STRATFORD PUBLIC SCHOOLS
Stratford, Connecticut

"Tantum eruditi sunt liberi"
Only The Educated Are Free

Chemistry 2

Samantha Rosenberg
PreK - 6 STEM Coordinator

Harold Greist
7 - 12 STEM Coordinator

Peter Bowe
Bunnell HS Department Head

Alison Lucas
Stratford HS Department Head

Janet Robinson, Ph.D.
Superintendent of Schools

Linda A. Gejda, Ed.D.
Assistant Superintendent

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ACKNOWLEDGEMENTS

Board of Education Members

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Amy Wiltsie-Vice Chair
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Andrea Corcoran
Janice Cupee
Bob DeLorenzo
Karen Rodia

Curriculum Writer

Sam Varma

DISTRICT MISSION STATEMENT

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The mission of the Stratford school community is to ensure that all students acquire the knowledge, character, and 21st century skills to succeed through high quality learning experiences and community partnerships within a culture of diversity and respect.

Portrait of a Stratford Graduate

- Responsible and Involved Citizen
  - Participate in and contribute with empathy and respect to the community.
  - Demonstrate knowledge of and respect for diverse cultures, identities, and perspectives.
  - Practice responsible digital and in person citizenship as a member of a community.

- Creative and Practical Problem-Solver
  - Define and analyze a problem/problems.
  - Select, evaluate, and apply appropriate resources/strategies necessary to find/generate a solution(s) for problems.
  - Generate and critically evaluate the effectiveness of a solution.

- Informed and Integrative Thinker
  - Apply knowledge from various disciplines and contexts to real life situations.
  - Analyze, evaluate, and synthesize information from multiple and diverse sources to build on and utilize knowledge.
  - Use evidence and reasoning to justify claims/solutions.

- Clear and Effective Communicator
  - Select and use communication strategies (questioning, clarifying, verifying, and challenging ideas) and interpersonal skills to collaborate with others (peers, teachers, community members, families) within a diverse community.
  - Demonstrate, adapt, and articulate thoughts and ideas effectively using/including oral, written, multimedia, non-verbal, and/or a performance appropriate for a particular audience.
  - Receive, understand and process information effectively and with consideration for others through active speaking and listening.

- Self-Directed and Lifelong Learner
  - Apply knowledge to set goals, make decisions, and assess new opportunities.
  - Demonstrates initiative, reliability and concern for quality results/solutions/resources/information within time constraints as applicable.
  - Demonstrate flexibility in thinking/problem-solving/etc. including the ability to incorporate new ideas and revise.

UNIT: ACIDS & BASES

Unit Overview
In this lab-based unit, students will explore an important class of chemicals: Acids & Bases. Students will understand the mechanism of neutralization reactions and the production of ionic salts with water, when combining common acids with bases. The central theme of this unit is for students to recognize acids (and bases), their chemical properties, and extend their understanding of chemical reactions to include this broad category of chemicals. The crosscutting concepts of patterns & structure-function will be used to explain pH and titration. This will explicitly drive instruction to help students analyze and reflect on biological processes through the prism of chemical reactions.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
Explaining the concept of pH using water, aqueous reactions with acids and bases, and the role of electrons and protons in defining acids and bases.	HS-PS1-2 HS-PS1-7	PS1.B
Predicting the formation of anions from acids and understanding the central role of protons in defining monoprotic and polyprotic acids.	HS-PS1-2 HS-PS1-4 HS-PS1-7	PS1.A PS1.B ETS1.C
Predict the structure and formula of bases from the location of the metals on the periodic table and the role of chemical indicators and laboratory techniques in quantifying the concentration of unknown acids with known concentrations of bases and vice versa.	HS-PS1-6	PS1.B ETS1.C

Big Idea: Explaining the concept of pH using water, aqueous reactions with acids and bases, and the role of electrons and protons in defining acids and bases		
PE #	Performance Expectation	Disciplinary Core Idea

