Project-Based Chemistry Unit 1 - Hydroponics

STAGE 1 | DESIRED RESULTS

Standards

3.2.9-12.A - Use scientific practices to model the structure and function of molecules in chemical reactions, including ionic and covalent bonds and interactions between solutes.

3.2.9-12.E - Analyze and evaluate how energy and matter are transferred and transformed in chemical reactions within living organisms.

3.3.9-12.C - Examine how energy flows through ecosystems, and how the transfer of energy and matter affects ecosystem dynamics and stability.

3.3.9-12.I - Analyze the relationship between human activities and the sustainability of ecosystems and resources.

3.4.9-12.A - Evaluate the properties of materials and the

Transfer

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

- ☐ Make and use observations to analyze relationships and patterns in order to explain phenomena, develop models, and make predictions.
- ☐ Approach science as a reliable and tentative way of knowing and explaining the natural world and designed world.

Meaning

UNDERSTANDINGS

Students will understand that...

- ☐ Chemical reactions are essential to chemical systems and can be applied to chemical technologies and processes.
- ☐ Human activities impact the availability of natural resources and the sustainability of ecosystems.
- ☐ Technologies are devised to reduce the impact of human activity on the environment.

ESSENTIAL QUESTIONS

Students will keep considering...

- ☐ How are chemical reactions essential to chemical systems, and how can reaction principles be applied to chemical technologies and processes?
- ☐ How do human activities impact the availability of natural resources and the sustainability of ecosystems?
- ☐ How do technologies reduce the impact of human activity on the environment?

Acquisition(need to align with above and standards)

Students will know...

PS1.B: Chemical Reactions

- ☐ How chemical reactions (e.g. nutrient dissolution and pH adjustments) affect the composition and availability of essential plant nutrients in a hydroponic system.
- ☐ How changes in temperature, pH, and concentration impact chemical reactions within the nutrient solution.

Students will be skilled at...

- ☐ *Planning and Carrying Out Investigations: Design and conduct controlled experiments to test the effects of different nutrient concentrations and pH levels on plant growth.*
- ☐ *Analyzing and Interpreting Data: Collect and analyze data on plant growth, water quality, and nutrient levels to evaluate the efficiency of their hydroponic system.*
- ☐ *Constructing Explanations and Designing Solutions: Develop evidence-based explanations*

design process to optimize a system for a specific purpose. 3.4.9-12.B - Design and build models of devices that function based on principles of chemistry, physics, and biology to solve real-world problems. 4.6.9-12.B - Analyze how human decisions impact the environment and the quality of life for people and other organisms. 4.7.9-12.A - Evaluate the role of sustainable technologies in environmental systems and how those technologies support environmental stewardship. 3.2.9-12.D - Design and conduct investigations to observe and measure chemical reactions, and analyze the data to determine outcomes and trends. 4.6.9-12.C - Use data and evidence to support claims related to the sustainability and environmental impact of technologies or processes.	**LS2.A: Interdependent Relationships in Ecosystems** ☐ How plant growth in a hydroponic system depends on the availability of key nutrients (e.g. nitrogen, phosphorus, potassium) and water quality. ☐ The role of nutrient cycling and how closed systems like hydroponics mimic natural processes while limiting resource waste. **ESS3.C: Human Impacts on Earth Systems** ☐ How hydroponic systems reduce the environmental impact of agriculture by conserving water, minimizing soil degradation, and reducing runoff. ☐ How human innovation and technology can create sustainable food production methods to address global resource challenges.	*for how chemical reactions within the system impact plant health, and design and refine a hydroponic system to optimize plant growth while minimizing environmental impact.* ☐ *Cause and Effect: Identify how specific changes in pH, nutrient concentration, and water quality directly impact plant growth and system function.* ☐ *Energy and Matter: Trace the flow of matter (nutrients and water) through the hydroponic system and explain how plants convert those inputs into energy and biomass.* ☐ *Stability and Change: Evaluate how maintaining chemical balance in a hydroponic system affects the stability of plant growth and long-term system health.*mation, habitat creation) Other skills ☐ *Use their understanding of chemical reactions, molecular behavior, and solution chemistry to analyze and optimize chemical systems, including hydroponic nutrient solutions, in real-world contexts.* ☐ *Evaluate and design systems that reduce environmental impact by conserving resources and minimizing pollution.* ☐ *Assess how human activities - such as modern, industrial agriculture practices - affect natural resources and ecosystem health, and propose science-based solutions to mitigate these effects.* ☐ *Collect and analyze quantitative data (e.g. nutrient concentrations, pH, dissolved gases) to make evidence-based decisions about improving system efficiency and sustainability.* ☐ *Communicate their findings and design solutions related to hydroponics, clearly explaining how chemical and environmental principles inform their design choices.*

Project-Based Chemistry Unit 2 - Bonding Fundamentals

STAGE 1 | DESIRED RESULTS

Standards

3.2.9-12.G - Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

3.2.9-12.H - Use mathematical and graphical representations of energy changes in chemical systems.

