CH | Chemistry

CH | Unit 1 The Physical Nature of Matter

RECOMMENDED TIME: 30 DAYS

Unit Overview:

Chemistry is the study of matter and energy explained and categorized using observable characteristics. All changes in matter are accompanied by changes in energy. Energy exists in many forms, and when these forms change, energy is conserved. Throughout history, humankind has tried to effectively use and convert various forms of energy. Energy is used to do work that makes life more productive and enjoyable. The Law of Conservation of Matter and Energy applies to phase changes, chemical changes, and nuclear changes, that help run our modern world. With a complete understanding of these processes and their application to the modern world comes a responsibility to take care of waste, limit pollution, and decrease potential risks.

Essential Question:
How can matter be explained in terms of stability and change?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 4: Energy exists in many forms, and when these forms change, energy is conserved.

NYS SCIENCE STANDARDS
http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 3.1dd, 3.1nn, 3.1q-u; 3.1jj; 3.1kk; 3.1oo; 3.1qq; 3.2a; 3.4a, b; 4.1a, b; 4.2a-c, 3.1pp

- Matter is classified as a pure substance or as a mixture of substances. **(3.1q)**
- A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample. **(3.1r)**
- Mixtures are composed of two or more different substances that can be separated by physical means. When different substances are mixed together, a homogeneous or heterogeneous mixture is formed. **(3.1s)**

continued

MST STANDARDS
http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 2: Information Systems

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

Examples include:

- use the Internet as a source to retrieve information for classroom use, e.g., Periodic Table, acid rain requiring improved investigations and experiments.

continued

NGSS CROSS-CUTTING CONCEPTS
http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.

continued

NYS SCIENCE STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

- The proportions of components in a mixture can be varied. Each component in a mixture retains its original properties. **(3.1t)**
- Elements are substances that are composed of atoms that have the same atomic number. Elements cannot be broken down by chemical change. **(3.1u)**
- Compounds can be differentiated by their chemical and physical properties. **(3.1dd)**
- The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure. **(3.1jj)**
- The three phases of matter (solids, liquids, gases) have different properties. **(3.1kk)**
- Differences in properties such as density, particle size, molecular polarity, boiling and freezing points, and solubility permit physical separation of the components of the mixture. **(3.1nn)**
- A solution is a homogeneous mixture of solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent. **(3.1oo)**
- The concentration of a solution may be expressed in molarity (M), percent by volume, percent by mass, or parts per million (ppm). **(3.1pp)**
- The addition of a nonvolatile solute to a solvent causes the boiling point of the solvent to increase and the freezing point of the solvent to decrease. The greater the concentration of the solute particles, the greater the effect. **(3.1qq)**
- A physical change results in the rearrangement of existing particles in a substance. A chemical change results in the formation of different substances with changed properties. **(3.2a)**

continued

MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 6: Interconnectedness: Common Themes

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

Standard 7: Interdisciplinary Problem Solving

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

NGSS CROSS-CUTTING CONCEPTS

http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

- Changes in systems may have various causes that may not have equal effects.

Scale, Proportion, and Quantity

- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Systems and System Models:

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

continued

NYS SCIENCE STANDARDS

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- The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure and high temperature. **(3.4a)**
- Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:
  - — are in random, constant, straight-line motion.
  - — are separated by great distances relative to their size; the volume of the gas particles is considered negligible.
  - — have no attractive force between them.
  - — have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant. **(3.4b)**
- Energy can exist in different forms, such as chemical, electrical, electromagnetic, thermal, mechanical, nuclear. **(4.1a)**
- Chemical and physical changes can be exothermic or endothermic. **(4.1b)**
- Heat is a transfer of energy (usually thermal energy) from a body of higher temperature to a body of lower temperature. Thermal energy is the energy associated with the random motion of atoms and molecules. **(4.2a)**
- Temperature is a measurement of the average kinetic energy of the particles in a sample of material. Temperature is not a form of energy. **(4.2b)**
- The concepts of kinetic and potential energy can be used to explain physical processes that include: fusion (melting), solidification (freezing), vaporization (boiling, evaporation), condensation, sublimation, and deposition. **(4.2c)**

NGSS CROSS-CUTTING CONCEPTS

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- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Cause and Effect: Mechanism and Prediction:

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.
- Changes in systems may have various causes that may not have equal effects.

Energy and Matter: Flows, Cycles, and Conservation:

- The total amount of energy and matter in closed systems is conserved.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Stability and Change:

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

COMMON CORE STATE STANDARDS http://www.corestandards.org/Math/ http://www.corestandards.org/ELA-Literacy/	ENVIRONMENTAL GUIDELINES FOR LEARNING http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf	TABLES: REFERENCE TABLES FOR PHYSICAL SETTING/ CHEMISTRY THAT ARE RELEVANT TO THE UNIT http://www.p12.nysed.gov/assessment/reftable/chemistry-rt/chemrt-2011.pdf
ELA/Literacy **RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **WHST.9–12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **WHST.9–12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **WHST.9–12.9:** Draw evidence from informational texts to support analysis, reflection, and research. **SL.11-12.5:** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **Mathematics** **MP.2:** Reason abstractly and quantitatively. **MP.4:** Model with mathematics. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	**Strand 2: Knowledge of Environmental Processes and Systems** ▪ Guideline B—Changes in Matter—Learners apply their understanding of chemical reactions to round out their explanations of environmental characteristics and everyday phenomena. ▪ Guideline C—Energy—Learners apply their knowledge of energy and matter to understand phenomena in the world around them.	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* Table A – Standard Temperature and Pressure Table B – Physical Constants for Water Table C – Selected Prefixes Table D – Selected Units The Periodic Table of Elements Table S – Properties of Selected Elements Table T – Important Formulas and Equations

