molecular motion, and the phase transitions within and between them). b. Classify matter as pure substances or mixtures, including homogeneous and heterogeneous mixtures and solution saturations, and investigate the conditions that impact mixture formation and stability (e.g., heat, agitation, solute-solvent compatibility, etc.). c. Develop a model of atomic and nuclear structure based on theory and knowledge of the fundamental particles including protons, neutrons, and electrons. d. Describe the properties and interactions of the three fundamental particles of the atom and explain the laws of conservation of mass, constant composition, definite proportions, and multiple proportions.

e. Use atomic numbers and mass numbers to calculate the number of protons, neutrons, and electrons in individual isotopes and ions.

3. Develop an understanding of the periodic table. DOK2
   a. Analyze patterns and trends and make predictions regarding the organization of elements in the periodic table and compare their relationships to their positions in the table (e.g., atomic number, atomic mass, metal and non-metal character, electronegativity, and reactivity).
   b. Following the Aufbau principle, write electron configurations and Lewis diagrams of elements and ions.
4. Investigate the way the atomic structure and arrangement in matter impact bonding and chemical reaction. DOK2, 3
   a. Use Lewis dot structures and periodic trends to predict and draw compound structures and formulas.
   b. Compare the properties of compounds according to their types of bonding, including metallic, ionic, and covalent bonding (e.g., non-polar and polar covalent bonds, single and multiple bonds [double and triple], and intermolecular forces, including hydrogen bonding and van der Waals forces).
   c. Classify reactions by type (synthesis, decomposition, single displacement, double displacement, combustion, and redox reactions), and identify reactants and the products involved in reaction, explaining how the electrons of reacting species interact to make these changes possible.
   d. Balance equations for chemical reactions, representing the connection between the microscopic (particles) and macroscopic (moles and bulk properties) levels of matter.

Enrichment

1. Research and explain the critical contributions and experiments of John Dalton, J. J. Thomson, Robert Millikan, Ernest Rutherford, Louis de Broglie, Erwin Schrödinger, and others to describe how each discovery contributed to the current model of atomic and nuclear structure.
2. Discuss the development of the periodic table and the contributions of Johannes Döbereiner, John Newlands, Dmitri Mendeleev, Henry Mosely, etc.
3. Use Lewis structures to predict molecular geometries (shapes and bond angles), polarities, hybridization, and intermolecular forces.
4. Using given reactants, predict possible reaction products.

Unit 3: Foundational Organic Chemistry

Competencies and Suggested Objectives
1. Identify common organic molecules and relate their structures to chemical and physical properties. DOK1 a. Construct models and illustrate structures for aliphatic, aromatic, and cyclic hydrocarbons, applying prior bonding knowledge. 2. Apply International Union of Pure and Applied Chemistry (IUPAC) nomenclature for simple organic structures and derivatives (i.e., functional groups such as alcohols, amines, aldehydes, ketones, carboxylic acids, esters, amides, ethers, etc.). DOK2, 3 a. Describe how functional groups affect properties of simple organic molecules.

Enrichment
1. Use Lewis structures to predict molecular geometries (shapes and bond angles), polarities, hybridization, and intermolecular forces. 2. Write and classify common reactions for aliphatic, aromatic, and cyclic hydrocarbons.

Unit 4: Polymers

Competencies and Suggested Objectives

1. Examine the history and development of the polymer and material science industries/professions, polymer and polymer architecture. DOK1
   a. Trace the development of polymer and material science technologies/industries from beginning through present day (e.g., Materials Through the Ages timeline, polymer development timeline).
   b. Research and describe career opportunities, including educational requirements, earnings potential, etc. for polymer and materials-related fields.
2. Differentiate between polymer structure and architecture. DOK3
   a. Structure
      - Chemical structure
      - Linear
      - Branched
      - Cross-linked
      - Tacticity
   b. Architecture
      - Phase diagram of block copolymers
        - Spherical domains
        - Continuous phase
      - Star
      - Comb
      - Brush
      - Ring
      - Dendrimer
3. Recognize and differentiate natural and synthetic polymers. DOK1, 2
   a. Describe natural polymers.
      - Cellulose
      - DNA/RNA
      - Natural rubber
      - Starches
      - Proteins
   b. Describe synthetic polymers.
      - Thermoplastics
      - Thermosets
      - Fiber
      - Films
      - Elastomers
      - Adhesives
   c. Differentiate between the properties of natural and synthetic polymers, including polydispersity, degree of polymerization, and molecular weight.

