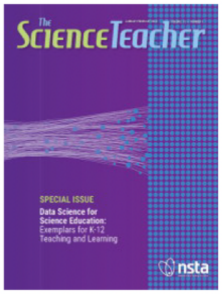

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Corn, Culture, and Chemistry: Building Understanding and Coherence About Rates of Reaction

Deena L. Gould, Daniel Delgado, Ian R. Gould, Lavern Wagner

Abstract

This instructional unit guides high school students to explore chemical reaction rates through the phenomenon of nixtamalization – a method of cooking corn in an alkaline solution to release nutrients. Nixtamalization shows the scientific ingenuity of Indigenous people who created the chemical process that enabled them to thrive on a diet of corn. In this set of lessons, students investigate how changes in concentration affect the rate of a chemical reaction by conducting hands-on experiments inspired by their observations and wonderings about nixtamalization. Structured around the 5E instructional model, the unit follows a coherent, phenomenon-driven storyline that begins with students' personal and cultural connections to corn and builds toward conceptual understanding using collision theory and molecular modeling. Students analyze data for patterns, construct explanatory models, support claims with evidence, and extend learning and leadership through interviews with family members or community elders. Differentiated formative and summative assessments align with NGSS three dimensions (HS-PS1-5). By centering Indigenous food science, this unit promotes engagement and relevance, helping students see and use science as a meaningful tool rooted in many cultures, identities, and daily lives.

Key Words: collision theory, culturally relevant pedagogy, phenomenon-based learning, and reaction rate.

Introduction

Corn is a dietary staple for more than 20% of the world's population. Beyond its nutritional value, corn has a deep cultural history and significance for many communities that can be used to anchor science instruction in lived experience and cultural relevance (Bang et al., 2009).

In this set of lessons, we build on students' background knowledge about the preparation and significance of corn to support them in developing understandings about chemical reaction rates and a process of alkaline cooking called nixtamalization. Nixtamalization is the process of cooking corn in an alkaline solution to release nutrients such as niacin and calcium, both important to human health. It also softens the corn to make it more malleable for dishes such as tamales and tortillas. Nixtamalization is a form of food chemistry that was invented, and practiced, by Indigenous tribes of the Americas as long as 3500 years ago (Blake, 2015).

In this set of lessons, we involved students in directing and monitoring the knowledge building process to understand the effects of changing the concentration of reacting particles on the rate at which a reaction occurs using collision theory, HS-PS1-5 (NGSS Lead States, 2013). We organized learning in a storyline about phenomena related to nixtamalization. We elicited students' background experiences, observations, questions, and interests (Reiser et al., 2021). As the story of nixtamalization and collision theory developed, the students' ideas, questions, discoveries, and gaps drove the investigations (Turley et al., 2016). The questions and discoveries that students generated were organized on an anchoring chart, "Observations Wonderings, Learnings". As students directed their learning process, they built scientific understanding as well as leadership skills which they applied to make sense of, and build, their own perspectives about health and well-being for their lives and communities.

Instructional Sequence (5E Model)

This unit was structured around a 5E instructional model (Watson, 2021) to guide students through a coherent, phenomenon-based, exploration of chemical reaction rates. The learning progression moved from eliciting students' cultural experiences to developing and applying disciplinary core ideas through hands-on investigations, modeling, and analyses of data sets. The unit lasts 7 class periods of 60 minutes each.

Engage (1 class period)

Students' personal and cultural connections: The unit began by asking students to reflect on, and share, personal and community experiences with corn (Bang et al., 2009). Our students told how family members and friends in their communities have cultivated, harvested, cooked, and eaten corn. They shared how corn is used for art, ceremonies, blessings, and healings in their communities. For example, corn-cake is important in the Kinaaldá coming-of-age ceremony for Navajo girls. Our students reported that they roasted, steamed, popped, and buttered corn. They also told about softening and grinding corn to make tortillas, tamales, and blue-corn mush. We invited community members with cultural knowledge to join us in this discussion which greatly enriched our learning and the learning of our students.

Anchor chart: The students recorded their knowledge, wonderings, and learnings on an anchor chart which evolved throughout the unit. Each group of 3 to 4 students created their anchor chart using post-it notes on a wall chart. The anchor chart could also be created using a shared cloud document.

Introduction to Nixtamalization

Next, we introduced students to nixtamalization. We created an investigation sheet (supplemental files) to guide students to use videos (online resources) to learn about the history, process, and current uses of nixtamalization. Students observed,

recorded, and discussed how a chef nixtamalized corn in a Mexican restaurant using slaked lime (calcium hydroxide). They also saw, recorded, and discussed how a chef nixtamalized corn for Native foods using ashes from hardwood trees. The videos and investigation sheet also guided students to discuss how Indigenous peoples of the Americas invented the nixtamalization process, how the process releases nutrients essential for human health, and some of the chemical changes that occur during nixtamalization. This dialogue prompted our students to ask a range of questions such as:
"What happens to the corn when you cook it with the lime?"
"How is the corn able to change like that? Is it because of something in the corn, the temperature, or the way it is cooked?"
What happens to the corn to make the nutritional properties?
How did they figure out how to make the nixtamalization happen?

The students were curious about when and how changes occurred and which chemicals were involved. Students' wonderings were recorded on the anchor chart.

Formative assessment: After reviewing the students' anchor charts and investigation sheets, we learned that some students misperceived nixtamalization as a process that eradicates harmful chemicals inside the corn instead of understanding that nixtamalization is a chemical process that releases helpful nutrients that are chemically bound to other molecules inside corn. Some students were also confused by the similarity in the names of slaked lime (limestones heated with water) and the more common citrus fruit called lime. We addressed these misconceptions in subsequent instruction, discussions, and worksheets.