CH | Unit 2 Atomic Concepts

RECOMMENDED TIME: 20 DAYS

Unit Overview:

Through decades of experimentation and modeling that began in the late 1800s, it was determined that matter was composed of particles called atoms. An atom has a small, dense nucleus in the center with electrons moving about in the empty space surrounding the nucleus. Energy was thought to exist in small, indivisible packets called quanta, and this theory was used to develop a model of the atom which had a central nucleus surrounded by shells of electrons. The model was used to explain the properties of chemical bonding, and additional experimentation with radioactivity provided evidence that atomic nuclei contained protons and neutrons. Changes in motion result from the interaction of matter and energy.

Essential Question:
How is the structure of an atom like other systems models?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 5: Energy and matter interact through forces that result in changes in motion.

NYS SCIENCE STANDARDS
http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 3.1a-f, h-n; 5.2c

- The modern model of the atom has evolved over a long period of time through the work of many scientists. **(3.1a)**
- Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons. **(3.1b)**
- Subatomic particles contained in the nucleus include protons and neutrons. **(3.1c)**
- The proton is positively charged, and the neutron has no charge. The electron is negatively charged. **(3.1d)**
- Protons and electrons have equal but opposite charges. The number of protons equals the number of electrons in an atom. **(3.1e)**

continued

MST STANDARDS
http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 2: Information Systems

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

Examples include:

- Use the Internet as a source to retrieve information for classroom use, e.g., research history of atomic structures and scientific development of modern atomic theory.

Standard 6: Interconnectedness: Common Themes

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

continued

NGSS CROSS-CUTTING CONCEPTS
http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments.
- Empirical evidence is needed to identify patterns.

continued

NYS SCIENCE STANDARDS

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- The mass of each proton and each neutron is approximately equal to one atomic mass unit. An electron is much less massive than a proton or a neutron. **(3.1f)**
- In the wave-mechanical model (electron cloud model) the electrons are in orbitals, which are defined as the regions of the most probable electron location (ground state). **(3.1h)**
- Each electron in an atom has its own distinct amount of energy. **(3.1i)**
- When an electron in an atom gains a specific amount of energy, the electron is at a higher energy state (excited state). **(3.1j)**
- When an electron returns from a higher energy state to a lower energy state, a specific amount of energy is emitted. This emitted energy can be used to identify an element. **(3.1k)**
- The outermost electrons in an atom are called the valence electrons. In general, the number of valence electrons affects the chemical properties of an element. **(3.1l)**
- Atoms of an element that contain the same number of protons but a different number of neutrons are called isotopes of that element. **(3.1m)**
- The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes. **(3.1n)**
- When an atom gains one or more electrons, it becomes a negative ion and its radius increases. When an atom loses one or more electrons, it becomes a positive ion and its radius decreases. **(5.2c)**

MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Energy and Matter: Flows, Cycles, and Conservation:

Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.

Structure and Function:

The way an object is shaped or structured determines many of its properties and functions.

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

NGSS CROSS-CUTTING CONCEPTS

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Cause and Effect: Mechanism and Prediction:

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.

Systems and System Models:

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

COMMON CORE STATE STANDARDS http://www.corestandards.org/Math/ http://www.corestandards.org/ELA-Literacy/	ENVIRONMENTAL GUIDELINES FOR LEARNING http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf	TABLES: REFERENCE TABLES FOR PHYSICAL SETTING/ CHEMISTRY THAT ARE RELEVANT TO THE UNIT http://www.p12.nysed.gov/assessment/reftable/chemistry-rt/chemrt-2011.pdf
ELA/Literacy **RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **WHST.9–12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **WHST.9–12.9:** Draw evidence from informational texts to support analysis, reflection, and research. **SL.11-12.5:** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **Mathematics** **MP.2:** Reason abstractly and quantitatively. **MP.4:** Model with mathematics. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	**Strand 2: Knowledge of Environmental Processes and Systems** ■ Guideline B—Changes in Matter—Learners apply their understanding of chemical reactions to round out their explanations of environmental characteristics and everyday phenomena. ■ Guideline C—Energy—Learners apply their knowledge of energy and matter to understand phenomena in the world around them.	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* Table C – Selected Prefixes Table D – Selected Units Table O – Symbols Used in Nuclear Chemistry The Periodic Table of Elements Table S – Properties of Selected Elements

CH | Unit 3 Nuclear Chemistry

RECOMMENDED TIME: 20 DAYS

Unit Overview:

The discovery of the energy stored in the nucleus of an atom, its uses, and its benefits and risks is a continuing process that began with the detection of the first radioactive isotope. Using radioactivity, the inner structure of the atom was defined by other researchers. Scientists involved in the development of nuclear fission and the atomic bomb explored both peaceful and destructive uses of nuclear energy. Modern researchers continue to search for ways in which the power of the nucleus can be used for the betterment of the world. With a complete understanding of these processes and their application to the modern world comes a responsibility to take care of waste, limit pollution, and decrease potential risks.