4. Relate plastics recycling/conservation principles and their effects on the environment. DOK2
    a. Classify the different types of plastics and their recycling codes.
        - PETE—Polyethylene terephthalate
        - HDPE—High-density polyethylene
        - V—Polyvinyl chloride
        - LDPE—Low-density polyethylene
        - PP—Polypropylene
        - PS—Polystyrene
        - Other plastics
    b. Research and describe the various sorting and recycling methods (e.g., primary, secondary, and tertiary recycling, or the three Rs).
    c. Debate the cost of using recycled polymers versus virgin polymers in manufacturing.
    d. Examine the human issues related to recycling for the different types of plastics, including e-waste and ocean pollution.

5. Relate small molecule chemistry to the production of polymer compounds. DOK2, 3
    - Polyethylene
    - Polypropylene
    - Polystyrene
    - Polytetrafluoroethylene
    - Polyvinyl chloride
    - Polyvinyl alcohol
    - Polyvinyl acetate
    - Polymethyl methacrylate
    - Polybutadiene
    - Polyurethanes
    - Epoxies
    - Phenolics (e.g., Bakelite, etc.)
    - Melamine

    a. Using models, demonstrate the structure of monomers and their repeat units.
    b. Using models, demonstrate the structure and synthesis of homopolymers illustrating the following: linearity, various types of branching, and tacticity.
    c. Using models, demonstrate the structure and synthesis of various types of copolymers and terpolymers illustrating the following: random, alternating, block, and graft structures.

6. Explore how the chemistry of polymer preparation affects performance properties. DOK2
    a. Describe and demonstrate different types of polymer syntheses to include condensation and addition polymerization.
    b. Communicate the relationship that exists between polymerization type (step-growth and chain-growth) and graphical representations of growth rates.
    c. Explore the effects of molecular weight, molecular weight distribution, branching, tacticity, and cross-linking on polymer properties.

7. Explore physical properties and how they affect end-use performance. DOK3
   a. Thermal transitions, glass transition temperature, and crystalline melting point
   b. Mechanical properties
   c. Rheological properties (e.g., viscosity, melt flow, etc.)

Enrichment

1. Implement additive and subtractive techniques to repurpose or reuse recyclable materials.
2. Investigate recycling and repurposing strands within the maker, tinker, and/or fab movements.
3. Research the history of rheology and viscosity.

Unit 5: Thermoplastic Polymer Processing

Competencies and Suggested Objectives
1. Differentiate between polymer synthesis, manufacturing, and processing. DOK2
2. Explain how basic processing techniques are used to convert polymer feedstock into plastic products, and manufacture plastic parts using each processing technique. DOK4 a. Describe and demonstrate single-step polymer processing techniques. • Extrusion • Injection molding • Thermoforming/vacuum-forming • Rotational molding • Fiber formation • Blow molding (extrusion and injection) • Blown film extrusion • Dip coating
3. Identify acceptable and unacceptable products for each single-step processing technique. DOK1 a. Identify short-shots, flashing, and warped parts. b. Troubleshoot various processing techniques to create good parts.
4. Apply the principles of computer-aided design and drafting (CADD) to create designs and prototypes for plastic parts. DOK3 a. Interpret and apply basic CADD symbols to create, edit, and print parts and drawings in preparation for making plastic parts. b. Demonstrate the importance of wall thickness, draft angles, ribs, fillets, and rounds in part design. c. Design, create, edit, and produce a rapid prototyped part from 2D and 3D prints/plots according to specifications. d. Compare and contrast additive and subtractive 2D and 3D manufacturing techniques in making quality parts.

Enrichment
1. Demonstrate the ability to read and interpret a basic blueprint. a. Demonstrate the ability to read the various parts of a blueprint. b. Demonstrate the ability to interpret the different views of a blueprint.