Explore (1 class period)
Hands-on investigations (investigation sheet, equipment list, and safety guidelines provided in supplemental files): Based on students' observations, interests, and wonderings on the anchor chart, students conducted controlled investigations**.** They varied the concentration of an alkaline substance in a water solution to cook dried corn**.** They chose calcium hydroxide or Juniper ash for their alkaline substance. Calcium hydroxide is commonly used in preparing Mexican foods in our communities. Juniper ash is commonly used in preparing Navajo foods in our communities.

Working in lab teams of 3 or 4, students recorded data to answer questions about how different concentrations of an alkaline substance (calcium hydroxide or Juniper ash) affected nixtamalization of corn. In the experiment, they compared the volume of corn kernels before and after nixtamalization at different concentrations. They also made observations to compare texture, color, smell, etc. before and after nixtamalization. They shared and compared data and observations across the class to allow for larger pattern recognition, application of vocabulary in context, and variability analysis**.** Embedded formative assessments included the lab data sheets, shared class data, and contributions of wondering and learnings to the evolving anchor charts.

At the end of this stage, our students reported that the volume of corn increased through nixtamalization. They also noticed that the corn softened and the color became brighter. They noticed similarities in the outcomes of experiments with calcium hydroxide and Juniper ash. They asked new questions such as, *"What does the corn go through to make it change like that? Does getting the corn all squishy make it release the nutrients? What makes it release the nutrients?"*
They agreed that they needed more, and better, data to make good claims about how the concentration of the alkaline substance affected the nixtamalization of corn.

Explain (2 class periods)
Molecular modeling: We designed a molecular kit and demonstration to guide students to model collisions in the chemical process of nixtamalization. A plastic tub represented the beaker, 21 white golf balls represented water molecules, 3 yellow golf balls represented corn molecules, and 7 golf balls of other colors represented the alkaline substance. We began by adding the balls representing water molecules to the tub. We shook it to represent kinetic energy. We narrated the representations as we demonstrated. We added the 3 yellow balls to represent corn molecules and continued shaking. We added 3 of the other colored balls to represent the lower concentration of alkaline substance. We told students that the niacin was chemically bound inside the corn. We modeled the use of vocabulary in context for students as we narrated the demonstration. We told them the corn molecules needed to collide with the molecules of alkaline substance to release the bound niacin. As we shook the tub, we asked students to count the number of collisions of molecules of alkaline substance with molecules of corn. We paused and asked the students how we could increase the number of collisions to release more niacin. They told us we could shake the tub more (increase kinetic energy), so we did. Students counted the number of collisions. They also told us we could add more alkaline substance to get more niacin released, which we modeled by adding the remaining 4 colored balls. Students again counted the number of collisions of molecules of alkaline substance with molecules of corn as we narrated that we had increased the concentration of alkaline substance and also the number of collisions.

Then, we guided students in groups of 3 or 4, to use the molecular kits and a vocabulary list to model and narrate collision theory in the process of nixtamalization (see details in supplemental files). The vocabulary list is used here in context as a scaffold for students. Context has been built first and then the words are introduced. The vocabulary list should not be used as a pre-teaching list. By the end of this activity, most students were able to explain that heating (increasing kinetic energy) caused more collisions and increased the rate of the chemical reaction. Most students were also able to explain that increasing the number of molecules of alkaline substance resulted in more collisions and increased the rate of chemical reaction.

Analyzing a scientific data set:
Next, we guided students to analyze a data set about nixtamalization that was generated from experiments we and other scientists (Christianson et al., 1968; Fernández et al., 2001) conducted. The data set and worksheet

(supplemental files) were organized similar to the students' earlier experiments. However, it contained data that wasn't possible for students to collect in the limited class time and using our limited laboratory tools. The data set included repeated measurements and also amounts of niacin released from corn at different concentrations. Students analyzed patterns in the data and looked for trends to make a claim about how the concentration of the alkaline substance (calcium hydroxide or Juniper ash) affected the percent change in corn kernel volume. Students also analyzed patterns in the data and looked for trends to make a claim about how the concentration of the calcium hydroxide or Juniper ash affected the amount of niacin released. We required students to use the cross-cutting concept (CCC) of observing patterns of change in data from the tables as evidence of causality to support their claims. One example of how to scaffold students to observe patterns of change to make a claim is to point to the data table and ask, "As the values in this column increased, what happened to the values in this column?" Additional strategies and prompts for scaffolding students to observe patterns of change to make scientific explanations can be found in the detailed lessons plan in the supplemental files.

Finally, we asked students which concentration of calcium hydroxide they would use to release the most niacin. We told students to use evidence from the data set to support their answer. We also told students to use evidence from collisions in the molecular modeling done earlier to support their answers. Evidence in supplemental **files** show a student's written responses to this data analysis task. The student correctly identified an upward trend in percent change in kernel volume (41.5% → 67.7% → 91.5%) and niacin release (3 μg/g → 5.8 μg/g → 8.3 μg/g) as concentration increased. The student then connected this quantitative pattern to collision theory, explaining that increasing concentration increased the number of particle collisions and therefore increased reaction rate. This example response shows the student's ability to apply scientific principles and evidence to explain how changing concentration of the reacting particles affects reaction rate (HS-PS1-5).

Students revisited, and added to, the anchor chart to share findings, highlight new questions, and show how their thinking had evolved (Reiser et al., 2021, Turley et al., 2016).