UNIT: ACIDS & BASES

HS-PS1-2 **HS-PS1-7**	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. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.] Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.] **Content Limits** Assessment is limited to main group elements and does not include quantitative understanding of ionization energy beyond	**PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **PS1.B: Chemical Reactions** 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.

	relative trends. Assessment does not include complex chemical reactions. Students do not need to know: Properties of individual elements, names of groups, or anomalous electron configurations (Chromium and Copper)	

Observable Features

- Students can identify the scope of the pH scale in measuring acidity.
  - Students can use litmus paper to identify an acid and a base as controls.
  - Students can explore common household reagents and make predictions about their properties.
  - Students can associate household chemicals with their pH values.
  - Students can relate atomic structure and the loss and gain of electrons with acidity.

- Students can identify the role of water in neutralization reactions and the pH scale
  - Students can understand how the pH scale is determined from water (K_w).
  - Students will use the structure of water molecules to understand how it is both an acid and a base.
  - Students can process the transfer of protons as the basis of many acid-base reactions.

Key Terms

Atom, valence electrons, protons, atomic number, cation, anion, polyatomic ion, charge, molar mass, formula weight, molecular weight, exponentials, groups, periods, functional groups, hydrogen ion, hydronium ion, acids, bases, electron configuration, amphoteric, pH scale

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hydrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane. PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

UNIT: ACIDS & BASES

They mystery pitcher pH demonstration

Indicator Sponge – discrepant event
https://www.youtube.com/watch?v=j_shWfKB9Ak

Combining Milk of Magnesia with hydrochloric acid to demonstrate a neutralization reaction. Have students understand the role of these reactions in a class of laxatives and explore the commercial potential of all chemical reactions, especially acid-base reactions. Discuss the solubility of bases and the physiology of colloidal substances and measure the pH of the different components of this reaction with pH strips.

Pouring a given volume of orange juice and reading the label calculate the grams of vitamin C present in this solution. Then have students measure out twice that volume, using water (distilled if available), and have them calculate how much ascorbic acid needs to be added to the water to get the same concentration of vitamin C, in grams per liter. Provide students with the chemical formula of ascorbic acid. Have students write down their observations of what happens when ascorbic acid is added to water. Introduce the structure of this organic acid (ascorbic acid) and describe the importance of acids in diseases (scurvy) and digestion.

Additional Resources
A colorful magic trick with acids and bases (Tyler DeWitt)
https://www.youtube.com/watch?v=ujkuW-0cpNw

Naming Acids (Tyler DeWitt)
https://www.youtube.com/watch?v=5Jb2u9ihfm4

Acids, Bases, and pH (Bozeman Science)
https://www.youtube.com/watch?v=Xeuyc55LqiY

ADI LAB – characteristics of Acids and Bases: How can the Chemical Properties of an Aqueous Solution Be used to Identify It as an Acid or a Base?

https://drive.google.com/file/d/1buOv4p0kkdnQgF2pCKC8njm-oBtuc5iR/view?usp=sharing

pH Analysis
https://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=432&ClassID=0

UNIT: ACIDS & BASES

https://docs.google.com/document/d/1ejtFzEUV_jhfRBE5itzT4qn8EunaT3wLV9cRcWHmb28/edit?usp=sharing

Big Idea: Predicting the formation of anions from acids and understanding the central role of protons in defining monoprotic and polyprotic acids.		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS1-2 **HS-PS1-4** **HS-PS1-7**	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. *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]* 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. *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change.* ***Examples of models could include molecular-level***	**PS1.A** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2)The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6) **PS1.B: Chemical Reactions** 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** 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. (secondary to HS-PS1-6)

	***drawings** and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]*	

Observable Features

- Students can construct an explanation for how the patterns of outermost electrons and the electronegativity of elements can be used to predict the number and types of bonds in any given chemical formula.
- Students can identify different components of common acids including structure, functional groups, derived anions and polyatomic ions.
- Students can associate many everyday chemicals with being acidic or basic and including formulas and names.
- Students can identify and describe the evidence used to construct the explanations for compound type and formulas, including:
    - Identification of compound type, including their chemical formulas and the electron configuration of the

elements.
    - Recognizing structural formulas and the identification of hydrogen atoms that contribute to the acidity of the compound

- The patterns of reactivity (e.g., the high reactivity of halogens and its correlation with atomic size or the electronegativity of atoms) at the macroscopic level in acids.