Unit 6: Polymer Safety and Concepts Review

Competencies and Suggested Objectives
1. Re-evaluate the local program and explore how personality traits and learning styles can impact success in the classroom and workplace. DOK1 a. Re-examine the local student handbook and program, establishing rules and guidelines. b. Re-examine how understanding personality and learning styles can impact learning and workplace performance, such as True Colors, animal communications, Myers-Briggs, learning style inventories, multiple intelligence assessments, etc. c. Describe student organizations (including SkillsUSA and TSA) activities and participate in a polymer skills competition.
2. Describe and demonstrate safe laboratory practices and environmental responsibility when working with laboratory equipment, chemicals, and processing equipment commonly encountered in polymer-related industries. DOK2 a. Apply safety rules/guidelines, colors, and symbols for the lab and workplace and establish how to use safety equipment properly (e.g., Flinn safety test/contract). b. Investigate how industrial, governmental, and environmental organizations impact safe operations in polymer-related industries (e.g., OSHA, EPA, CSB, ACS, ANSI, FDA, etc.). c. Identify basic laboratory equipment and functions while correctly and safely using selected pieces of equipment. d. Detail safe practices related to the operation of equipment in polymer-related laboratories and manufacturing facilities (e.g., lockout tags, safety zones and floor markings, emergency stop buttons, etc.). e. Evaluate resources available for safe handling and disposal of chemicals (e.g., DOT placards, NFTA safety diamond, SDS documents).

Note: Safety is to be taught as an ongoing part of the program. Students are required to complete a written safety test with 100% accuracy before entering the workspace. Documentation should be kept on file.
Note: This unit will be ongoing throughout the year. Time allotted for this unit will be distributed over the entire year.

Unit 7: Industry Guided Work-Based Learning

Competencies and Suggested Scenarios
1. Identify a materials science related problem encountered in industry. DOK1
2. Reach out to the polymer science advisory committee members or industry professionals to get a list of possible problems that could produce a viable solution after the students work through the scientific design process. DOK3 a. Select one materials science related problem submitted by industry to be investigated using the scientific design process.
3. Develop a detailed plan for investigating the problem. DOK3 a. Research the problem. b. Brainstorm possible solutions. c. Consider or establish constraints and specifications. d. Select option for further analysis. e. Create procedures appropriate to investigate the problem.
4. Test or research the chosen solution (i.e., prototype, process, etc.), recording any data or observations. DOK4
5. Analyze all the accumulated data and organize the findings in a clear fashion for communication of the results (i.e., graphs, tables, charts, diagrams, literary reviews, etc.). DOK4
6. Independently prepare detailed documentation of the research experience (i.e., lab report, multimedia presentation, journal article, etc.). DOK4
7. Present documentation to industry representatives for evaluation. DOK4

Unit 8: Advanced Polymer Manufacturing

Competencies and Suggested Objectives
1. Explain how additives affect the properties of a polymeric material. [DOK2] a. Explain how compounding and formulation change the properties and processing of polymers by using additives or modifiers.
2. Explain how advanced manufacturing techniques are used to create products. [DOK3] a. Describe and demonstrate advanced manufacturing processes. • Casting • Open- and closed-cell foam processing • Expanded bead molding • Calendering • Compression molding
3. Differentiate between acceptable and unacceptable products for each advanced processing technique. [DOK3] a. Troubleshoot the various processing techniques to create good parts.

Unit 9: Metals

Competencies and Suggested Objectives
1. Demonstrate a foundational understanding of the properties of metals and related materials. DOK3 a. Analyze the properties of metals as compared to other materials, including alloys, ceramics, and composites. b. Relate the macroscopic properties of metallic substances to crystalline metal microstructures.
2. Demonstrate a foundational understanding of the processing techniques for metals and related materials. DOK3 a. Assess the importance of, describe the processes used, and apply various methods of reduction to obtain metals from their ores as it pertains to industrial metals production. b. Perform conditioning processes to harden, temper, and anneal metal.

Enrichment
1. Use materials testing to analyze the macroscopic properties of metals and other materials that arise from processing and work hardening stresses.

Unit 10: Ceramics and Glass

Competencies and Suggested Objectives
1. Demonstrate a foundational understanding of the properties of ceramics and glass. [DOK3] a. Analyze the relationship between the metallic ores, metals, and ceramic materials arising from the oxidation of metallic materials. b. Assess how chemical bonding and the observable properties of ceramic materials give rise to a wide variety of ceramic uses in our society. c. Analyze the amorphous structure and properties of glass (also known as the special ceramic).
2. Demonstrate a foundational understanding of the manufacturing techniques for ceramics and glass. [DOK3] a. Examine and perform ceramic processing techniques, including Raku.

Enrichment
1. Examine and demonstrate glass batching and other glass processing techniques.