Elaborate (2 class period)

Students chose how to extend their learning. Options included:

- Interview a family member or community elder about corn, cooking corn, and / or nixtamalization
- Read Nez, Asdzaan. (2021). Cooking blue corn: Indigenous science. *Indigenous Goddess Gang* (supplemental files)
- Read a paper about nixtamalization published in a food science or cultural journal (supplemental files)
- Experiment using the PhET simulation *Reaction and Rates* (online resources)

Students chose how to share their extended learning. Options included:

- Short oral presentations with visuals
- Digital media posts (e.g., infographics or videos)

In this stage, we aimed to extend chemistry concepts and support the development of student leadership while also inviting and valuing cultural and linguistic knowledge.

Evaluate (ongoing + final assessment)

Assessments were woven throughout the unit and culminated in differentiated summative options (supplemental files). The options reflected student strengths and diverse modalities. The final 3 dimensional NGSS assessments included student-created particle models or diagrams and writing prompts that required that students construct and defend explanations using scientific evidence. The differentiated assessments included sentence frames, word banks, visual supports, and flexible response formats to support varied learning needs. Scoring was aligned to HS-PS1-5. Student explanations on the differentiated data analysis task and the final written NGSS assessment were evaluated using a three-level rubric (developing, proficient, advanced) aligned to HS-PS1-5. The rubric included criteria for accurate use of quantitative evidence, correct explanation of how concentration and temperature affect collision frequency and reaction rate, identification and interpretation of patterns in percent change and niacin release, and clarity of scientific reasoning. We persisted throughout this set of lessons to maintain rigorous expectations and personal relevance for ALL students, not just students who have typically been considered high-achieving (NASEM, 2021).

Conclusion

This unit offered students opportunity to engage in culturally grounded, hands-on science that connected chemical concepts to their lived experiences (Bang et al., 2009). By investigating nixtamalization, a traditional Indigenous process relevant in many communities, students explored core ideas in reaction rate chemistry, built molecular models using collision theory, analyzed and discussed patterns of change in data, and applied evidence-based reasoning to make explanations. Many students also learned how their Indigenous ancestors and relatives have used chemistry to solve problems and protect the health and well-being of their communities (Cajete, 2000, 2020).

Throughout the instructional sequence, students took an active role in their learning by generating questions, conducting investigations, constructing explanations, and sharing knowledge in ways that reflected their interests, identities, and communities (Penuel et al., 2024). In doing so, they developed not only scientific understanding, but also communication and leadership skills, cultural awareness, and a deeper appreciation for the relevance of science in their everyday lives.

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Online resources

The Ancient Chemistry Inside Your Taco by Science History Institute of Philadelphia

Wood Ash Nixtamal by Sioux Chef Sean Sherman

PhET Reaction and Rates simulation

HS-PS1-5: Matter and Its Interactions
https://www.nextgenscience.org/pe/hs-ps1-5-matter-and-its-interactions
This chart shows how this nixtamalization lesson aligns with the NGSS. Other valid connections may exist. The instructional activities presented here represent one meaningful pathway toward the performance expectation.

Performance Expectation	Connections to Classroom Activity
HS-PS1-5. Apply scientific principles to explain the effect of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	Students carry out investigations on nixtamalization, a traditional corn cooking process, to determine how varying the temperature and concentration of calcium hydroxide impacts the rate of reaction. Students collect data, develop particle models, and use collision theory to explain observed differences in corn softening across conditions.
Science and Engineering Practice	**Connections to Classroom Activity**
Constructing Explanations Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	Students develop models and construct written and oral explanations to explain observed changes in corn texture and volume. They apply collision theory to explain how increased temperature and concentration affect particle collisions and reaction rate.
Disciplinary Core Idea	**Connections to Classroom Activity**
PS1.B – Chemical Reactions The 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.	Students model how calcium hydroxide and heat accelerate the breaking and reforming of molecular bonds during corn processing. They connect bond rearrangement and collision theory to real-world phenomena by analyzing changes in corn kernels exposed to different concentrations and temperatures. Students explain how kinetic energy influences reaction rate by interpreting their experimental data and using a molecular model for explanation.

Crosscutting Concept	Connections to Classroom Activity
Patterns Observed patterns of change can be used to make scientific predictions or explanations.	Students identify and analyze patterns in kernel volume, pH, amount of niacin released, and softening across varying concentrations and temperatures. These patterns are used to construct scientific explanations that connect particle-level interactions to macroscopic changes. Students also compare outcomes across groups to refine predictions and recognize trends that support causal reasoning.
Common Core State Standards Connections ELA/Literacy: RST.11-12.1; WHST.9-12.2; SL.11-12.5 Mathematics: HSN-Q.A.1; MP.2	Students read, write, and communicate about community-based interviews and also about cultural and scientific publications related to nixtamalization.

The Chemistry of Nixtamalization
Experiment and Background Science for Teachers

In this section, we provide explanations of the chemistry of nixtamalization. This background information supports teachers in developing a deeper understanding of the science to help them guide discussions, investigations, explanations, and modeling for the lessons in this unit. This background information is more advanced than our lessons for high school students. However, it supports teachers in deepening their content knowledge.

In this section, we also describe how we conducted our experiments, calculations, and estimates used in the data set provided for student analyses.

