

## HS-PS1-5

Students who demonstrate understanding can:

**HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Constructing Explanations and Designing Solutions</b></p> <p>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.</li> </ul>	<p><b>PS1.B: Chemical Reactions</b></p> <ul style="list-style-type: none"> <li>Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.</li> </ul>	<p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>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.</li> </ul>

### Observable features of the student performance by the end of the course:

1	Articulating the explanation of phenomena
a	Students construct an explanation that includes the idea that as the kinetic energy of colliding particles increases and the number of collisions increases, the reaction rate increases.
2	Evidence
a	Students identify and describe* evidence to construct the explanation, including: <ol style="list-style-type: none"> <li>i. Evidence (e.g., from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increase the reaction rate, and vice versa; and</li> <li>ii. Evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa.</li> </ol>
3	Reasoning
a	Students use and describe* the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation: <ol style="list-style-type: none"> <li>i. Molecules that collide can break bonds and form new bonds, producing new molecules.</li> <li>ii. The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy.</li> <li>iii. Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.</li> <li>iv. At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often.</li> <li>v. A high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature.</li> </ol>