Key Terms
Atom, valence electrons, protons, atomic number, atomic radius, cation, anion, polyatomic ion, charge, electronegativity, molar mass, formula weight, molecular weight, exponentials, groups, periods, functional groups, hydrogen ion, hydronium ion, acids, bases, electron configuration, amphoteric, pH scale, monoprotic, polyprotic, amphoteric, amino acids.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hydrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane. PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

Have students set up a reaction of strips of magnesium with 0.5M hydrochloric acid. Have students measure the temperature of the reaction over time (usually 10 second intervals) and explain the chemical reaction that occurs. Have students write out the balanced equation and understand the transformation of a piece of metal to a soluble salt of magnesium.

What causes Kidney Stones?
https://www.youtube.com/watch?v=W0GpIMNTPYg

Reaction of Magnesium hydroxide with an acid in the presence of pH indicators
https://www.youtube.com/watch?v=FKoNE_hzQm0
Milk of Magnesia - what happens when you add an acid based drain cleaner
https://www.youtube.com/watch?v=6Fy0sTMDFuw

UNIT: ACIDS & BASES

Extracting citric acid from lemons
https://www.youtube.com/watch?v=FMtayizdFiw&t=846s **DO NOT ATTEMPT AT HOME**

What are acids and bases?
https://www.youtube.com/watch?v=Vbh52HDorkc&feature=emb_logo (IsaacsTEACH)

Acids, Bases, pH and pOH
https://www.youtube.com/watch?v=NNXvokAcSuE&t=42s (Professor Dave explains)

Review
Explaining the process of generating formulas and the names for molecular compounds
https://www.youtube.com/watch?v=DejkvR4pvRw
https://www.youtube.com/watch?v=nijb6UMvZuE&t=209s

Additional Resources

Alkaline water
https://flexbooks.ck12.org/cbook/ck-12-chemistry-flexbook-2.0/section/21.2/related/rwa/why-so-foamy

pH pOH crash course
https://flexbooks.ck12.org/cbook/ck-12-chemistry-flexbook-2.0/section/21.9/related/lecture/ph-and-poh%3a-crash-course

Comparison of two chemical reactions – excellent lab for tabulating data
https://drive.google.com/file/d/1ACT_drtUAQGXVJpdld7N92yFpFo5DcFj/view?usp=sharing

Answers for this lab
https://drive.google.com/file/d/1rGdauud1Ap-c1pWPOrLGUsOLnhS9m1OQ/view?usp=sharing

UNIT: ACIDS & BASES

Big Idea: Predict the structure and formula of bases from the location of the metals on the periodic table and the role of chemical indicators and laboratory techniques in quantifying the concentration of unknown acids with known concentrations of bases and vice versa.		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS1-2 **HS-PS1-4** **HS-PS1-5** **HS-PS1-7**	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. *[Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]* 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. *[Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change.* ***Examples of models could include molecular-level***	**PS1.A** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2)The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6) **ETS1.C** 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. (secondary to HS-PS1-6)

	drawings *and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]* 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. *(example: higher acidity will neutralize faster thereby allowing for comparison matching)* Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]*	
Observable Features		

UNIT: ACIDS & BASES

- Students can determine the formulas of group 1 and group 2 bases from the patterns of outermost electrons and their reactivity can be predicted from the location on the periodic table.
- Students can identify different components of common acid base reactions and be able to list the reactants and products along with their balanced equations.
- Students can explain the concept of indicator solutions and their role in measuring pH.

- Students can demonstrate laboratory techniques to quantify unknown acids or bases.
    - Calculating the concentration using simple titrations of strong acids and bases
    - Learning to use a pH meter to quantify the proton ion concentration.