Essential Questions:

Why is this alternative energy source so controversial?

Is this really an alternative energy source?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 4: Energy exists in many forms, and when these forms change, energy is conserved.

Key Idea 5: Energy and matter interact through forces that result in changes in motion.

NYS SCIENCE STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 3.1m-p; 4.1a, 4.4a-f; 5.3a-c

- Atoms of an element that contain the same number of protons but a different number of neutrons are called isotopes of that element. **(3.1m)**
- The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes. **(3.1n)**
- Stability of an isotope is based on the ratio of the neutrons and protons in the nucleus. Although most nuclei are stable, some are unstable and spontaneously decay, emitting radiation. **(3.1o)**

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MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 2: Information Systems

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

Key Idea 2: Knowledge of the impacts and limitations of information systems is essential to its effectiveness and ethical use.

Standard 6: Interconnectedness: Common Themes

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

continued

NGSS CROSS-CUTTING CONCEPTS

http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

continued

NYS SCIENCE STANDARDS

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- Spontaneous decay can involve the release of alpha particles, beta particles, positrons and/or gamma radiation from the nucleus of the unstable isotope. These emissions differ in mass, charge, ionizing power and penetrating power. **(3.1p)**
- Energy can exist in different forms, such as chemical, electric, electromagnetic, thermal, mechanical, nuclear. **(4.1a)**
- Each radioactive isotope has a specific mode and rate of decay (half-life). **(4.4a)**
- Nuclear reactions include natural and artificial transmutation, fission and fusion. **(4.4b)**
- Nuclear reactions can be represented by equations that include symbols which represent atomic nuclei (with mass number and atomic number), subatomic particles (with mass number and charge), and/or emissions such as gamma radiation. **(4.4c)**
- Radioactive isotopes have many beneficial uses. Radioactive isotopes are used in medicine and industrial chemistry for radioactive dating, tracing chemical and biological processes, industrial measurement, nuclear power and detection and treatment of diseases. **(4.4d)**
- There are inherent risks associated with radioactivity and the use of radioactive isotopes. Risks can include biological exposure, long-term storage and disposal, and nuclear accidents. **(4.4e)**
- There are benefits and risks associated with fission and fusion reactions. **(4.4f)**
- A change in the nucleus of an atom that converts it from one element to another is called transmutation. This can occur naturally or can be induced by the bombardment of the nucleus with high-energy particles. **(5.3a)**

continued

MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

Standard 7: Interdisciplinary Problem Solving

Key Idea 1: The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena.

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

NGSS CROSS-CUTTING CONCEPTS

http://www.nextgenscience.org/next-generation-science-standards

Scale, Proportion, and Quantity:

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Energy and Matter: Flows, Cycles, and Conservation:

Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.

- The total amount of energy and matter in closed systems is conserved.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

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NYS SCIENCE STANDARDS http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf		NGSS CROSS-CUTTING CONCEPTS http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf
■ Energy released in a nuclear reaction (fission or fusion) comes from the fractional amount of mass that is converted into energy. Nuclear changes convert matter into energy. **(5.3b)** ■ Energy released during nuclear reactions is much greater than the energy released during chemical reactions. **(5.3c)**		**Structure and Function:** The way an object is shaped or structured determines many of its properties and functions. ■ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **Stability and Change:** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. ■ Much of science deals with constructing explanations of how things change and how they remain stable. ■ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

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ELA/Literacy **RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **SL.11-12.5:** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **Mathematics** **MP.4:** Model with mathematics. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	**Strand 2: Knowledge of Environmental Processes and Systems** ▪ Guideline B—Changes in Matter—Learners apply their understanding of chemical reactions to round out their explanations of environmental characteristics and everyday phenomena. ▪ Guideline C—Energy—Learners apply their knowledge of energy and matter to understand phenomena in the world around them.	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* Table C – Selected Prefixes Table D – Selected Units Table N – Selected Radioisotopes Table O – Symbols Used in Nuclear Chemistry The Periodic Table of Elements Table S – Properties of Selected Elements

CH | Unit 4 Chemical Bonding

RECOMMENDED TIME: 20 DAYS

Unit Overview:

The concept of a chemical bond is the core principle behind most of chemistry. Bonding is what enables atoms of elements to join in multiple combinations to form more than fifty million chemical substances in our world. There are several types of chemical bonds with specific characteristics that require unique circumstances to account for the various chemical combinations we find on earth.

Essential Question:

Why do some atoms form chemical bonds to form stable compounds and others do not?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 5: Energy and matter interact through forces that result in changes in motion.

