**Unit 5: Chemical Reactions & Calculations

Content Area: **Science**
Course(s):
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Unit Summary

Chemists use the mole to count atoms, molecules, ions, and formula units. A mole always contains the same number of particles; however, moles of different substances have different masses. The molar mass of a compound can be calculated from its chemical formula and can be used to convert from mass to moles of that compound. A molecular formula of a compound is a whole-number multiple of its empirical formula. Hydrates are solid ionic compounds in which water molecules are trapped. : Millions of chemical reactions in and around us transform reactants into products, resulting in the absorption or release of energy. Chemical reactions are represented by balanced equations. There are four main types of chemical reactions: synthesis, combustion, decomposition, and replacement (single and double) reactions. Double replacement reactions occur between substances in aqueous solutions and produce precipitates, water, or gases The amount of each reactant present at the start of a chemical reaction determines how much product can form. The solution to every stoichiometric problem requires a balanced chemical equation. A chemical reaction stops when one of the reactants is used up. Percent yield is a measure of the efficiency of a chemical reaction.

Enduring Understanding

The properties of elements determine how atoms and molecules interact.

Matter is neither created nor destroyed.

The interactions of substances with one another create new products in a predictable, quanitifiable way.

The conservation of atoms in chemical reactions leads to the law of conservation of mass.

Essential Questions

How can one convert between various metric measurements? (As done in Unit 1)

How can conversions be made among particles, mass, and moles of any substance?

What is the difference between empirical and molecular formulas?

Why do we need a properly balanced equation to solve a stoichiometry problem?

Why is the mole such a large number (Avogadro’s number)?

How can you support the law of conservation of mass using a chemical equation?

How can you determine if a chemical reaction will occur?

How can you identify the different types of reactions based on the reactant(s) and product(s)?

How can you predict the products of a single replacement or double replacement reaction?

How can you prove that mass is conserved during a chemical reaction?

What are the differences between an exothermic reaction and an endothermic reaction?

How is the limiting reactant related to the theoretical yield?

Why is there a difference between the theoretical yield and actual yield?

How do you calculate the percent composition by mass of any given compound?

What information can be conveyed by a balanced chemical equation?

What types of products are obtained from chemical reactions?

How are quantities of substances in chemical reactions calculated?

How is the law of conservation of matter applied to chemical reactions?

Student Learning Objectives (PE, SEP, DCI, CCC) & Aligned Standards

Performance Expectations

HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [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.]

HS-PS1-7: 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.]

Concepts & Formative Assessment

Metric:

Use dimensional analysis to solve a variety of single-step and multistep problems.

Convert between various metric measurements (Kilo, base, centi, milli) as done in Unit 1

Differentiate between accuracy and precision.

Use significant figures in calculations as done in Unit 1

Moles:

Calculate the number of atoms, molecules, ions, formula units, etc. in a sample of material using the mole concept.

Define Avogadro's number as one mole equals 6.02 x 10^23 particles (atoms, formula units, ions, or molecules).

Define molar mass and use the periodic table to obtain or calculate the molar mass for any given substance.

Calculate the percent composition of a given substance. (students will be given guided notes to assist in completing the task)

Chemical Reactions

Identify and differentiate between physical and chemical changes and identify physical and chemical properties.

identify the reactants and products in a chemical reaction.

Write a balanced equation when given the names or formulas of all reactants and products in a chemical reaction.

Deduce that chemical reactions can be described by writing balanced equations.

Classify a reaction as synthesis (combination), decomposition, combustion, single replacement or double replacement.

Use the appropriate symbol to indicate a reactant or product as a solid, liquid, gas, or aqueous

Prove that conservation of mass occurs during a chemical reaction.

Stoichiometry:

Understand that coefficients in a chemical reaction describe the quantities of individual particles (atoms, molecules, and formula units) and moles of the substances involved.

Prove that the mass of the reactants equals the mass of the products (law of conservation of mass) in a

chemical reaction.

Perform stoichiometric calculations to determine the mass and/or mole relationships between reactants and products and calculations for limiting reactants and percent yield. (simplified/basic problems)

Define, differentiate and apply the concepts of theoretical, actual, and percent yield.