3.2.9-12.I - Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

3.2.9-12.J - Develop a model to illustrate how the structure of molecules determines the properties of that substance.

3.2.9-12.P - Construct and revise an explanation for the outcome of a simple chemical reaction based on outer electron states of atoms, trends in the periodic table, and patterns of chemical properties.

Transfer

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

- ☐ Evaluate how molecular-level structures (types of bonds and particle arrangements) determine macroscopic properties of materials.
- ☐ Use chemistry to explain and justify material choices in solving real–world problems.
- ☐ Apply structure-property reasoning to innovate or refine the design of functional chemical systems.
- ☐ Weigh evidence and use scientific approaches to ask questions, investigate, and make informed decisions.
- ☐ Explain how the natural and designed worlds are interrelated, and how chemical design has both intended and unintended impacts.

Meaning

UNDERSTANDINGS

Students will understand that...

- ☐ The structure of atoms and the type of bonding between them (ionic, covalent, metallic) determines a materials' physical and chemical properties.
- ☐ Ionic, covalent, and metallic bonding are governed by electrostatic forces between particles, which vary in strength and directionality.
- ☐ Bulk-scale material behavior (e.g. conductivity, solubility, malleability, melting point) arises from molecular-level bonding and structure.
- ☐ Different bonding types result in different behaviors, in response to heat, force, or electricity.

ESSENTIAL QUESTIONS

Students will keep considering...

- ☐ How do the types of atomic bonding influence the behavior of materials in the real world?
- ☐ How can we explain the properties of a material by looking at the forces between its particles?
- ☐ What is the relationship between microscopic structure and macroscopic function?
- ☐ Why are certain materials suited for some applications and not others?
- ☐ How do chemists manipulate matter at the molecular level to solve problems or design new technologies?

Acquisition(need to align with above and standards)

Students will know...

PS1.A - Structure and Properties of Matter

- ☐ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

Students will be skilled at...

- ☐ *Developing and Using Models: Represent types of bonding (ionic, covalent, metallic) and predict the physical behavior of associated materials.*
- ☐ *Constructing Explanations and Designing Solutions: Construct explanations that relate*

3.5.9-12.A - Define a design problem that involves a societal need or want and includes criteria and constraints on materials, time, or cost. 3.5.9-12.D - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints.	☐ Ionic compounds are generally hard and brittle with high melting points. Molecular compounds can be gases, liquids, or solids with lower melting points. ☐ Metals have free-moving electrons that give rise to conductivity and malleability. **PS2.B - Types of Interactions** ☐ Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter.	*macroscopic material properties to particle-level bonding interactions.* ☐ *Planning and Carrying Out Investigations: Design and execute tests (e.g. for conductivity, melting point, solubility, brittleness) that reveal information about material bonding and structure.* ☐ *Analyzing and Interpreting Data: Analyze physical property data to identify trends among different bonding types and infer molecular causes.* ☐ *Using Mathematical and Computational Thinking: Create and interpret graphs or data tables that show structure-property relationships (e.g. melting point vs. bond type)* ☐ *Engaging in Argument from Evidence: Support claims about why a given material behaves as it does using structure-property reasoning grounded in bonding concepts.* ☐ *Obtaining, Evaluating, and Communicating Information: Summarize and present how molecular-level bonding explains real-world material performance in the context of a selected design challenge.* ☐ *Structure and Function: Relate how the structure and type of atomic/molecular bonding determines bulk properties like malleability, conductivity, or brittleness.* ☐ *Cause and Effect: Use bonding type to explain cause-and-effect relationships in how materials respond to heat, force, or electricity.* ☐ *Systems and System Models: Define the boundaries and components of a material system and explain how altering one variable affects the whole.*

Project-Based Chemistry Unit 3 - Soap

STAGE 1 | DESIRED RESULTS

Standards

3.2.9-12.E - Apply scientific principles and evidence to explain how temperature or concentration changes affect reaction rates.

3.2.9-12.F - Refine chemical system designs by specifying yield at equilibrium.

3.2.9-12.G - Use mathematical representations to support the conservation of atoms and mass in chemical reactions.