NYS SCIENCE STANDARDS
http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 5.2a-e, 5.2g-n, 3.1cc, 3.1ee, 3.1oo, 3.1pp, 3.1qq, 3.2b, 3.3a, c, e

- Chemical bonds are formed when valence electrons are:
  - transferred from one atom to another (ionic)
  - shared between atoms (covalent)
  - mobile within a metal (metallic) **(5.2a)**
- Atoms attain a stable valence electron configuration by bonding with other atoms. Noble gases have stable valence configurations and tend not to bond. **(5.2b)**
- When an atom gains one or more electrons, it becomes a negative ion and its radius increases. When an atom loses one or more electrons, it becomes a positive ion and its radius decreases. **(5.2c)**

continued

MST STANDARDS
http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 6: Interconnectedness: Common Themes

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

NGSS CROSS-CUTTING CONCEPTS
http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Cause and Effect: Mechanism and Prediction:

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

continued

NYS SCIENCE STANDARDS http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf	NGSS CROSS-CUTTING CONCEPTS http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

- Electron-dot diagrams (Lewis structures) can represent the valence electron arrangement in elements, compounds, and ions. **(5.2d)**
- In a multiple covalent bond, more than one pair of electrons is shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond. **(5.2e)**
- Two major categories of compounds are ionic and molecular (covalent) compounds. **(5.2g)**
- Metals tend to react with nonmetals to form ionic compounds. Nonmetals tend to react with other nonmetals to form molecular (covalent) compounds. Ionic compounds containing polyatomic ions have both ionic and covalent bonding. **(5.2h)**
- When a bond is broken, energy is absorbed. When a bond is formed, energy is released. **(5.2i)**
- Electronegativity indicates how strongly an atom of an element attracts electrons in chemical bonds. Electronegativity values are assigned according to arbitrary scales. **(5.2j)**
- The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond. **(5.2k)**
- Molecular polarity can be determined by the shape of the molecule and distribution of charge. Symmetrical (nonpolar) molecules include CO_2, CH_4, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH_3, and H_2O. **(5.2l)**
- Intermolecular forces created by the unequal distribution of charge result in varying degrees of attraction between molecules. Hydrogen bonding is an example of a strong intermolecular force. **(5.2m)**
- Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point and boiling point. **(5.2n)**
- A compound is a substance composed of two or more different elements that are chemically combined in a fixed proportion. A chemical compound can be broken down by chemical means. A chemical compound can be represented by a specific chemical formula and assigned a name based on the IUPAC system. **(3.1cc)**
- Types of chemical formulas include empirical, molecular, and structural. **(3.1ee)**
- A solution is a homogeneous mixture of solute and solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent. **(3.1oo)**
- The concentration of a solution may be expressed in molarity (M), percent by volume, percent by mass, or parts per million (ppm). **(3.1pp)**
- The addition of a nonvolatile solute to a solvent causes the boiling point of the solvent to increase and the freezing point of the solvent to decrease. The greater the concentration of solute particles, the greater the effect. **(3.1qq)**
- The types of chemical reactions include synthesis, decomposition, single replacement, and double replacement. **(3.2b)**
- In all chemical reaction there is a conservation of mass, energy and charge. **(3.3a)**

continued

- Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system.

Scale, Proportion, and Quantity:

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Systems and System Models:

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Energy and Matter: Flows Cycles, and Conservation:

Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.

- The total amount of energy and matter in closed systems is conserved.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

continued

NYS SCIENCE STANDARDS http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf	NGSS CROSS-CUTTING CONCEPTS http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf
■ A balanced chemical equation represents conservation of atoms. The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction. **(3.3c)** ■ The formula mass of a substance is a sum of the atomic masses. The molar mass (gram-formula mass) of a substance equals one mole of that substance. **(3.3e)**	■ Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems. ■ Energy drives the cycling of matter within and between systems. **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions. ■ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **Stability and Change:** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. ■ Much of science deals with constructing explanations of how things change and how they remain stable. ■ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

COMMON CORE STATE STANDARDS http://www.corestandards.org/Math/ http://www.corestandards.org/ELA-Literacy/	ENVIRONMENTAL GUIDELINES FOR LEARNING http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf	TABLES: REFERENCE TABLES FOR PHYSICAL SETTING/ CHEMISTRY THAT ARE RELEVANT TO THE UNIT http://www.p12.nysed.gov/assessment/reftable/chemistry-rt/chemrt-2011.pdf
ELA/Literacy **WHST.9–12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **WHST.9–12.5:** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. **SL.11-12.5:** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **Mathematics** **MP.2:** Reason abstractly and quantitatively. **MP.4:** Model with mathematics. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	**Strand 1: Questioning, Analysis and Interpretation Skills** ▪ Guideline E—Organizing Information—Learners are able to organize and display information in ways appropriate to different types of environmental investigations and purposes. ▪ Guideline F—Working with Models and Simulations — Learners are able to create, use, and evaluate models to understand environmental phenomena	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* Table E – Selected Polyatomic Ions Table F – Solubility Guidelines for Aqueous Solutions The Periodic Table of Elements Table S – Properties of Selected Elements

CH | Unit 5 Periodicity

RECOMMENDED TIME: 5 DAYS

Unit Overview:

The element phosphorous was isolated and "discovered" in the late 1600s, but it was not until the mid-1800s that a serious attempt at organizing the arrangement of elements was made by a Russian chemist named Dimitri Mendeleev. In his development of the periodic table, Mendeleev became aware of repeating patterns and knew that there were elements that had yet to be discovered and so left open spaces in the Periodic Table of elements to accommodate for future discoveries. Through meticulous investigations and careful organization, the Periodic Table of Elements is a wealth of chemical information.