Key Terms
Atom, valence electrons, protons, atomic number, atomic radius, cation, anion, polyatomic ion, charge, electronegativity, molar mass, formula weight, molecular weight, exponentials, groups, periods, functional groups, hydrogen ion, hydronium ion, electron configuration, amphoteric, pH scale, monoprotic, polyprotic, amphoteric, amino acids, strong acids, strong bases, indicator solutions, phenolpthalein, titration, burets.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hydrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane. PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon
Acid Rain – provides a great overview of acids and the impact on the environment and specifically discusses strong and weak acids.
https://www.youtube.com/watch?v=Nf8cuvl62Vc

Introducing the idea of titration using insulin therapy
https://www.youtube.com/watch?v=JnVyMY7xBPA

Using titrations to quantify asprin (no audio)

https://www.youtube.com/watch?v=ZkKbyiYuXnE
Additional Resources PHET simulation of pH scale https://phet.colorado.edu/en/simulation/ph-scale PHET simulation of acid base solutions. https://phet.colorado.edu/en/simulation/acid-base-solutions Student web based and lab activity to understand the impact of acid rain on the environment https://drive.google.com/file/d/1KcVNoV0jdoiTbmJ4jgYUTbgPWBa4b34e/view?usp=sharing https://drive.google.com/file/d/1E-lr3gDWTXw7P_vlmtsxFFgTEldSDFaq/view?usp=sharing https://drive.google.com/file/d/1NilZ-pFgzaDlTrTnzwtgsCL15ZR-3inC/view?usp=sharing ADI lab from NSTA on Acid-Base Titration and Neutralization Reactions What is the concentration of acetic acid in each sample of vinegar? https://drive.google.com/file/d/1gSoNnh9jm4d0LuGQydEX1FQlleBBASGN/view?usp=sharing Gizmos titration virtual lab https://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=1045 https://docs.google.com/document/d/17xZy8-hkQh5xUh2KHMhTOxySX7O7DF3h-0oZrRZk0Dc/edit?usp=sharing Lab on the effect of Acid deposition on Aquatic systems https://drive.google.com/file/d/1NhLP2rCQ_9LY26juAlJMbwTlJKhnOxv3/view?usp=sharing

UNIT: THERMOCHEMISTRY

Unit Overview
In this unit students will be introduced to energy transformations and the heat changes that occur in chemical reactions. The properties of polar molecules, specifically water, and ionic compounds will be discussed in the context of intra and intermolecular forces and their role in enthalpy changes. Students will differentiate between temperature and heat and the crosscutting concepts will encompass systems and system models and the energy flows. Students will track heat energy flows into and out of systems and develop a paradigm to explain enthalpy changes that are exothermic or endothermic.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
The development of models comprising a system and its surrounding and using this framework to explain energy transfers as exothermic or endothermic. This includes the relationship between energy transfers, types of matter and the changes in temperature caused by changes in average kinetic energy of particles.	HS-PS3-1 HS-PS1-7	PS3.A PS1.B

Big Idea: The development of models comprising a system, its surrounding, and using this framework to explain energy transfers as exothermic or endothermic.		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS3-1 **HS-PS1-7**	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. [Clarification Statement:	**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. That there is a single quantity called energy is due to the fact that a

UNIT: THERMOCHEMISTRY

	Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary : Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy , kinetic energy , and/or the energies in gravitational, magnetic, or electric fields.] Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.] **Content Limits** Assessment is limited to main group elements and does not include quantitative understanding of ionization energy beyond relative trends. Assessment does not include complex chemical reactions. Students do not need to know: Properties of	system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). **PS3.B: Conservation of Energy and Energy Transfer** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) **PS1.B: Chemical Reactions** 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.

	individual elements, names of groups, or anomalous electron configurations (Chromium and Copper)	

Observable Features

- Students can explain the relationship between energy and heat
    - Identify heat changes that occur during chemical reactions.
    - Be able to understand that chemical potential energy is closely linked to the molecular structure and bonding patterns of molecules.