Unit 11: Surface Coatings

Competencies and Suggested Objectives
1. Describe the production of various types of surface coatings. DOK2 a. Differentiate between the types of coatings (e.g., Architectural [DIY], Original Equipment Manufacturer [OEM], and specialty purpose coatings, their properties, and their uses in industry). b. Research and communicate the development of coatings through the years, including binder type advancements (from drying oils through high solids coatings). c. Illustrate the synthesis of waterborne binders for surface coatings (i.e., emulsions). d. Identify legislation that influences the push for low to no volatile organic compounds (VOCs) coatings and discuss industry responses.
2. Demonstrate the properties of coatings. DOK3 a. Expand understanding of the use of additives with regards to coatings formulations to influence performance properties. b. Evaluate application suitability of surface coatings using various properties (e.g., impact, adhesion, hardness, flexibility, etc.).

Unit 12: Composite Materials, Manufacturing, and Applications

Competencies and Suggested Objectives
1. Examine composite materials and their configurations in final parts to determine how each affects the finished properties of a composite structure. DOK2 a. Evaluate possible matrix and reinforcement materials in terms of chemistries and forms (e.g., particulate, fiber-reinforced, laminar, etc.). b. Assess how composite performance is influenced by various structural configurations of reinforcements (e.g., stressed skin, oriented fibers, tubes vs. rods, etc.).
2. Investigate different composite manufacturing methods and composite applications. DOK3 a. Research and communicate how advanced needs and technologies have influenced the development of composites materials and processing (e.g., Portland cement, aerocrete, fiberoptic concrete, aerogels, plywood, glulam, particle board, fiberglass, carbon fiber, and graphene). b. Evaluate various composites manufacturing techniques (e.g., hand lay-up, spray lay-up, Vacuum Assisted Resin Transfer Molding [VARTM], vacuum bagging, autoclave prepreg, etc.) emphasizing their influences on finished products. c. Investigate the automation of manufacturing processes (e.g., Resin Transfer Molding [RTM], filament winding, pultrusion, automated tape lay-up [ATL], etc.).

Student Competency Profile

Student's Name: ____

This record is intended to serve as a method of noting student achievement of the competencies in each unit. It can be duplicated for each student, and it can serve as a cumulative record of competencies achieved in the course.

In the blank before each competency, place the date on which the student mastered the competency.

Unit 1: Orientation to Industrial Employability and Safety		
	1.	Evaluate the local program and explore how personality traits and learning styles can impact success in the classroom and workplace.
	2.	Explain and demonstrate employability skills over the course of the program.
	3.	Explain and demonstrate the roles human relations, teamwork, and leadership play in plastics and polymer manufacturing.
	4.	Describe and demonstrate safe laboratory practices and environmental responsibility when working with laboratory equipment, chemicals, and processing equipment commonly encountered in polymer-related industries.
	5.	Demonstrate the ability to manage a computer operating system in relation to plastics and polymer applications.
Unit 2: Chemistry of Solids and Solutions		
	1.	Apply inquiry-based and problem-solving processes and skills to scientific investigations.
	2.	Demonstrate an understanding of the atomic model of matter by explaining atomic structure.
	3.	Develop an understanding of the periodic table.
	4.	Investigate the way the atomic structure and arrangement in matter impact bonding and chemical reaction.
Unit 3: Foundational Organic Chemistry		
	1.	Identify common organic molecules and relate their structures to chemical and physical properties.
	2.	Apply International Union of Pure and Applied Chemistry (IUPAC) nomenclature for simple organic structures and derivatives (i.e., functional groups such as alcohols, amines, aldehydes, ketones, carboxylic acids, esters, amides, ethers, etc.).
Unit 4: Polymers		
	1.	Examine the history and development of the polymer and material science industries/professions, polymer and polymer architecture.
	2.	Differentiate between polymer structure and architecture.
	3.	Recognize and differentiate natural and synthetic polymers.