Essential Questions:

What are the trends in the Periodic Table of Elements as you go from left to right and top to bottom?

What are the factors that determine each of the trends you see?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 5: Energy and matter interact through forces that result in changes in motion.

NYS SCIENCE STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 3.1y, 3.1aa, 3.1bb, 3.1g, l, 3.1v-z, 5.2b, f, h

- The placement or location of an element on the Periodic Table gives an indication of the physical and chemical properties of the element. The elements on the Periodic Table are arranged in order of increasing atomic number. **(3.1y)**
- The succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/non-metallic properties. **(3.1aa)**

continued

MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 2: Information Systems

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

Standard 6: Interconnectedness: Common Themes

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

NGSS CROSS-CUTTING CONCEPTS

http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Mathematical representations are needed to identify some patterns.

Scale, Proportion, and Quantity:

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

continued

NYS SCIENCE STANDARDS http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf	NGSS CROSS-CUTTING CONCEPTS http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

- The succession of elements across the same period demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties. **(3.1bb)**
- The number of protons in an atom (atomic number) identifies the element. The sum of the protons and neutrons in an atom (mass number) identifies the isotope. Common notations that represent isotopes include: ^{14}C, $^{14}_{6}C$, carbon-14, C-14. **(3.1g)**
- The outermost electrons in an atom are called the valence electrons. In general, the number of valence electrons affects the chemical properties of an element. **(3.1l)**
- Elements can be classified by their properties and are located on the Periodic Table as metals, non-metals, metalloids (B, Si, Ge, As, Sb, Te) and noble gases. **(3.1v)**
- Elements can be differentiated by physical properties. Physical properties of substances, such as density, conductivity, malleability, solubility and hardness differ among elements. **(3.1w)**
- Elements can also be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction. **(3.1x)**
- The placement or location of an element on the Periodic Table gives an indication of the physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number. **(3.1y)**
- For Groups 1, 2, 13–18 on the Periodic Table, elements with the same group have the same number of valence electrons (helium is the exception) and therefore similar chemical properties. **(3.1z)**
- Atoms attain a stable valence electron configuration by bonding with other atoms. Nobel gases have stable valence configurations and tend not to bond. **(5.2b)**
- Some elements exist in two or more forms in the same phase. These forms differ in their molecular or crystal structure, and hence their properties. **(5.2f)**
- Metals tend to react with nonmetals to form ionic compounds. Nonmetals tend to react with nonmetals to form molecular (covalent) compounds. Ionic compounds containing polyatomic ions have both ionic and covalent bonding. **(5.2h)**

- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Structure and Function:

The way an object is shaped or structured determines many of its properties and functions.

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Stability and Change:

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Systems can be designed for greater or lesser stability.

COMMON CORE STATE STANDARDS http://www.corestandards.org/Math/ http://www.corestandards.org/ELA-Literacy/	ENVIRONMENTAL GUIDELINES FOR LEARNING http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf	TABLES: REFERENCE TABLES FOR PHYSICAL SETTING/ CHEMISTRY THAT ARE RELEVANT TO THE UNIT http://www.p12.nysed.gov/assessment/reftable/chemistry-rt/chemrt-2011.pdf
ELA/Literacy **RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **WHST.9–12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **WHST.9–12.5:** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. **WHST.9–12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **WHST.11-12.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. **WHST.9–12.9:** Draw evidence from informational texts to support analysis, reflection, and research. **SL.11-12.5:** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.	**Strand 1: Questioning, Analysis, and Interpretation Skills** ▪ Guideline E—Organizing Information—Learners are able to organize and display information in ways appropriate to different types of environmental investigations and purposes. ▪ Guideline F—Working with Models and Simulations—Learners are able to create, use and evaluate models to understand environmental phenomena. **Mathematics** **MP.2:** Reason abstractly and quantitatively. **MP.4:** Model with mathematics. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* The Periodic Table of Elements Table S – Properties of Selected Elements

CH | Unit 6 Moles/Stoichiometry

RECOMMENDED TIME: 12 DAYS

Unit Overview:

Stoichiometry is the term used for the calculation of a balanced chemical reaction. As per the Law of Conservation of Matter, the number and type of atoms that go into a reaction must match the number and type of atoms that are formed as the product of the reaction. This means that if the amounts of the separate reactants are known, then the amount of the product can be calculated. As with algebra, once this is known, the variable can be determined. A mole is a unit of measurement in chemistry expressed as Avogadro's constant (6.02×10^{23}) and equal to a substance's mean molecular mass.

Essential Questions:

What is the purpose of knowing the amounts of substances involved in chemical equations?