I. Overview of the Experiment

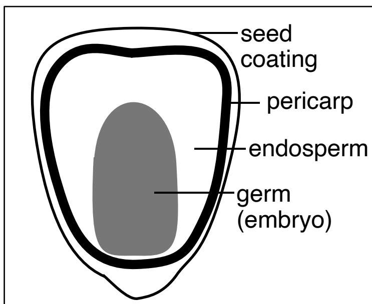
Reaction Component	Composition Chemical Formula
Corn	62% starch (carbohydrate glucose polymers amylose and amylopectin), 19% protein & fiber, 15% water, 4% oil (lipids)
Calcium Hydroxide	$Ca(OH)_2$
Water	H_2O

A chemical equation for nixtamalization in the presence of calcium hydroxide, $Ca(OH)_2$, as the alkaline substance is shown below. The equation shows that water is the reactant, and that calcium hydroxide acts as a catalyst. .

$$\text{Niacin–Starch} + H_2O \xrightarrow[\textit{catalyst}]{Ca(OH)_2} \text{Niacin-OH} + \text{H-Starch}$$

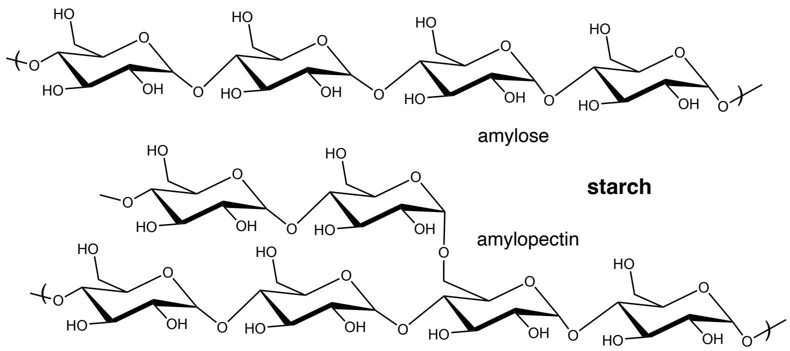
II. The Organic Chemistry of Nixtamalization - Release of Bound Niacin

The nixtamalization process results in a large number of complex chemical reactions (see, for example, Santiago-Ramos et al., 2018). At early times these reactions are dominated by hydrolysis and solubilization of the carbohydrate and lipids components of the pericarp outer structure. After the pericarp starts to disintegrate, hydrolysis of starch granules in the interior endosperm occurs, resulting in gelatinization. Gelatinization is understood as a transformation of starch from a rigid structure composed of hydrogen-bonded carbohydrate polymer molecules into a swollen gel-like structure where intermolecular hydrogen bonds have been broken and replaced with water molecules.



diagrammatic representation of a corn kernel

Starch consist of two polymeric hydrocarbons, amylose and amylopectin (BeMiller & Whistler, 2009), and after extensive nixtamalization, the amylose polymer starts to leach out of the endosperm.



The alkaline chemicals most commonly used in nixtamalization are sodium or potassium hydroxide, also known as lye, and calcium hydroxide, also known as lime. Their chemical formulae are shown below, including their formal charges. These charges are not usually shown in chemical formulae, but are included here to emphasize the ionic character of these chemicals.

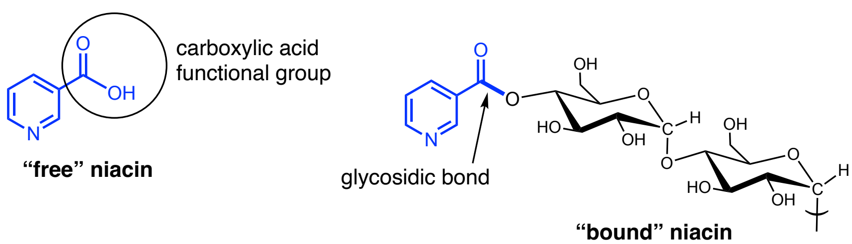
$Na^+\ ^-OH$	$K^+\ ^-OH$	$Ca^{2+}\ (^-OH)_2$
sodium hydroxide	potassium hydroxide	calcium hydroxide

Calcium, Ca, is one of the most abundant mineral elements in trees since it is involved in many structural and regulatory processes (**McLaughlin & Wimmer, 1999). Consequently,** $Ca(OH)_2$ is abundant in hardwood tree ashes, which have been used historically by Native populations when nixtamalizing corn (Hudson, 1979).

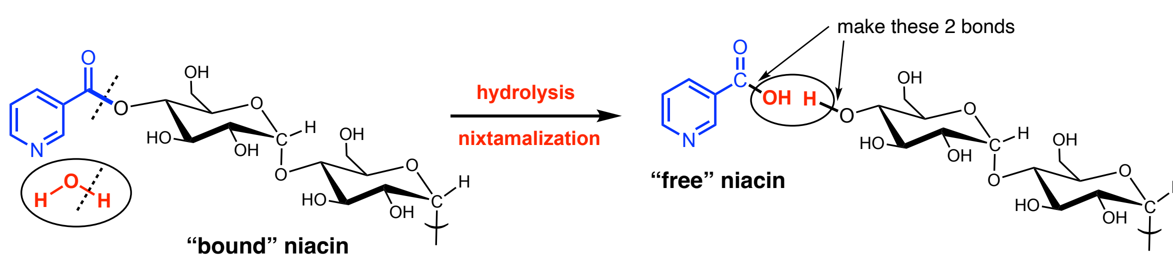
In addition to hydrolysis reactions, nixtamalization with $Ca(OH)_2$ results in uptake and incorporation of calcium into the corn, which adds significant nutritional value (Hudson, 1979). The bioavailability of other mineral elements such as iron, zinc and magnesium can also increase.

Nixtamalization also increases the bioavailability of many other important nutrients, specifically, niacin, lysine, and tryptophan and other amino acids, as a result of hydrolysis reactions. We will focus on the release of "free" niacin as one of the most important of these hydrolysis reactions.