- Students can identify the distinction between heat and temperature

- Students can construct an explanation for what constitutes a system and its surroundings.

    - Students can then leverage this to understand the transfer of heat in the context of exothermic and endothermic chemical reactions.
    - Quantify the direction of heat flow (q) as > 0 and < 0

- Students can describe heat capacity and specific heat capacity.
    - Define the units of heat capacity
    - Identify the specific heat capacity of water as unique in relationship to other common substances.
    - Explain the impact of the high specific heat capacity of water on climate and agriculture.

- Students can identify and describe the relevant components in a mathematical representation of a chemical reaction:
    - Quantities of reactants and products of a chemical reaction in terms of atoms, moles, and mass
    - Molar mass of all components of the reaction
    - Use of balanced chemical equation(s)
    - Enthalpy diagrams showing thermochemical equations

- Students can **describe** how the mathematical representations of mass and energy are conserved during chemical reactions
    - Commercial use of this phenomenon

- Students can systematically evaluate the potential heat transfer capabilities for the materials in the system and compare the cooling efficiency of air and water.

UNIT: THERMOCHEMISTRY

- Students can refine the given system by making tradeoffs that would optimize the designed system improving heat transfer and address process engineering questions.

Key Terms

Proton, electron, neutron, system, surroundings, joule, calories, exothermic, endothermic, heat capacity, specific heat capacity, q, initial state, final state, delta H, heat flow, enthalpy, enthalpy diagram, extensive properties, intensive properties, group, period, family, electron configuration.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hydrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

- **The combination of an oxidizer, potassium permanganate, with glycerol produces a very exothermic reaction. Great way to introduce thermochemistry**
  https://www.youtube.com/watch?v=ZIAyNFLRFuw

- Reaction of hydrogen peroxide with manganese dioxide is also an exothermic reaction that generates heat. Use 3% hydrogen peroxide with manganese dioxide. Avoid using 30% hydrogen peroxide because manganese dioxide is a strong oxidizer and this reaction can become explosive very easily. NEVER BRING OUT the 30% hydrogen peroxide container if you are working with manganese dioxide.

- Using thermite for welding- a highly exothermic reaction
  https://www.youtube.com/watch?v=5uxsFglz2ig

- Endothermic reaction demo with Barium hydroxide and Ammonium chloride
  https://www.youtube.com/watch?v=w_PUydkKKoQ

- Elephant toothpaste is an exothermic reaction again with hydrogen peroxide – be very careful if you are doing this demo as

30% hydrogen peroxide is very strong and can cause a chemical burn.
https://www.youtube.com/watch?v=p1eG2y2mn54

Additional Resources

What is temperature
https://drive.google.com/file/d/1vxOHMvacujVN2aPf-5MnVGoLfWmGVC4s/view?usp=sharing

Introduction to thermodynamics - modeling energy transfer
https://drive.google.com/file/d/1W75J9Kb40hpwxpSypItkHQ62WvHQmLIv/view?usp=sharing

Understanding specific heat capacity
https://teachchemistry.org/classroom-resources/understanding-specific-heat-simulation

Reaction Energy
https://www.explorelearning.com/index.cfm?method=cResource.dspView&resourceID=1065

Storyline Unit:
Why do some things get colder (or hotter) when they react?

Video: Phase Changes: Exothermic or Endothermic? Tyler DeWitt
https://www.youtube.com/watch?v=0cUK4jcAEaU

Argument Driven Inquiry in Chemistry - Lab 20. Enthalpy Change of Solution: How Can Chemists Use the Properties of a Solute to Predict If an Enthalpy Change of Solution Will Be Exothermic or Endothermic?
https://drive.google.com/file/d/1r08ikXbnYMDKXvDh8_woGTUYcsF-Izoc/view?usp=sharing
Argument Driven Inquiry in Chemistry - Lab 28. Designing a Cold Pack: Which Salt Should Be Used to Make an Effective but Economical Cold Pack?
https://drive.google.com/file/d/1imnloT2kDMGr6Ip6FpOXdL7GU4cJ2bR8/view?usp=sharing

