## Grade 7 Science, Unit 3
# Chemical Reactions

## Overview

### Unit abstract

Upon completion of this unit of study, students will be able to provide molecular-level accounts of states of matters and changes between states, of how chemical reactions involve regrouping of atoms to form new substances, and of how atoms rearrange during chemical reactions. Students will also be able to apply an understanding of optimization design and process in engineering to chemical reaction systems. The crosscutting concept of energy and matter is the organizing concept for these disciplinary core ideas. Students are expected to demonstrate proficiency in developing and using models; analyzing and interpreting data; designing solutions; and obtaining, evaluating, and communicating information. Students use these science and engineering practices to demonstrate understanding of the disciplinary core ideas.

In this unit students will define problems more precisely in order to conduct a more thorough process of choosing the best solution and to optimize the final design. The focus is on a two-stage process of evaluating proposed ideas, using a systematic method to determine which proposed solutions are most promising, testing different solutions, and then combining the best ideas into a new solution that may be better than any of the preliminary ideas. Improving designs involves an iterative process in which students test the best design, analyze the results, modify the design accordingly, and then retest and modify the design again. Students may go through this cycle two, three, or more times in order to reach the optimal (best possible) result.

### Essential questions

- How do atomic and molecular interactions explain the properties of matter that we see and feel?
- How does thermal energy affect particles?

# Written Curriculum

## Next Generation Science Standards

**MS. Chemical Reactions**

Students who demonstrate understanding can:

**MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.<br>▪ Develop a model to describe unobservable mechanisms. (MS-PS1-5)<br>--------------------------------------<br>***Connections to Nature of Science***<br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>▪ Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-5) | **PS1.B: Chemical Reactions**<br>▪ 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. (MS-PS1-5) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-3.)*<br>▪ The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5) | **Energy and Matter**<br>▪ Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5) |

*Connections to other DCIs in this grade-band*: **MS.LS1.C** (MS-PS1-5); **MS.LS2.B** (MS-PS1-5); **MS.ESS2.A** (MS-PS1-5)

*Articulation across grade-bands:* **5.PS1.B** (MS-PS1-5); **HS.PS1.B** (MS-PS1-5)

*Common Core State Standards Connections:*

*ELA/Literacy –*

**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). *(MS-PS1-5)*

*Mathematics –*

**MP.2** Reason abstractly and quantitatively. (MS-PS1-5)
**MP.4** Model with mathematics. (MS-PS1-5)
**6.RP.A.3** Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-5)

**MS. Chemical Reactions**

Students who demonstrate understanding can:

**MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.<br>▪ Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. (MS-PS1-6) | **PS1.B: Chemical Reactions**<br>▪ Some chemical reactions release energy, others store energy. (MS-PS1-6)<br>**ETS1.B: Developing Possible Solutions**<br>▪ A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. *(secondary to MS-PS1-6)*<br>**ETS1.C: Optimizing the Design Solution**<br>▪ Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. *(secondary to MS-PS1-6)*<br>▪ The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *(secondary to MS-PS1-6)* | **Energy and Matter**<br>▪ The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6) |

*Connections to other DCIs in this grade-band*: **MS.PS3.D** (MS-PS1-6)

*Articulation across grade-bands:* **HS.PS1.A** (MS-PS1-6); **HS.PS1.B** (MS-PS1-6); **HS.PS3.A** (MS-PS1-6); **HS.PS3.B** (MS-PS1-6); **HS.PS3.D** (MS-PS1-6)