Assessments

Possible Assessment Tasks:

Practice Worksheets for each section

Balancing reactions (phet simulation- online- HTML5) https://phet.colorado.edu/en/simulation/balancing-chemical-equations ( )

Lab: Physical/Chemical Changes

Lab: Stoichiometry: Limiting Reactant/Excess Reactant

Lab: Stoichiometry: Percent Yield

Demonstration: Percent Yield

Connecting with English Language Arts Literacy and Mathematics

Connections to English Language Arts/Literacy-

- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations showing that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy to enhance understanding of findings, reasoning, and evidence and to add interest.
- Cite specific textual evidence to support the concept that changing the temperature or concentration of the reacting particles affects the rate at which a reaction occurs.
- Develop an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Construct short as well as more sustained research projects to answer how to increase amounts of products at equilibrium in a chemical system. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Connections to Mathematics-

- Represent an explanation that atoms, and therefore mass, are conserved during a chemical reaction

symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the conservation of atoms and mass during chemical reactions symbolically and manipulate the representing symbols.

- Use units as a way to understand the conservation of atoms and mass during chemical reactions; choose and interpret units consistently in formulas representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale; choose and interpret the scale and origin in graphs and data displays representing the conservation of atoms and mass in chemical reactions.
- Define appropriate quantities for the purpose of descriptive modeling of the proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing proportional relationships between masses of atoms in the reactants and products and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale.
- Use a mathematical model to explain how the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Represent an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols. Make sense of quantities and relationships about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs symbolically and manipulate the representing symbols.
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- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Use a mathematical model to explain how to increase amounts of products at equilibrium in a chemical system. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem, and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
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Research on Student Learning

Middle- and high-school student thinking about chemical change tends to be dominated by the obvious features of the change. For example, some students think that when something is burned in a closed container, it will weigh more because they see the smoke that was produced. Further, many students do not view chemical changes as interactions. They do not understand that substances can be formed by the recombination of atoms in the original substances. Rather, they see chemical change as the result of a separate change in the

original substance, or changes, each one separate, in several original substances. For example, some students see the smoke formed when wood burns as having been driven out of the wood by the flame (NSDL, 2015).

Prior Learning

By the end of Grade 8, students know that:

Physical science-

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using models of matter. Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy; others store energy.
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object or a ball, respectively). • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- A system of objects may also contain stored (potential) energy, depending on their relative positions.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.
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Life science-

- Plants, algae (including phytoplankton), and many microorganisms use energy from light to make sugars (food) from carbon dioxide from the atmosphere and water, through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules to support growth or to release energy.
- Food webs are models that demonstrate how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

Earth and space sciences-

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

Connections to Other Courses

Physical Science

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 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. • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • 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. In some cases, the relative position of 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. • 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. The availability of energy limits what can occur in any system. • Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

Life Science

The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. • The sugar molecules thus formed contain carbon, hydrogen, and oxygen: Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. • Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

Resources

Links to Free and Low Cost Instructional Resources

Note- The majority of the student sense-making experiences found at these links predate the NGSS. Most will need to be modified to include science and engineering
practices, disciplinary core ideas, and cross cutting concepts. The EQuIP Rubrics for Science can be used as a blueprint for evaluating and modifying instructional
materials.

- American Association for the Advancement of Science: http://www.aaas.org/programs
- American Chemical Society: http://www.acs.org/content/acs/en/education.html
- Concord Consortium: Virtual Simulations: http://concord.org/
- International Technology and Engineering Educators Association: http://www.iteaconnect.org/
- National Earth Science Teachers Association: http://www.nestanet.org/php/index.php

• National Science Digital Library: https://nsdl.oercommons.org/
• National Science Teachers Association: http://ngss.nsta.org/Classroom-Resources.aspx
• North American Association for Environmental Education: http://www.naaee.net/
• Phet: Interactive Simulations https://phet.colorado.edu/
• Science NetLinks: http://www.aaas.org/program/science-netlinks

References

Adapted from the New Jersey NGSS Science Model Curriculum