	4.	Relate plastics recycling/conservation principles and their effects on the environment.
	5.	Relate small molecule chemistry to the production of polymer compounds.
	6.	Explore how the chemistry of polymer preparation affects performance properties.
	7.	Explore physical properties and how they affect end-use performance.
Unit 5: Thermoplastic Polymer Processing		
	1.	Differentiate between polymer synthesis, manufacturing, and processing.
	2.	Explain how basic processing techniques are used to convert polymer feedstock into plastic products, and manufacture plastic parts using each processing technique.
	3.	Identify acceptable and unacceptable products for each single-step processing technique.
	4.	Apply the principles of computer-aided design and drafting (CADD) to create designs and prototypes for plastic parts.
Unit 6: Polymer Safety and Concepts Review		
	1.	Re-evaluate the local program and explore how personality traits and learning styles can impact success in the classroom and workplace.
	2.	Describe and demonstrate safe laboratory practices and environmental responsibility when working with laboratory equipment, chemicals, and processing equipment commonly encountered in polymer-related industries.
Unit 7: Industry Guided Work-Based Learning		
	1.	Identify a materials science related problem encountered in industry.
	2.	Reach out to the polymer science advisory committee members or industry professionals to get a list of possible problems that could produce a viable solution after the students work through the scientific design process.
	3.	Develop a detailed plan for investigating the problem.
	4.	Test or research the chosen solution (i.e., prototype, process, etc.), recording any data or observations.
	5.	Analyze all the accumulated data and organize the findings in a clear fashion for communication of the results (i.e., graphs, tables, charts, diagrams, literary reviews, etc.).
	6.	Independently prepare detailed documentation of the research experience (i.e., lab report, multimedia presentation, journal article, etc.).
	7.	Present documentation to industry representatives for evaluation.
Unit 8: Advanced Polymer Manufacturing		
	1.	Explain how additives affect the properties of a polymeric material.
	2.	Explain how advanced manufacturing techniques are used to create products.
	3.	Differentiate between acceptable and unacceptable products for each advanced processing technique.
Unit 9: Metals		

	1.	Demonstrate a foundational understanding of the properties of metals and related materials.
	2.	Demonstrate a foundational understanding of the processing techniques for metals and related materials.
Unit 10: Ceramics and Glass		
	1.	Demonstrate a foundational understanding of the properties of ceramics and glass.
	2.	Demonstrate a foundational understanding of the manufacturing techniques for ceramics and glass.
Unit 11: Surface Coatings		
	1.	Describe the production of various types of surface coatings.
	2.	Demonstrate the properties of coatings.
Unit 12: Composite Materials, Manufacturing, and Applications		
	1.	Examine composite materials and their configurations in final parts to determine how each affects the finished properties of a composite structure.
	2.	Investigate different composite manufacturing methods and composite applications.

Appendix A: National Standards

	Units	1	2	3	4	5	6	7	8	9	10	11	12
Standards													
HS-PS1-1			X										
HS-PS1-2			X	X									
HS-PS1-3			X					X					
HS-PS1-4			X	X	X			X			X	X	X
HS-PS1-5			X	X	X			X					
HS-PS1-6		X	X	X					X				
HS-PS1-7			X	X	X						X		
HS-PS1-8			X		X								
HS-PS2-1			X	X				X					
HS-PS2-2			X	X	X								
HS-PS2-3		X				X		X		X			
HS-PS2-4			X										
HS-PS2-5			X					X					
HS-PS3-1			X										
HS-PS3-2			X							X			
HS-PS3-3		X	X			X		X					
HS-PS3-4			X		X	X		X		X			
HS-PS3-5			X	X									
HS-PS4-1			X								X		
HS-PS4-2			X			X							
HS-PS4-3													
HS-PS4-4			X										
HS-PS4-5			X		X								X

NGSS - A Framework for K-12 Science Education

HS-PS1 Matter and Its Interactions

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.
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.
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.
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.
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.

6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-PS2 Motion and Stability: Forces and Interactions

1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
3. Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

HS-PS3 Energy

1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).
3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
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).
5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-PS4 Waves and Their Applications in Technologies for Information Transfer

1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

2. Evaluate questions about the advantages of using digital transmission and storage of information.
3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