How can this knowledge inform the work of chemical engineers?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

NYS SCIENCE STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 3.1cc, 3.1ee, 3.1n, 3.3a, c-f, 3.4e, 3.1oo, 3.1pp, 3.1qq, 3.2b

- A compound is a substance composed of two or more different elements that are chemically combined in fixed proportions. A chemical compound can be broken down by chemical means. A chemical compound can be represented by a specific chemical formula and assigned a name based on the IUPAC (International Union of Pure and Applied Chemistry — http://www.iupac.org/) System **(3.1cc)**
- Types of chemical formulas include empirical, molecular, and structural. **(3.1ee)**
- The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes. **(3.1n)**

continued

MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 6: Interconnectedness: Common Themes

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

NGSS CROSS-CUTTING CONCEPTS

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Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Scale, Proportion, and Quantity:

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

continued

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- The formula mass of a substance is the sum of the atomic masses of its atoms. The molar mass (gram-formula mass) of a substance equals one mole of that substance. **(3.3e)**
- Equal volumes of gases at the same temperature and pressure contain an equal number of particles. **(3.4e)**
- The empirical formula of a compound is the simplest whole-number ratio of the atoms of elements in the compound. It may be different from the molecular formula, which is the actual ratio of atoms in a molecule of that compound. **(3.3d)**
- A balanced chemical equation represents conservation of atoms. The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction. **(3.3c)**
- In all chemical reactions, there is a conservation of mass, energy and charge. **(3.3a)**
- A solution is a homogeneous mixture of solute dissolved in solvent. The solubility of the solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and the solvent. **(3.1oo)**
- The concentration of the solution may be expressed in molarity (M), percent by volume, percent by mass or parts per million (ppm). **(3.1pp)**
- The addition of a nonvolatile solute to a solvent causes the boiling point of the solvent to increase and the freezing point of the solvent to decrease. The greater the concentration of solute, the greater the effect. **(3.1qq)**
- The percent composition by mass of each element in a compound can be calculated mathematically. **(3.3f)**
- Types of chemical reaction include synthesis, decomposition, single replacement, and double replacement. **(3.2b)**

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Systems and System Models:

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Energy and Matter: Flows, Cycles, and Conservation:

Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.

- The total amount of energy and matter in closed systems is conserved.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Structure and Function:

The way an object is shaped or structured determines many of its properties and functions.

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Stability and Change:

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

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- Systems can be designed for greater or lesser stability.

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ELA/Literacy **WHST.9–12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **WHST.9–12.7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **SL.11-12.5:** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **Mathematics** **MP.2:** Reason abstractly and quantitatively. **MP.4:** Model with mathematics. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	**Strand 2: Knowledge of Environmental Processes and Systems** ▪ Guideline B—Changes in Matter—Learners apply their understanding of chemical reactions to round out their explanations of environmental characteristics and everyday phenomena. ▪ Guideline C—Energy—Learners apply their knowledge of energy and matter to understand phenomena in the world around them.	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* Table A – Standard Temperature and Pressure Table B – Physical Constants for Water Table C – Selected Prefixes Table D – Selected Units Table E – Selected Polyatomic Ions Table F – Solubility Guidelines for Aqueous Solutions Table G – Solubility Curves at Standard Temperature and Pressure Table I – Heats of Reaction at 101.3 kPA and 29K The Periodic Table of Elements Table S – Properties of Selected Elements Table T – Important Formulas and Equations

CH | Unit 7 Kinetics & Equilibrium

RECOMMENDED TIME: 15 DAYS

Unit Overview:

Chemical equilibrium is the state of constant composition attained when opposing reaction rates become equal in a closed system. In other words, the reactants and the products do not have to necessarily be equal, but the rate at which they are formed is equal. Kinetics is the term for particles in motion, and the movement of these particles will be determined by the forces or stresses that are added or removed from a system. Chemical reactions happen when particles with adequate energy and proper orientation collide. This process may absorb or release energy and can be represented visually using a graph of potential energy.

Essential Questions:

How is the equilibrium of a chemical system the same as homeostasis in living things? A balance of vectors in engineering?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 4: Energy exists in many forms, and when these forms change, energy is conserved.

NYS SCIENCE STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators 3.4a-d, f-j; 4.1c, d; 3.1Il, 3.1mm; 4.2 b, c

- Collision theory states that a reaction is most likely to occur if reactant particles collide with proper energy and orientation. **(3.4d)**
- The rate of a chemical reaction depends on several factors: temperature, concentration, nature of the reactants, surface area, and the presence of a catalyst. **(3.4f)**
- The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the gas is at low pressure and high temperature. **(3.4a)**
  — Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:

continued

MST STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Standard 2: Information Systems