*Common Core State Standards Connections:*

*ELA/Literacy –*

**RST.6-8.3** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS1-6)

**WHST.6-8.7** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS1-6)

| MS. Engineering Design | | |
|---|---|---|
| Students who demonstrate understanding can:<br>**MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.** | | |
| The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*: | | |
| **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **Analyzing and Interpreting Data**<br>Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.<br>▪ Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3) | **ETS1.B: Developing Possible Solutions**<br>▪ There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-3)<br>▪ Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)<br>**ETS1.C: Optimizing the Design Solution**<br>▪ Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3) | N/A |
| *Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:*<br>**Physical Science:** MS-PS3-3<br>*Connections to MS-ETS1.B: Developing Possible Solutions Problems include:*<br>**Physical Science:** MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5<br>*Connections to MS-ETS1.C: Optimizing the Design Solution include:*<br>**Physical Science**: MS-PS1-6 | | |
| *Articulation of DCIs across grade-bands:* **3-5.ETS1.A** (MS-ETS1-3); **3-5.ETS1.B** (MS-ETS1-3); **3-5.ETS1.C** (MS-ETS1-3); **HS.ETS1.B** (MS-ETS1-3); **HS.ETS1.C** (MS-ETS1-3) | | |
| *Common Core State Standards Connections:*<br>*ELA/Literacy –*<br>**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts. *(MS-ETS1-3)*<br>**RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (*MS-ETS1-3)*<br>**RST.6-8.9** Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-3)<br>*Mathematics –*<br>**MP.2** Reason abstractly and quantitatively. *(MS-ETS1-3)*<br>**7.EE.3** Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-ETS1-3)* | | |

## Clarifying the standards

### *Prior learning*

The following disciplinary core ideas are prior learning for the concepts in this unit of study. By the end of Grade 5, students know that:

- When two or more different substances are mixed, a new substance with different properties may be formed.
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.)

### *Progression of current learning*

<table>
<tr><th colspan="2">Driving question 1<br>How can a model be developed and used to describe that the total number of atoms in a chemical reaction does not change and thus mass is conserved?</th></tr>
<tr><td>Concepts<ul><li>Substances react chemically in characteristic ways.</li><li>In a chemical process, the atoms that make up the original substances are regrouped into different molecules.</li><li>New substances created in a chemical process have different properties from those of the reactants.</li><li>The total number of each type of atom in a chemical process is conserved, and thus the mass does not change (the law of conservation of matter).</li><li>Matter is conserved because atoms are conserved in physical and chemical processes.</li><li>The law of conservation of mass is a mathematical description of natural phenomena.</li></ul></td><td>Practices<ul><li>Use physical models or drawings, including digital forms, to represent atoms in a chemical process.</li><li>Use mathematical descriptions to show that the number of atoms before and after a chemical process is the same.</li></ul></td></tr>
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**Driving question 2**
How can a device be designed, constructed, tested, and modified that either releases or absorbs thermal energy by chemical processes?

Concepts

- Some chemical reactions release energy, while others store energy.
- The transfer of thermal energy can be tracked as energy flows through a designed or natural system.
- Models of all kinds are important for testing solutions.
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.
- A solution needs to be tested and then modified on the basis of the test results in order to for it to be improved.
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process.
- Some of the characteristics identified as having the best performance may be incorporated into the new design.

Practices

- Undertake a design project, engaging in the design cycle, to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. Specific criteria are limited to amount, time, and temperature of a substance.
- Analyze and interpret data for the amount, time, and temperature of a substance in testing a device that either releases or absorbs thermal energy by chemical processes to determine similarities and differences in findings.
- Develop a model to generate data for testing a device that either releases or absorbs thermal energy by chemical processes, including those representing inputs and outputs of thermal energy.
- Track the transfer of thermal energy as energy flows through a designed system that either releases or absorbs thermal energy by chemical processes.

*Integration of content, practices, crosscutting concepts, and engineering*

Students begin by gaining understanding that substances react chemically in very characteristic ways. To develop this understanding, students will follow precisely a multistep procedure when carrying out experiments that involve chemical reactions that release energy and chemical reactions that absorb energy. As part of their data analysis, students will integrate quantitative information about atoms before and after the chemical reaction. The analysis will include translating written information into information that is expressed in a physical model or drawing or in digital forms. Reasoning both quantitatively and abstractly to communicate their understanding of these reactions, students will model the law of conservation of matter. They will use ratio and rate to demonstrate that the total number of atoms involved in the chemical reactions does not change and therefore mass is conserved.

Within this unit, students will develop a model of the reactions they observe to describe how the total number of atoms does not change in a chemical reaction. Examples of models could include physical models, drawings, or digital forms that represent atoms. Student models ideally should have the ability to be manipulated to represent the rearrangement of reactants to products as a way to demonstrate that matter is conserved during chemical processes. Students will show how their model provides evidence that the law of conservation of matter is a mathematical description of what happens in nature.