Appendix B: College and Career Readiness Standards

	Units	1	2	3	4	5	6	7	8	9	10	11	12
Standards													
CHE.1.1		X	X			X		X					
CHE.1.2		X	X		X			X					
CHE.1.3		X	X		X	X		X	X			X	X
CHE.2.1			X		X								
CHE.2.2			X		X								
CHE.2.3		X	X				X	X					
CHE.2.4			X										
CHE.3.1			X		X					X	X		
CHE.3.2			X					X		X	X		
CHE.3.3			X					X		X	X		
CHE.4.1			X	X	X	X			X				
CHE.4.2			X	X	X	X							
CHE.4.3			X										
CHE.4.4			X	X	X				X		X		
CHE.4.5			X	X	X					X	X		X
CHE.4.6			X		X				X	X		X	X
CHE.4.7			X					X		X		X	X
CHE.4.8			X		X			X		X		X	X
CHE.5.1			X	X	X				X			X	
CHE.5.2			X					X	X			X	
CHE.5.3			X	X		X		X	X			X	
CHE.6.1			X	X	X	X						X	
CHE.6.2		X	X	X	X			X				X	X
CHE.6.3		X	X	X	X				X			X	
CHE.6.4			X					X		X	X		X
CHE.6.5			X					X					
CHE.6.6			X										
CHE.6.7			X					X				X	
CHE.7.1			X		X								
CHE.7.2		X	X			X		X					
CHE.7.3		X	X					X		X	X		
CHE.7.4			X		X					X			
CHE.7.5		X	X			X		X					X
CHE.7.6			X	X									
CHE.7.7			X					X					
CHE.7.8		X	X					X					
CHE.8.1		X	X			X		X		X	X		
CHE.8.2			X	X	X								
CHE.8.3			X		X	X				X		X	
CHE.8.4			X					X					

CHE.8.5		X	X			X		X					
CHE.8.6			X		X		X	X					
CHE.8.7			X	X				X					
CHE.8.8		X			X		X						
CHE.9.1			X	X				X		X	X		
CHE.9.2			X	X				X		X	X		
CHE.9.3			X					X					
CHE.9.4			X	X									
CHE.9.5			X	X									
CHE.9.6			X	X				X					
CHE.10.1			X	X	X								
CHE.10.2			X	X				X					
CHE.10.3			X	X	X			X			X		
CHE.10.4			X		X								X
CHE.11.1			X	X	X				X	X			
CHE.11.2			X	X				X					
CHE.11.3			X	X		X		X					
CHE.12.1			X	X							X	X	X
CHE.12.2			X	X	X						X		
CHE.12.3			X	X	X							X	

Chemistry: 2018 Mississippi College and Career Readiness Standards for Science -Applied Academic Credit Benchmarks

CHE.1 Mathematical and Computational Analysis Conceptual Understanding: Mathematical and computational analysis is a key component of scientific investigation and prediction of outcomes. These components create a more student-centered classroom.

CHE.1 Students will use mathematical and computational analysis to evaluate problems.

1. Use dimensional analysis (factor/label) and significant figures to convert units and solve problems.
2. Design and conduct experiments using appropriate measurements, significant figures, graphical analysis to analyze data.
3. Enrichment: Research information from multiple appropriate sources and assess the credibility, accuracy, possible bias, and conclusions of each publication.

CHE.2 Atomic Theory Conceptual Understanding: Atomic theory is the foundation of modern chemistry concepts. Students must be presented with a solid foundation of the atom and its components. These concepts lead to an understanding of the interactions of these components to explain macro-observations of the world.

CHE.2 Students will demonstrate an understanding of the atomic structure and the historical developments leading to modern atomic theory.

1. Investigate the historical progression leading to the modern atomic theory, including, but not limited to, work done by Dalton, Rutherford’s gold foil

experiment, Thomson's cathode ray experiment, Millikan's oil drop experiment, and Bohr's interpretation of bright line spectra.
2. Construct models (e.g., ball and stick, online simulations, mathematical computations) of atomic nuclei to explain the abundance weighted average (relative mass) of elements and isotopes on the published mass of elements.
3. Investigate absorption and emission spectra to interpret explanations of electrons at discrete energy levels using tools such as online simulations, spectrometers, prisms, flame tests, and discharge tubes. Explore both laboratory experiments and real-world examples.
4. Research appropriate sources to evaluate the way absorption and emission spectra are used to study astronomy and the formation of the universe.

CHE.3 Periodic Table Conceptual Understanding: Modern chemistry is based on the predictability of atomic behavior. Periodic patterns in elements led to the development of the periodic table. Electron configuration is a direct result of this periodic behavior. The predictable behavior of electrons has led to the discovery of new compounds, elements, and atomic interactions. Predictability of atom behavior is a key to understanding ionic and covalent bonding and production of compounds or molecules.

CHE.3 Students will demonstrate an understanding of the periodic table as a systematic representation to predict properties of elements.