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

Standard 6: Interconnectedness: Common Themes

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NGSS CROSS-CUTTING CONCEPTS

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– are in random, constant straight-line motion. – are separated by great distances relative to their size; the volume of the gas particles is considered negligible. – have no attractive forces between them. – have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant. **(3.4b)** ■ Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collision among gas particles. **(3.4c)** ■ A catalyst provides an alternative reaction pathway, which has a lower activation energy than an uncatalyzed reaction. **(3.4g)** ■ Some chemical and physical changes can reach equilibrium. **(3.4h)** ■ At equilibrium the rate of the forward reaction equals the rate of the reverse reaction. The measureable quantities of reactants and products remain constant at equilibrium. **(3.4i)** ■ Le Chatelier's principle can be used to predict the effect of stress (change in pressure, volume, concentration, and temperature) on a system at equilibrium. **(3.4j)** ■ Energy released or absorberd during a chemical reaction can be represented by a potential energy diagram. **(4.1c)** ■ Energy released or absorbed during a chemical reaction (heat of reaction) is equal to the difference between the potential energy of the products and the potential energy of the reactants. **(4.1d)** ■ Temperature is the measurement of the average kinetic energy of the particles in a sample of material and not a form of energy. **(4.2b)** *continued*	**Key Idea 3:** The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems. **Key Idea 4:** Equilibrium is a state of stability due either to a lack of change (static equilibrium) or a balance between opposing forces (dynamic equilibrium). **Key Idea 5:** Identifying patterns of change is necessary for making predictions about future behavior and conditions.	**Cause and Effect: Mechanism and Prediction:** Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. ■ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ■ Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system. ■ Changes in systems may have various causes that may not have equal effects. **Scale, Proportion, and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. ■ The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ■ Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. ■ Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. ■ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). *continued*

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▪ The concept of kinetic and potential energy can be used to explain physical processes that include: fusion (melting), solidification (freezing), vaporization (boiling, evaporation), condensation, sublimation, and deposition. **(4.2c)** ▪ Entropy is a measure of the randomness or disorder of a system. A system with greater disorder has greater entropy. **(3.1ll)** ▪ Systems in nature tend to undergo changes toward lower energy and higher entropy. **(3.1mm)**	**Systems and System Models:** A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. **Energy and Matter: Flows, Cycles, and Conservation:** Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior. ▪ The total amount of energy and matter in closed systems is conserved. ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. ▪ Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.	**Stability and Change:** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. ▪ Much of science deals with constructing explanations of how things change and how they remain stable. ▪ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. ▪ Feedback (negative or positive) can stabilize or destabilize a system. ▪ Systems can be designed for greater or lesser stability.

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ELA/Literacy **RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **WHST.9–12.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. **WHST.9–12.9:** Draw evidence from informational texts to support analysis, reflection, and research. **Mathematics** **MP.2:** Reason abstractly and quantitatively. **HSN-Q.A.1:** Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.2:** Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	**Strand 2: Knowledge of Environmental Processes and Systems** ▪ Guideline B—Changes in Matter—Learners apply their understanding of chemical reactions to round out their explanations of environmental characteristics and everyday phenomena. ▪ Guideline C—Energy—Learners apply their knowledge of energy and matter to understand phenomena in the world around them.	*[Refer to Appendix B – Reference Tables for Physical Setting/Chemistry]* Table A – Standard Temperature and Pressure Table G – Solubility Curves at Standard Temperature and Pressure Table H – Vapor Pressure of Four Liquids Table I – Heats of Reaction at 101.3kPa and 298K The Periodic Table of Elements Table S – Properties of Selected Elements Table T – Important Formulas and Equations

CH | Unit 8 Acids & Bases

RECOMMENDED TIME: 15 DAYS

Unit Overview:

Understanding acids and bases is important for grasping chemistry concepts. Simple double-replacement reactions can make the difference between solutions that can cause great harm and those that are relatively benign. The uses for both acids and bases are seemingly endless and a major topic of study in the general chemistry course.

Essential Questions:

What are the essential components of both acids and bases that make them similar? Different?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

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http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from New York State Performance Indicators 3.1rr-zz, 5.2n, 3.2b

- An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions. **(3.1rr)**
- Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point, and boiling point. **(5.2n)**
- The acidity or alkalinity of an aqueous solution can be measured by its pH value. The relative level of acidity or alkalinity of these solutions can be shown by using indicators. **(3.1ss)**
- On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration. **(3.1tt)**

continued

MST STANDARDS
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Standard 2: Information Systems

Key Idea 1: Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

Standard 6: Interconnectedness: Common Themes

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.

continued

NGSS CROSS-CUTTING CONCEPTS
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Patterns:

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Cause and Effect: Mechanism and Prediction:

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which t hey are mediated, is a major activity of science and engineering.

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▪ Behavior of many acids and bases can be explained by the Arrhenius theory. Arrhenius acids and bases are electrolytes. **(3.1uu)** ▪ Arrhenius acids yield H^+(aq), hydrogen ion as the only positive ion in an aqueous solution. The hydrogen ion may also be written as H_3O^+(aq), hydronium ion. **(3.1vv)** ▪ Arrhenius bases yield OH^-(aq), hydroxide ion as the only negative ion in an aqueous solution. **(3.1ww)** ▪ In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form a salt and water. **(3.1xx)** ▪ There are alternate acid-base theories. One theory states that an acid is an H^+ donor and a base is an H^+ acceptor. **(3.1yy)** ▪ Titration is a laboratory process in which a volume of a solution of known concentration is used to determine the concentration of another solution. **(3.1zz)** ▪ Types of chemical reactions include synthesis, decomposition, single replacement, and double replacement. **(3.2b)**	**Standard 7: Interdisciplinary Problem Solving** **Key Idea 1:** The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena. **Key Idea 2:** Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results. If students are asked to do a project, then the project would require students to: ▪ Work effectively ▪ Gather and process information ▪ Generate and analyze ideas ▪ Observe common themes ▪ Realize ideas ▪ Present results	▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ▪ Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system. ▪ Systems can be designed to cause a desired effect. ▪ Changes in systems may have various causes that may not have equal effects. **Scale, Proportion, and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change ▪ Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. ▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Systems and System Models:** A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. ▪ Systems can be designed to do specific tasks. ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