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Energy Diagram and lab creating Magnesium oxide (Requires the use of Bunsen Burners – CAUTION)

UNIT: THERMOCHEMISTRY

Go over the powerpoint and have students fill out their notes as a prelab activity.

https://docs.google.com/presentation/d/1oOQc76qrT_UoMunuXRFY7wI9at0QQzF07Vs257dd3Do/edit?usp=sharing
(POWERPOINT LINK)

Student notesheet
https://docs.google.com/document/d/1r10TKKuDHAOeFfnQZRK8NB29PL-UufdQkHDjhJRPiMI/edit?usp=sharing

Lab Activity
https://docs.google.com/document/d/1UQxQ9ylvyq-n09pIEUsJM8T4N7k2USvINgDS0mNVYLE/edit?usp=sharing

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UNIT: Pressure & Gases

Unit Overview
In this lab-based unit, students will understand the relationship between pressure, temperature, volume, and molecular weight and use this knowledge to predict the spatial distribution, solubility and behavior of gas particles in the real world. The implications of atmospheric pressure on the behaviors and physical properties of select chemicals will be explored using phase diagrams and the role that the collision of particles has on pressure in a container. The scientific and engineering practices will involve basic algebra, computational modeling including the visualization of data and engaging in argument from evidence. The acquisition, analysis and the interpretation of data will follow protocols in *A Framework for K–12 Science Education. Cause and effect* and *Systems and system models* will be the crosscutting concepts that students will apply to their learning of the gas laws and states of matter.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
What is pressure and how much variation in pressure do we as humans observe in our surroundings? The ramifications of even the narrow pressure changes humans experience in our daily lives. Students will also explore how changes in pressure (and temperature) will affect the solubility of gases in an aqueous solution. Atmospheric pressure will be used to profile the phase diagram of water.	HS-PS3-2	PS3.A
Students will develop models, using the kinetic-molecular theory of gases, to explain what happens to gas particles when pressure and temperature are changed.	HS-PS3-1 HS-PS1-6	PS3.B ETS1.C
Students investigate the mathematical relationship between pressure temperature and volume. Students will also visualize the molecular effects of changing the variable associated with each of the	HS-PS3-1 HS-PS3-2	PS3.B PS3.A

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three fundamental gas laws, Boyle's Law, Charles' Law and Gay-Lusaac's Law.		

Big Idea: What is pressure and how much variation in pressure do we as humans observe in our surroundings? The ramifications of even the narrow pressure changes humans experience in our daily lives. Students will also explore how changes in pressure and temperature will affect the solubility of gases in an aqueous solution.		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS3-2	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). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]	**PS3.A: Definitions of Energy** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3). These relationships are better understood at the microscopic scale, at which all the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

Observable Features

- Students can identify the impact of atmospheric pressure on physical change and solubility
  - Students can identify the different units associated with the measurement of pressure.
  - Students can translate the impact of altitude on pressure and its effect on the boiling point of chemicals.
  - Students can explore different regions on earth and calculate the pressure at these locales and then make predictions about changes in solubility of gases.
  - Students can associate these changes in solubility with human activities including breathing, cooking and scuba diving.

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- Students can relate rates of chemical reactions to changes in pressure and temperature.

- Students can identify the relationship between pressure and temperature in establishing the boundaries for physical states.
  - Students can understand how the phase diagram of water establishes the equilibrium between different physical states.
  - Students will revisit the structure of water molecules to understand the uniqueness of this chemical for all life forms.
  - Students can process thermochemistry concepts between phase changes.

Key Terms
Atom, molecule, phase diagram, triple point, sublimation, melting point, boiling point, vaporization, evaporation, normal boiling point, gas pressure, vacuum, vacuum pump, atmospheric pressure, barometer, pascal (Pa), standard atmosphere (atm), pounds per square inch (psi), bell jar, hemoglobin, solubility, temperature, vapor pressure, the bends, hyperbaric oxygen therapy.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane. High pressure containers and vacuum pumps are also used during class. PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

Boiling water in the high Himalayas
https://www.youtube.com/watch?v=JTL4dj3Gx1o

Getting to Everest base camp
https://www.youtube.com/watch?v=Cxzm_GgfcIs

The impact that atmospheric pressure/ altitude has on boiling water. Have students discuss what the impact would be compared to Stratford, CT. Discuss the height of Mt. Everest and have them try and figure out where the highest mountain in the world is.