3.4.9-12.A - Analyze and interpret how issues, trends, technologies, and policies impact agricultural, food, and environmental systems and resources.

3.5.9-12.A - Define a design problem that involves a societal need or want and includes criteria and constraints.

3.5.9-12.D - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs.

Transfer

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

- ☐ Approach science as a reliable and tentative way of knowing and explaining the natural world and designed world.
- ☐ Weigh evidence and use scientific approaches to ask questions, investigate, and make informed decisions.
- ☐ Make and use observations to analyze relationships and patterns in order to explain phenomena, develop models, and make predictions.
- ☐ Evaluate systems in order to connect how form determines function and how any change to one component affects the entire system.
- ☐ Explain how the natural and designed worlds are interrelated and the application of scientific knowledge and technology can have beneficial, detrimental, or unintended consequences.

Meaning

UNDERSTANDINGS

Students will understand that...

- ☐ All forms of matter exist as a result of the combination or rearrangement of atoms.
- ☐ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and rearrangements of atoms.
- ☐ When investigating or describing a system, the boundaries and initial conditions need to be defined.

ESSENTIAL QUESTIONS

Students will keep considering...

- ☐ How do particles combine to form the variety of matter one observes?
- ☐ How do substances combine or change to make new substances? How does one characterize, explain, and predict them?
- ☐ When investigating or describing a system, how do you define the boundaries and initial conditions?

Acquisition(need to align with above and standards)

Students will know...

PS1.B Chemical Reactions

- ☐ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in

Students will be skilled at...

- ☐ **Planning and Carrying Out Investigations:** Design and perform experiments comparing foaming, solubility, or microemulsion properties.
- ☐ **Constructing Explanations & Designing Solutions:** Explain how their sustainable soap formulation addresses both chemical and environmental criteria.

3.5.9-12.D - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints.	the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. ☐ In many situations, a dynamic and conditiondependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. ☐ The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **ETS1.C Optimizing the Design Solution** ☐ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. **Key Vocabulary:** electronegativity, molecular polarity, intermolecular forces, micelle, surfactant, saponification, distillation, phase equilibrium.	☐ **Analyzing and Interpreting Data:** Use charts / pH strips / percent yield calculations to support process improvements. ☐ **Evaluating and Communicating Information**: Critique lab reports and environmental claims of commercial surfactants. ☐ **Structure and Function:** Draw connections between molecular polarity, micelle structure, and cleaning performance.

Project-Based Chemistry Unit 4 - Coffee

STAGE 1 | DESIRED RESULTS

Standards

3.2.9-12.A - Analyze how the structure and function of molecules in chemical reactions relate to energy changes.

3.2.6-8.D - Use models to explain how chemical reactions occur and are influenced by various factors (e.g. temperature, concentration, pH, and pressure).

3.3.9-12.A - Investigate the availability of natural resources and how human activity impacts their sustainability

Transfer

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

- ☐ Weigh evidence and use scientific approaches to ask questions, investigate, and make informed decisions.
- ☐ Make and use observations to analyze relationships and patterns in order to explain phenomena, develop models, and make predictions.

Meaning

UNDERSTANDINGS

Students will understand that...

- ☐ Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- ☐ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms.

ESSENTIAL QUESTIONS

Students will keep considering...

- ☐ What is energy? How can one explain the varied effects that involve energy?
- ☐ How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?

Acquisition(need to align with above and standards)

Students will know...

PS1.B: Chemical Reactions

- ☐ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms.

PS3.B: Conservation of Energy and Energy Transfer

- ☐ Energy cannot be created or destroyed, only converted from one form to another. The total energy within a system is conserved.

Students will be skilled at...

- ☐ **Developing and using models:** Roasting profiles, energy vs. time graphs, predictive tase outcomes.
- ☐ **Planning and carrying out investigations:** Designing roast variations, measuring temperature/time and cupping results.
- ☐ **Constructing explanations and designing solutions:** Linking observed flavor to roast parameters and refining profiles.
- ☐ **Using mathematical and computational thinking:** Modeling relationships between

	PS3.A: Definitions of Energy ☐ Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. **PS1.A: Structure and Properties of Matter** ☐ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **ETS1.C: Optimizing the Design Solution -** ☐ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed. **Key Vocabulary:** enthalpy, activation energy, thermal energy transfer, Maillard reaction, caramelization, pyrolysis, reaction kinetics, temperature threshold, roast profile iteration.	thermal input, reaction rate, and flavor metrics. ☐ **Analyzing and interpreting data:** Evaluating patterns across roast profiles and cupping results for flavor optimization.