Niacin, vitamin B$_3$, is an essential water-soluble vitamin that plays critical roles in energy metabolism, DNA repair, and cellular signaling (Meyer-Ficca & Kirkland, 2016)**. Pellagra is a human disease caused primarily by niacin deficiency. Most of the niacin in corn is "bound" niacin which has no nutritional value since it can't be used in niacin-critical biochemical processes. Niacin is made bioavailable by nixtamalization in a hydrolysis chemical reaction.**



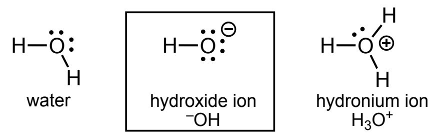
In organic chemistry, hydrolysis means a reaction of water ("hydro-") that results in covalent bond breaking ("-lysis"). The chemical structure of bound niacin is complex (Bender, 1989), but a representative likely structure is shown above. In bound niacin, the carboxylic acid functional group has reacted with an -OH group in a starch polymer, in this case amylopectin, to form a strong covalent carbon-oxygen bond. In carbohydrate notation, this carbon-oxygen bond is a glycosidic bond, and in order for free niacin to be released, the glycosidic bond must be broken. This bond breaking reaction with a water molecule is shown in the scheme below.



The reaction breaks the glycosidic bond and also one of the oxygen-hydrogen bonds in water indicated by the dashed lines. The products of the reaction are free niacin and amylopectin. Two new bonds have been formed, and the water molecule has been incorporated into the product molecules. This reaction shows one way in which nixtamalization incorporates water into the corn in a chemical reaction (there are many others).

From a molecular perspective, bound niacin hydrolysis represents an excellent example of the definition of a chemical process (as opposed to a physical process), since it involves breaking chemical bonds followed by making new bonds and new chemical structures., in this case the free niacin

What is the role of calcium hydroxide, $Ca(OH)_2$? Water will hydrolyze the bound niacin, but very slowly, because water is not very chemically reactive. The hydroxide anion (and the hydronium ion) can be considered more chemically reactive forms of water.



In nixtamalization, the hydroxide anion from $Ca^{2+}(^{-}OH)_2$ initiates reaction much more quickly than water can, and at the end of the reaction the hydroxide anion is regenerated. $Ca^{2+}(^{-}OH)_2$ makes the reaction go faster, but is not overall consumed, corresponding to the definition of a catalyst.

A full curved-arrow pushing mechanism using standard organic chemistry notation is provided in Appendix A below.

Although not a simple one, the niacin hydrolysis reaction aligns well with standard kinetic theory. The reaction increases in rate as the number of useful molecular collisions increases. In this case the important collisions are between the hydroxide anion and the bound niacin, since this is the slowest, rate determining step in the reaction. The number of useful collisions increase with increasing concentration of the $Ca^{2+}(^{-}OH)_2$, and with increasing temperature.

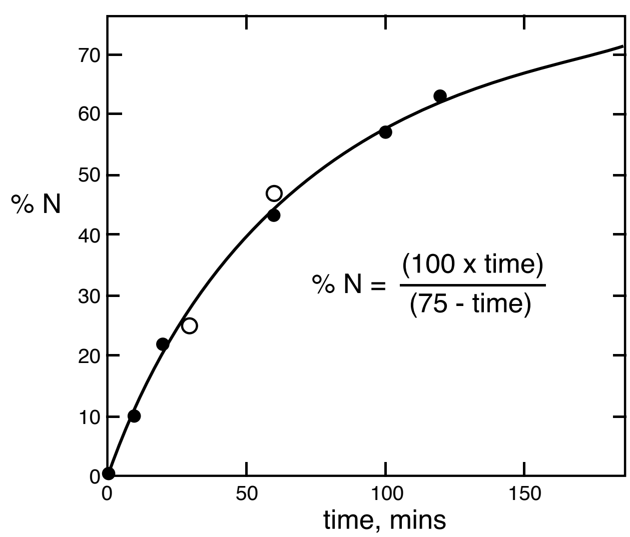
III. Measurements and Data Generation

After multiple experiments, we decided that the volume of the corn kernels served as the best measure of the extent of nixtamalization. This is a relatively easy measurement for students to make, and kernel mass was found to be less reproducible than volume. The kernel volume is controlled mainly by the extent of hydrolysis and water absorption (Santiago-Ramos et a., 2018), which are central to the entire nixtamalization process.

Because the focus of the investigation is niacin release, we needed a way to provide students with this information.

Christianson et al. (1968) extracted "free", unbound niacin from nixtamalized and non-nixtamalized corn. They extracted 3 micrograms of free niacin per gram of corn (3μg/G) for the non-nixtamalized corn, and 16.3μg/G of free niacin for the nixtamalized corn. We assume that 16.3μg/G is the maximum quantity of free niacin that can be extracted from a nixtamalized corn kernel, i.e., at 100% nixtamalization.

Experiments on conversion with time in corn nixtamalization have been reported by Fernández-Muñoz et al. (2011). Some of their data is shown in the plot below. These researchers showed that that the extent of nixtamalization could be described using Michaelis-Menton kinetics, as shown in the plot.



Plot of % nixtamalization, %N, versus reaction time, mins, for (closed circles) data from Fernández-Muñoz et al. (2011), and (open circles) this work. The curved line represents a fit to the data using the equation provided in the plot.

We performed experiments for nixtamalization of corn in the presence of 1.5 g of calcium hydroxide in 200 mL water (0.13M, 0.2N) for 30 minutes and for 60 minutes. These conditions are very similar to those of Fernández-Muñoz et al. (2011). The measured volume changes were converted into % nixtamalization by normalizing our data to those in the plot. In this way, % nixtamalizations could be estimated for the different concentrations of $Ca(OH)_2$ and Juniper Ash provided to the students, and corresponding free niacin values obtained using the yield data from Christianson et al. (1968).