1. Explore and communicate the organization of the periodic table, including history, groups, families, family names, metals, nonmetals, metalloids, and transition metals.
2. Analyze properties of atoms and ions (e.g., metal/nonmetal/metalloid behavior, electrical/heat conductivity, electronegativity and electron affinity, ionization energy, and atomic/ionic radii) using periodic trends of elements based on the periodic table.
3. Analyze the periodic table to identify quantum numbers (e.g., valence shell electrons, energy level, orbitals, sublevels, and oxidation numbers).

CHE.4 Bonding Conceptual Understanding: A firm understanding of bonding is necessary to further development of the basic chemical concepts of compounds and chemical interactions.

CHE.4 Students will demonstrate an understanding of the types of bonds and resulting atomic structures for the classification of chemical compounds.

1. Develop and use models (e.g., Lewis dot, 3-D ball-stick, 3-D printing, or simulation programs such as PhET) to predict the type of bonding between atoms and the shape of simple compounds.
2. Use models such as Lewis structures and ball and stick models to depict the valence electrons and their role in the formation of ionic and covalent bonds.
3. Predict the ionic or covalent nature of different atoms based on electronegativity trends and/or position on the periodic table.
4. Use models and oxidation numbers to predict the type of bond, shape of the compound, and the polarity of the compound.
5. Use models of simple hydrocarbons to exemplify structural isomerism.
6. Use mathematical and computational analysis to determine the empirical formula and the percent composition of compounds.

7. Use scientific investigation to determine the percentage of composition for a substance (e.g., sugar in gum, water and/or unpopped kernels in popcorn, percent water in a hydrate). Compare results to justify conclusions based on experimental evidence.
8. Plan and conduct controlled scientific investigations to produce mathematical evidence of the empirical composition of a compound.

CHE.5 Naming Compounds Conceptual Understanding: Polyatomic ions (radicals) and oxidation numbers are used to predict how metallic ions, nonmetals, and transition metals are used in naming compounds.

CHE.5 Students will investigate and understand the accepted nomenclature used to identify the name and chemical formulas of compounds.

1. Use the periodic table and a list of common polyatomic ions as a model to derive chemical compound formulas from compound names and compound names from chemical formulas.
2. Generate formulas of ionic and covalent compounds from compound names. Discuss compounds in everyday life and compile lists and uses of these chemicals.
3. Generate names of ionic and covalent compounds from their formulas. Name binary compounds, binary acids, stock compounds, ternary compounds, and ternary acids.

CHE.6 Chemical Reactions Conceptual Understanding: Understanding chemical reactions and predicting products of these reactions is essential to student success.

CHE.6 Students will demonstrate an understanding of the types, causes, and effects of chemical reactions.

1. Develop and use models to predict the products of chemical reactions (e.g., synthesis reactions; single replacement; double displacement; and decomposition, including exceptions such as decomposition of hydroxides, chlorates, carbonates, and acids). Discuss and/or compile lists of reactions used in everyday life.
2. Plan, conduct, and communicate the results of investigations to demonstrate different types of simple chemical reactions.
3. Use mathematics and computational analysis to represent the ratio of reactants and products in terms of masses, molecules, and moles (stoichiometry).
4. Use mathematics and computational analysis to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Give real-world examples (e.g., burning wood).
5. Plan and conduct a controlled scientific investigation to produce mathematical evidence that mass is conserved. Use percent error to analyze the accuracy of results.
6. Use mathematics and computational analysis to support the concept of percent yield and limiting reagent.
7. Plan and conduct a controlled scientific investigation to produce mathematical evidence to predict and confirm the limiting reagent and percent yield in the reaction. Analyze quantitative data, draw conclusions, and communicate findings. Compare and analyze class data for validity.

CHE.7 Gas Laws Conceptual Understanding: The comparison and development of the molecular states of matter are an integral part of understanding matter. Pressure, volume, and temperature are imperative to understanding the states of matter.

CHE.7 Students will demonstrate an understanding of the structure and behavior of gases.