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The concept of boiling point:
https://flexbooks.ck12.org/cbook/ck-12-chemistry-flexbook-2.0/section/13.9/primary/lesson/boiling-point-chem

Demonstration using a bell jar and a vacuum pump, to lower the pressure in the bell jar to the point where a vacuum is created and water boils at room temperature. This is a very effective demonstration and explains why space travel requires pressurized suits.

Justin Beiber increases oxygen content in blood (video discusses more than oxygen levels in blood so use with discretion).
https://www.youtube.com/watch?v=G3CPIkhT8VU

Oxygen in the blood
https://www.youtube.com/watch?v=YyMiSUfZtyU

Like to fish? What is dissolved oxygen?
https://www.chesapeakebay.net/discover/ecosystem/dissolved_oxygen

Additional Resources
Crush the can (excellent demo) where students can analyze the impact of atmospheric pressure & the change in temperature on gas volume and pressure.
https://www.youtube.com/watch?v=xg5NiOwf_Zw

Myth busters tanker car implosion
https://www.youtube.com/watch?v=UpWeU2fvFGs

Pressure units and conversions – excellent resource to get students using conversion factors while calculating pressure.
https://flexbooks.ck12.org/cbook/ck-12-chemistry-flexbook-2.0/section/13.4/primary/lesson/pressure-units-and-conversions-chem/

The use of phase diagrams to explain phase changes
https://www.youtube.com/watch?v=zSwG59d8OCc

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PHET simulation: Describing states of matter and phase changes https://phet.colorado.edu/sims/html/states-of-matter/latest/states-of-matter_en.html GIZMOS: Phase changes https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&resourceID=557 https://docs.google.com/document/d/1tNDIRiWY1iIsbPPZ8i6HCIXOUE-dtoMczP-YAiCDBwA/edit?usp=sharing

Big Idea: Students will develop models, using the kinetic-molecular theory of gases, to explain what happens to gas particles when pressure and temperature are changed.		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS3-1 **HS-PS1-6**	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. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy , and/or the energies in gravitational, magnetic, or electric fields.] Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. * [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of	**PS3.B** Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) The availability of energy limits what can occur in any system. (HS-PS3-1) Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) **ETS1.C** 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 (tradeoffs) may be needed. (secondary to HS-PS1-6)

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	chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]	

Observable Features

- Students can construct an explanation for why gases expand when heated, at constant pressure - the motion of gas particles according to the kinetic theory
- Students can interpret why gas pressure increases when gas molecules are compressed in terms of kinetic energy.
- Students can assay the dependence of molecular speed on mass with examples of gases escaping through small holes and the molecules of a perfume diffusing through air.

Key Terms

Atom, molecule, kinetic energy, kinetic theory, melting point, boiling point, vaporization, evaporation, normal boiling point, gas pressure, vacuum, vacuum pump, atmospheric pressure, barometer, pascal (Pa), standard atmosphere (atm), pounds per square inch (psi), bell jar, hemoglobin, solubility, vapor pressure.

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Suggested Phenomenon

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Kinetic Energy of upside down buoyancy https://www.youtube.com/watch?v=bodsuTucSxQ Introduction to temperature and particle motion (Maxwell-Boltzmann distribution) https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&resourceID=555 https://docs.google.com/document/d/1oVCzmbI-jOVHpboVMcYdItCsxn2IouN2mXcAzNPiKgM/edit?usp=sharing Vapor pressure and the drinking duck https://flexbooks.ck12.org/cbook/ck-12-chemistry-flexbook-2.0/section/13.8/primary/lesson/vapor-pressure-chem/
Additional Resources PHET simulation: https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_en.html Kinetic Molecular Theory and particle motion while experimenting with a marshmallow https://drive.google.com/file/d/1i31NT9D5oLP6Chgx5mqmNAIowIlgwxJq/view?usp=sharing Kinetic Theory and Temperature (Bozeman Science) https://www.youtube.com/watch?v=1S9cuYascPQ&t=281s Rates of Reaction - Boltzmann Distribution Curves https://www.youtube.com/watch?v=BB1Uj08hAqY