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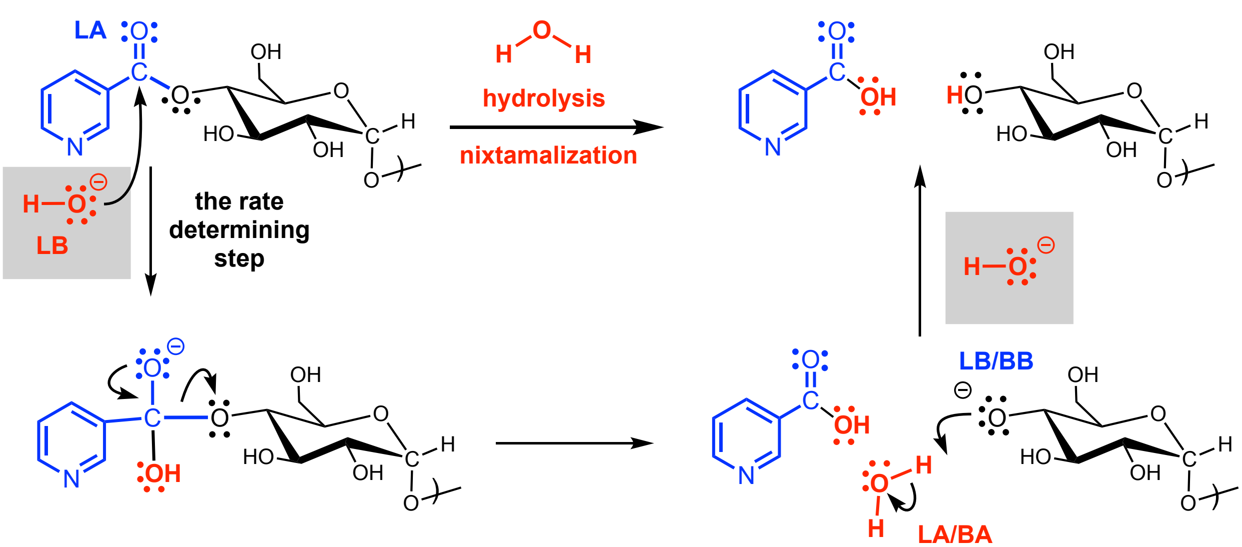
Appendix

Full curved arrow-pushing mechanism for hydroxide anion catalyzed hydrolysis of starch-bound niacin. LA and LB refer to species acting as a Lewis acid or Lewis base at each step, and BA and BB refer to species acting as Brønsted acids and bases.



Short Version

Free niacin values were estimated assuming 16.3 mg/G for 100% nixtamalized corn (Christianson et al., 1968), with % nixtamalization values estimated using the kinetic fitting procedure described by Fernández-Muñoz et al. (2011).

Corn in the Diné Culture

Background Knowledge for Teachers

by Lavern Wagner

The Diné belief of interconnectedness between life, nature, and spirituality that is essential to the concept of balance, harmony, and beauty is referred to hózhó. Hózhó is embedded with the cornstalk philosophy of learning which is a model for human growth and development from birth to old age. During a baby's first laugh, he/she is given corn pollen on the tip of the tongue with prayers that symbolize a blessing transition from the spirit world to the physical world. The Baby's First Laugh ceremony is celebrated with corn stew and tortillas or frybread together with family and friends.

During the time of transition from childhood to adolescence in girls, the Kinaaldá ceremony is acknowledged. It is a four ǫday ritual puberty ceremony with family and community involvement. A large corn cake, alkaan is baked in the earth with much detail work including corn grinding, stitching together corn husk, and making white corn mush. The white corn is ground into cornmeal with mano and metate Į̨grinding stonesÓ by the Kinaaldá and helpful individuals. The Diné grinding corn song is sung during this process. The alkaan is cooked in the ground overnight in the earth oven. On the final éth day, a feast is celebrated with the main dish – alkaan.

Another traditional ceremony is the Diné wedding, like all ceremonies, tádídíín is used to offer prayers and blessings. The bride's family prepares blue corn mush Į̨tósh chíínÓ to honor her life's milestone. The tósh chíín holds deep spiritual significance associated with strength, healing, and nourishment. In addition, it provides dietary value and health benefits, often prepared with juniper ash for digestibility and flavor. Frequently, women are given tósh chíín after childbirth for nourishment, healing, and strength.

The Diné treatment of naadą́ą́' involves laborious demanding processes. The preparation methods stem from planting, harvesting, and preparation skills and techniques for cooking corn dishes and tádídíín for prayers, blessings, and ceremonies.

Note: I wrote this narrative based on my grandmother's traditional knowledge and teachings. She taught me a rich wealth of Diné traditional knowledge and teachings. What I shared is a tip of a much bigger knowledge and stories.

Online Supplemental Files

Name ____ Period ____________

Corn Chemistry: Nixtamalization

Watch *The Ancient Chemistry Inside Your Taco* by Science History Institute of Philadelphia. (6 minutes)
https://www.sciencehistory.org/stories/magazine/the-ancient-chemistry-inside-your-taco/

Answer these questions:

1. What alkaline (pH basic) substance did Ben Miller and Christina Martinez use to nixtamalize the corn?

2. What nutrient did the narrator of the video say was released from the corn through the process of nixtamalization? Why is that nutrient important to our bodies?

3. What people or civilization(s) invented the chemical process of nixtamalization?

4. What happened when poor people of Italy tried to live on a diet of corn that was not nixtamalized? In other words, what is pellagra? Why did people that relied on corn as a main staple of their diet need the corn to be nixtamalized to survive?

5. What changes occur during nixtamalization? How do those changes occur? In your own words, what is the chemical process of nixtamalization?

6. What nutrient did Christina Martinez say was released from the corn through the process of nixtamalization? What did she say about why that nutrient important?

7. Find two questions from the Anchor Chart that was answered in the video. Write the questions below and then write the answers to the questions below.