In prior units of study, students have learned about the behavior of particles of matter during a change of state and about characteristic chemical and physical properties of matter. This unit will leverage that prior learning by having students undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. For example, students could design a device that releases heat in a way similar to how heat is released when powdered laundry detergent is mixed with water to form a paste. Students will need to be able to track energy transfer as heat energy is either released to the environment or absorbed from the environment. Students could also design a device that absorbs and stores heat from the environment.

The design problem has already been identified; therefore, the emphasis is on designing the device, controlling the transfer of energy to the environment, and modifying the device according to factors such as type and concentration of substance. The criteria for a successful design have not been determined; therefore, teachers will need to work with students to determine criteria for a successful design. Before attempting to determine criteria, students will conduct a short research project to familiarize themselves with scientific information they can use when designing the device. Students must draw on several sources and generate additional focused questions that allow for further avenues of exploration.

After completing their research, students will compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from their reading about the design of the device. Students, with the support of the teacher, will then write design criteria.

Students are now at a point where they can begin the design process. Prior to construction, students should develop a probability model and use it as part of the process for testing their device. They will use the probability model to determine which designs have the greatest probability of success.

It is important that students use mathematics appropriately when analyzing their test results. They must apply properties of operations to calculate numerical data with numbers in any form, convert between forms as appropriate, and assess the reasonableness of answers using mental computations and estimation strategies. Students will collect and analyze these numerical data to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

## *Integration of DCI from prior units within this grade level*

The content from PS1.B: Chemical Reactions was introduced in Units 1 and 2. Content in this unit builds on this prior learning.

## *Integration of mathematics and English Language Arts/literacy*

### *Mathematics*

- Integrate quantitative information expressed in words about atoms before and after a chemical process with a version of that information expressed in a physical model or drawing, including digital forms.
- Reason quantitatively and abstractly during communication about melting or boiling points.
- Use mathematics to model the law of conservation of matter.

- Use ratio and rate reasoning to describe how the total number of atoms does not change in a chemical reaction, and thus mass is conserved.
- Reason quantitatively and abstractly: Reason quantitatively using numbers to represent the criteria (amount, time, and temperature of substance) when testing a device that either releases or absorbs thermal energy by chemical processes; reason abstractly by assigning labels or symbols.
- Collect and analyze numerical data from tests of a device that either releases or absorbs thermal energy by chemical processes. Determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. Pose problems with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate the numerical data with numbers in any form, convert between forms as appropriate, and assess the reasonableness of answers using mental computations and estimation strategies.
- Develop a probability model and use it as part of an iterative process for testing to find the probability that a promising design solution will lead to an optimal solution. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy in order to ultimately develop an optimal design.

### *English language arts/literacy*

- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks *related to chemical reactions that release energy and some that store energy.*
- Cite specific textual evidence to support analysis of science and technical texts on the design and modification of a device that controls the transfer of energy to the environment using factors such as type and concentration of a substance.
- Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text *on the design and modification of a device that controls the transfer of energy to the environment using factors such as type and concentration of a substance.*
- Conduct research on the design and modification of a device that controls the transfer of energy to the environment using factors such as type and concentration of a substance to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
- Draw evidence from informational texts to support analysis, reflection, and research on the design and modification of a device that controls the transfer of energy to the environment using factors such as type and concentration of a substance.
- Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points *on the design and modification of a device that controls the transfer of energy to the environment.*

## *Future learning*

### *Physical science*

- Each atom has a charged substructure consisting of a nucleus made of protons and neutrons and surrounded by electrons.
- The periodic table orders elements horizontally according to the number of protons in nucleus of an element's atoms and places elements with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.
- Electrical forces within and between atoms determine the structure and interactions of matter at the bulk scale.
- A stable molecule has less energy than the same set of atoms separated; at least this much energy must be provided in order to take the molecule apart.
- Chemical processes, their rates, and whether or not they store or release energy can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- 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.

## Number of Instructional Days

*Recommended number of instructional days: 24 (1 day = approximately 50 minutes)*

**Note—**The recommended number of days is an estimate based on the information available at this time. Teachers are strongly encouraged to review the entire unit of study carefully and collaboratively to determine whether adjustments to this estimate need to be made.