1. Analyze the behavior of ideal and real gases in terms of pressure, volume, temperature, and number of particles.
2. Enrichment: Use an engineering design process to develop models (e.g., online simulations or student interactive activities) to explain and predict the behavior of each state of matter using the movement of particles and intermolecular forces to explain the behavior of matter.
3. Analyze and interpret heating curve graphs to explain the energy relationship between states of matter (e.g., thermochemistry-water heating from -20oC to 120oC).
4. Use mathematical computations to describe the relationships comparing pressure, temperature, volume, and number of particles, including Boyle's law, Charles's law, Dalton's law, combined gas laws, and ideal gas laws.
5. Enrichment: Use an engineering design process and online simulations or lab investigations to design and model the results of controlled scientific investigations to produce mathematical evidence that confirms the gas-laws relationships.
6. Use the ideal gas law to support the prediction of volume, mass, and number of particles produced in chemical reactions (i.e., gas stoichiometry).
7. Plan and conduct controlled scientific investigations to produce mathematical evidence that confirms that reactions involving gases conform to the law of conservation of mass.
8. Enrichment: Using gas stoichiometry, calculate the volume of carbon dioxide needed to inflate a balloon to occupy a specific volume. Use an engineering design process to design, construct, evaluate, and improve a simulated air bag.

CHE.8 Solutions Conceptual Understanding: Solutions exist as solids, liquids, or gases. Solution concentration is expressed by specifying relative amounts of solute to solvent.

CHE.8 Students will demonstrate an understanding of the nature of properties of various types of chemical solutions.

1. Use mathematical and computational analysis to quantitatively express the concentration of solutions using the concepts such as molarity, percent by mass, and dilution.
2. Develop and use models (e.g., online simulations, games, or video representations) to explain the dissolving process in solvents on the molecular level.
3. Analyze and interpret data to predict the effect of temperature and pressure on solids and gases dissolved in water.
4. Design, conduct, and communicate the results of experiments to test the conductivity of common ionic and covalent compounds in solution.

5. Use mathematical and computational analysis to analyze molarity, molality, dilution, and percentage dilution problems.
6. Design, conduct, and communicate the results of experiments to produce a specified volume of a solution of a specific molarity and dilute a solution of a known molarity.
7. Use mathematical and computational analysis to predict the results of reactions using the concentration of solutions (i.e., solution stoichiometry).
8. Enrichment: Investigate parts per million and/or parts per billion as it applies to environmental concerns in your geographic region, and reference laws that govern these factors.

CHE.9 Acids and Bases (Enrichment)

CHE.9 Enrichment: Students will understand the nature and properties of acids, bases, and salt solutions.

1. Enrichment: Analyze and interpret data to describe the properties of acids, bases, and salts.
2. Enrichment: Analyze and interpret data to identify differences between strong and weak acids and bases (i.e., dissociation).
3. Enrichment: Plan and conduct investigations using the pH scale to classify acid and base solutions.
4. Enrichment: Analyze and evaluate the Arrhenius, Bronsted-Lowry, and Lewis acid-base definitions.
5. Enrichment: Use mathematical and computational thinking to calculate pH from the hydrogen ion concentration.
6. Enrichment: Obtain, evaluate, and communicate information about how buffers stabilize pH in acid-base reactions.

CHE.10 Thermochemistry (Enrichment)

CHE.10 Enrichment: Students will understand that energy is exchanged or transformed in all chemical reactions.

1. Enrichment: Construct explanations to explain how temperature and heat flow in terms of the motion of molecules (or atoms).
2. Enrichment: Classify chemical reactions and phase changes as exothermic or endothermic based on enthalpy values. Use a graphical representation to illustrate the energy changes involved.
3. Enrichment: Analyze and interpret data from energy diagrams and investigations to support claims that the amount of energy released or absorbed during a chemical reaction depends on changes in total bond energy.
4. Enrichment: Use mathematical and computational thinking to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.

CHE.11 Equilibrium (Enrichment)

CHE.11 Enrichment: Students will understand that chemical equilibrium is a dynamic process at the molecular level.

1. Enrichment: Construct explanations to explain how to use Le Chatelier's principle to predict the effect of changes in concentration, temperature, and pressure.
2. Enrichment: Predict when equilibrium is established in a chemical reaction.

3. Enrichment: Use mathematical and computational thinking to calculate an equilibrium constant expression for a reaction.

CHE.12 Organic Nomenclature (Enrichment)

CHE.12 Enrichment: Students will understand that the bonding characteristics of carbon allow the formation of many different organic molecules with various sizes, shapes, and chemical properties.

1. Enrichment: Construct explanations to explain the bonding characteristics of carbon that result in the formation of basic organic molecules.
2. Enrichment: Obtain information to communicate the system used for naming the basic linear hydrocarbons and isomers that contain single bonds, simple hydrocarbons with double and triple bonds, and simple molecules that contain a benzene ring.
3. Enrichment: Develop and use models to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.