Corn Chemistry: Nixtamalization Part 2

Watch *How to Nixtamalize Corn with Wood Ash by Sioux Chef Sean Sherman* (Oglala Lakota Sioux), 1 minute https://www.youtube.com/watch?v=EiMWLFI-yd0

Answer these questions:

1. What alkaline (pH basic) substance did Sioux Chef Sherman use to nixtamalize the corn?

2. Why did Sioux Chef Sherman wear gloves?

Anchor Chart: Return to the anchor chart for. Write notes to be added to the chart in the categories of Observations, Wonderings, and Learnings. Add at least two statements about what you learned since the start of this unit. Add at least two new questions or wonderings that emerged for you.

Name____ Period _________________

Chemistry of Nixtamalization Experiment

Background:

A chemical process changes corn to hominy. The process is called nixtamalization.
Cooking the corn in a water solution of an alkaline substance nixtamalizes the corn. An alkaline solution has a pH greater than 7. An alkaline substance is also called a “base”. The alkaline substance for nixtamalization has come from many sources. The peoples of ancient Mesoamerica, such as the Aztec, used rocks made of “limestone” which were burnt in a fire. Limestone is a stone; not a citrus fruit. The Maya people used calcium salts from the ashes of burnt seashells for the alkaline substance. Tribes north of Mexico nixtamalized with ashes from burnt hardwood trees. For example, the Diné have used ashes left over from burning a Juniper tree.

Chemical Reaction

Experimental Question:

How does the concentration of alkaline substance affect the nixtamalization of corn kernels?

Record:

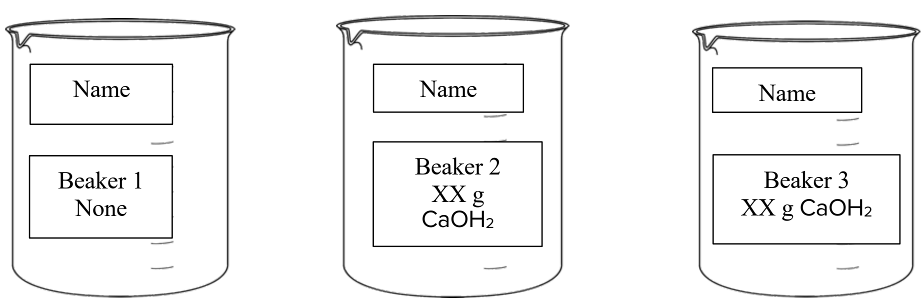
1. What is the alkaline substance you will use in your experiment?

____

2. How will you vary the concentration of the alkaline substance?

____

Directions to prepare the experiment:



1. Label each of your three 250 mL beakers with your name.
2. Label each beaker with the name and amount of your alkaline substance. Include the unit g for grams. Include a control beaker with NO alkaline substance.
3. Use the balance to measure and add the alkaline substance to each beaker according to your choice of different concentrations.
4. Measure the length, width, and depth of one corn kernel for each beaker. Use the cm side of the ruler. Measure to the nearest tenth of a cm. Use a decimal. Record your measurements in the data table below. Calculate the volume in cm^3. Add each corn kernel to the correct beaker.
5. Add 200 mL of water to each beaker.
6. Stir the mixture and use a pH strip to measure the pH of the liquid mixture in each beaker. Record it in the data table.

Before Nixtamalization Data Table Date ___________________________

Beaker	Which Alkaline Substance and How Much (g)	Length of Corn Kernel (cm)	Width of Corn Kernel (cm)	Depth of Corn Kernel (cm)	Volume of Corn Kernel (cm^3)	How Much Water mL	pH
1	None (control)					200 mL	
2						200 mL	
3						200 mL	

7. Boil the corn on the hot plate at medium setting for 30 minutes.
8. Record measurements after nixtamalization.

After Nixtamalization Data Table Date ___________________________

Beaker	Which Alkaline Substance and How Much (g)	Length of Corn Kernel (cm)	Width of Corn Kernel (cm)	Depth of Corn Kernel (cm)	Volume of Corn Kernel (cm^3)	How Much Liquid left mL	pH
1	None (control)						
2							
3							

9. Closely observe a kernel of corn that has not been nixtamalized. Closely observe a kernel of corn after nixtamalization. Make a sketch below. What do you notice? Label and describe your sketches and observations.

10. Compare

Calculate the percent change in volume after nixtamalization for each concentration.
The Percent Change in Volume (% Change) is calculated as follows:

$$\% \text{ Change} = \frac{(\text{Volume After} - \text{Volume Before}) \times 100}{\text{Volume Before}}$$

Beaker	How Much Alkaline Substance (g)	Volume of Kernel Before (cm^3)	Volume of Kernel After (cm^3)	% Change in Kernel Volume
1	Control (None)			
2				
3				

11. Share: What do your observations and data tell you? Share your observations and data with the class. Your teacher might have you share your data and observations digitally online or on a board in the classroom.

12. Record Below: What do you notice about the shared data about nixtamalization? What does it tell you? What numbers did you compare? What do those numbers mean? What could make your data collection better? What could make your data-analysis better?

Name____ Period _________________

Data Analysis: Chemistry of Nixtamalization
Using Calcium Hydroxide $CaOH_2$

Background: A chemical process changes corn to hominy or nixtamal. The process is called nixtamalization. Cooking corn in a water solution of calcium hydroxide nixtamalizes corn. Niacin is chemically bound in the corn. Nixtamalization releases the bound niacin so our bodies can use its nutrition. We wanted to learn how much calcium hydroxide would best make the corn soak up water and release niacin. We conducted an experiment. We asked, "How does the concentration of calcium hydroxide affect the rate of chemical reaction for soaking up water and releasing niacin?"

Compare Before and After Nixtamalization

1. Examine our data tables below and on the next page. How is our experiment similar to your nixtamalization experiment? How is our experiment different from your nixtamalization experiment? Record your responses on the next page.