continue

NGSS CROSS-CUTTING CONCEPTS

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- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Energy and Matter: Flows, Cycles, and Conservation:

Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.

- The total amount of energy and matter in closed systems is conserved.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Stability and Change:

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Feedback (negative or positive) can stabilize or destabilize a system.
- Systems can be designed for greater or lesser stability.

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CH | Unit 9 Oxidation & Reduction

RECOMMENDED TIME: 15 DAYS

Unit Overview:

Redox is a term that is used to describe any and all chemical reactions in which the oxidation state of the atoms in the reaction changes. Reduction is the gaining of these electrons, and oxidation is the loss of the electrons. These half- reactions involving the transfer of electrons from one to another occur simultaneously.

Essential Question:
How can we make electrochemistry work for us?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

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http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from New York State Performance Indicators 3.1b, 3.2d-l, 3.3a, b

- Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons. **(3.1b)**
- An oxidation-reduction (redox) reaction involves the transfer of electrons (e-). **(3.2d)**
- Reduction is the gain of electrons. **(3.2e)**
- A half-reaction can be written to represent reduction. **(3.2f)**
- Oxidation is the loss of electrons. **(3.2g)**
- A half-reaction can be written to represent oxidation. **(3.2h)**
- In a redox reaction the number of electrons lost is equal to the number of electrons gained. **(3.3b)**
- Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred. **(3.2i)**
- In all chemical reactions there is a conservation of mass, energy, and charge. **(3.3a)**

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Standard 6: Interconnectedness: Common Themes—Equilibrium and Stability

Key Idea 4: Equilibrium is a state of stability due either to a lack of changes (static equilibrium) or a balance between opposing forces (dynamic equilibrium).

- Each electron in an atom has its own distinct amount of energy. **(3.1i)**
- An electrochemical cell can be either voltaic or electrolytic. In an electrochemical cell, oxidation occurs at the anode and reduction at the cathode. **(3.2j)**
- A voltaic cell spontaneously converts chemical energy to electrical energy. **(3.2k)**
- An electrolytic cell requires electrical energy to produce a chemical change. This process is known as electrolysis. **(3.2l)**

NGSS CROSS-CUTTING CONCEPTS
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Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Energy and Matter

- The total amount of energy and matter in closed systems is conserved.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

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CH | Unit 10 Carbon and Organic Chemistry

RECOMMENDED TIME: 13 DAYS

Unit Overview:

Organic compounds always contain carbon and are the basis of all living things. The chemical structure of carbon includes four valence electrons, which allows for a multitude different structures. Naturally occurring carbon compounds include carbohydrates, lipids, proteins, and nucleic acids. Synthetic carbon-based compounds include credit cards, disposable diapers, spandex clothing, and many parts of automobiles.

Essential Questions:

What are the changes that have occurred in the last 50 years due to the increased use of carbon-based products?

Do the benefits outweigh the environmental risks?

Key Ideas:

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

NYS SCIENCE STANDARDS

http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

Major Understandings:

Quoted from the New York State Performance Indicators: 3.1ff-ii, 3.1jj, 3.1n, 5.2e, 3.2c

- Organic compounds contain carbon atoms, which bond to one another in chains, rings, and networks to form a variety of structures. Organic compounds can be named using the IUPAC (International Union of Pure and Applied Chemistry – http://www.iupac.org) System. **(3.1ff)**
- Hydrocarbons are compounds that contain only carbon and hydrogen. Saturated hydrocarbons contain only single carbon-carbon bonds. Unsaturated hydrocarbons contain at least one multiple carbon-carbon bond. **(3.1gg)**
- Organic acids, alcohols, esters, aldehydes, ketones, ethers, halides, amines, amides, and amino acids are categories of organic compounds that differ in their structures. Functional groups impart distinctive physical and chemical properties to organic compounds. **(3.1hh)**
- Isomers of organic compounds have the same molecular formula, but different structures and properties. **(3.1ii)**
- In a multiple covalent bond, more than one pair of electrons is shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond. **(5.2e)**
- Types of organic reactions include: addition, substitution, polymerization, esterification, fermentation, saponification, and combustion. **(3.2c)**

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Standard 6: Interconnectedness: Common Themes—Equilibrium and Stability

Key Idea 4: Equilibrium is a state of stability due either to a lack of changes (static equilibrium) or a balance between opposing forces (dynamic equilibrium).

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Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Energy and Matter

- The total amount of energy and matter in closed systems is conserved.
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Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

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