Big Idea: Students investigate the mathematical relationship between pressure temperature and volume. Students will also visualize the molecular effects of changing the variable associated with each of the three fundamental gas laws, Boyle's Law, Charles' Law and Gay-Lusaac's Law.		
PE #	Performance Expectation	Disciplinary Core Idea

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HS-PS3-1 **HS-PS3-2**	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. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy , and/or the energies in gravitational, magnetic, or electric fields.] 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). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]	**PS3.B** Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) The availability of energy limits what can occur in any system. (HS-PS3-1) Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) **PS3.A: Definitions of Energy** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3). These relationships are better understood at the microscopic scale, at which all the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

Observable Features

- Students can visualize a mathematical relationship between pressure, volume and temperature for a contained gas.
- Students can identify the specific gas law being presented, describing the relationship between the variables and then apply it to problems involving temperature, volume, and pressure.
- Students can demonstrate an understanding of the gas laws by explaining real world examples through models and data analysis.

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Key Terms
Atom, molecule, phase diagram, boiling point, vaporization, vacuum, vacuum pump, atmospheric pressure, barometer, pascal (Pa), standard atmosphere (atm), pounds per square inch (psi), temperature, Celsius, Kelvin, volume, Boyle's Law, Charles' Law, Gay-Lussac's law, pressure cookers, direct relationships, and inverse relationships.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hydrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane. High pressure containers and vacuum pumps are also used during class. PPE must be worn, and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

Demonstration using a bell jar and a vacuum pump – use marshmallows to demonstrate Boyle's Law. Excellent demonstration that students find exceptionally interesting and generates a significant discussion around the concepts of pressure.
Video of the process:
https://www.youtube.com/watch?v=MsZOq-CnRgw

Demonstration using liquid nitrogen to explain the concept of Charles' Law. The directional relationship between volume and temperature when pressure is kept constant is superbly illustrated when balloons filled with air are dipped in liquid nitrogen.
Video:
https://www.youtube.com/watch?v=nvQ4RM-nRLw

Hot air ballooning
https://www.youtube.com/watch?v=JHzpK1JVwko

Demonstration using a pressure cooker (Gay-Lussac's law)
https://www.youtube.com/watch?v=I4nOIRoe6mU

Pressure cooker safety – Instant Pot
https://www.youtube.com/watch?v=LGxAiFqV05k

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Additional Resources PHET simulation of gas laws https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html https://drive.google.com/file/d/1JwD5EIdPhN6JLGCATAGJf0vTkSke2Q2H/view?usp=sharing GIZMOS: Boyle's Law & Charles' Law https://www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=422 https://docs.google.com/document/d/1fdS3n0BBAOadtBRjBmkRPefDBIuGsNsanhOphIC9fgQ/edit?usp=sharing Relationship between temperature and volume https://docs.google.com/document/d/1GNzhSuYPsu-dWaOi-WVJ0k5Gp1OG8wqL5e4ed85y4Os/edit?usp=sharing ADI lab from NSTA:. Pressure, Temperature, and Volume of Gases: How Does Changing the Volume or Temperature of a Gas Affect the Pressure of That Gas? ***Requires pressure and temperature sensors****.* https://drive.google.com/file/d/1qYqEfUmEU4EF_G2iDCNYzZU2pCMiwv1R/view?usp=sharing Vernier Lab – **requires Vernier probes** Boyle's Law: Pressure – volume relationship in gases https://drive.google.com/file/d/1S2WiumBF7IhgduzJatjeufW_oaS3SNXr/view?usp=sharing