Date Table: Before Nixtamalization

Beaker	How many Kernels	Which Alkaline Substance and How Much (g)	Length Each Corn Kernel (cm)	Width Each Corn Kernel (cm)	Depth Each Corn Kernel (cm)	Volume Each Corn Kernel (cm^3)	How Much Water mL	pH
1	4	None (control)	Kernel 1 1.3 Kernel 2 1.4 Kernel 3 1.3 Kernel 4 1.4	Kernel 1 0.8 Kernel 2 0.8 Kernel 3 0.8 Kernel 4 0.8	Kernel 1 0.4 Kernel 2 0.4 Kernel 3 0.4 Kernel 4 0.4	Kernel 1 .416 Kernel 2 .448 Kernel 3 .416 Kernel 4 .336 Mean .404	200 mL	6.0
2	4	$CaOH_2$ .4g	Kernel 1 1.35 Kernel 2 1.35 Kernel 3 1.3 Kernel 4 1.4	Kernel 1 0.8 Kernel 2 0.8 Kernel 3 0.8 Kernel 4 0.8	Kernel 1 0.4 Kernel 2 0.35 Kernel 3 0.45 Kernel 4 0.3	Kernel 1 .432 Kernel 2 .378 Kernel 3 .468 Kernel 4 .336 Mean .404	200 mL	10
3	4	$CaOH_2$ 1.25g	Kernel 1 1.35 Kernel 2 1.4 Kernel 3 1.3 Kernel 4 1.3	Kernel 1 0.75 Kernel 2 0.8 Kernel 3 0.75 Kernel 4 0.8	Kernel 1 0.45 Kernel 2 0.4 Kernel 3 0.4 Kernel 4 0.4	Kernel 1 .456 Kernel 2 .448 Kernel 3 .390 Kernel 4 .416 Mean .427	200 mL	13

Date Table: After Nixtamalization

Beaker	Time cooked	Which Alkaline Substance and How Much (g)	Length of Each Corn Kernel (cm)	Width of Each Corn Kernel (cm)	Depth of Each Corn Kernel (cm)	Volume of Each Corn Kernel (cm^3)	How Much Liquid left mL
1	30 min. boiling	None (control)	Kernel 1 1.45 Kernel 2 1.4 Kernel 3 1.4 Kernel 4 1.4	Kernel 1 .8 Kernel 2 .9 Kernel 3 .9 Kernel 4 .9	Kernel 1 .45 Kernel 2 .4 Kernel 3 .5 Kernel 4 .5	Kernel 1 .522 Kernel 2 .504 Kernel 3 .63 Kernel 4 .63 Mean .572	100 mL
2	30 min. boiling	$CaOH_2$ .4g	Kernel 1 1.6 Kernel 2 1.6 Kernel 3 1.5 Kernel 4 1.55	Kernel 1 .9 Kernel 2 1.0 Kernel 3 .95 Kernel 4 1.0	Kernel 1 .4 Kernel 2 .45 Kernel 3 .5 Kernel 4 .45	Kernel 1 .576 Kernel 2 .720 Kernel 3 .713 Kernel 4 .698 Mean .677	100 mL
3	30 min. boiling	$CaOH_2$ 1.25g	Kernel 1 1.6 Kernel 2 1.55 Kernel 3 1.55 Kernel 4 1.55	Kernel 1 1.05 Kernel 2 1.0 Kernel 3 .95 Kernel 4 .90	Kernel 1 .5 Kernel 2 .6 Kernel 3 .5 Kernel 4 .55	Kernel 1 .84 Kernel 2 .930 Kernel 3 .736 Kernel 4 .767 Mean .818	100 mL

2. Record: How is our experiment similar to your nixtamalization experiment? How is our experiment different from your nixtamalization experiment?

3. Record: Why might several measurements and a mean for each concentration be better than one measurement for each concentration?

Compare Before and After Nixtamalization

Change in Volume: We calculated the percent change in volume of corn kernels after nixtamalization for each concentration. We used this formula to calculate the percent change:

$$\% \text{ Change} = \frac{(\text{Mean Volume After - Mean Volume Before}) \times 100}{\text{Mean Volume Before}}$$

Change in Niacin: We also calculated the amount of bound niacin released for each concentration. We used data from a scientific paper published by Christianson et al., (1968) to calculate the amount of bound niacin released for each concentration.

Data Table: Change in Volume and Change in Niacin Vs. Concentration

Beaker	How Much Alkaline Substance (g)	Mean Volume of Kernels Before (cm^3)	Mean Volume of Kernels After (cm^3)	% Change in Kernel Volume	Amount of Niacin Released
1	Control (None)	.402	.572	41.5	3 µg/G
2	$CaOH_2$ .4g	.404	.677	67.7	5.8 µg/G
3	$CaOH_2$ 1.25g	.427	.818	91.5	8.3 µg/G

Analyze the Data

4. How does the amount, or concentration, of calcium hydroxide affect the percent change in kernel volume? What trend do you notice? Use data from the table as evidence to support your claim.

5. How does the amount, or concentration, of calcium hydroxide affect the amount of niacin released? What trend do you notice? Use data from the table as evidence to support your claim.

6. Which concentration of calcium hydroxide would you use to release the most niacin? Support your answer with evidence from the table.

Name____ Period __________________

Data Analysis: Chemistry of Nixtamalization
Using Juniper Ash

Background: A chemical process changes corn to hominy or nixtamal. The process is called nixtamalization. Cooking corn in a water solution of calcium hydroxide nixtamalizes corn. Niacin is chemically bound in the corn. Nixtamalization releases the bound niacin so our bodies can use its nutrition. We wanted to learn how much calcium hydroxide would best make the corn soak up water and release niacin. We conducted an experiment. We asked, "How does the concentration of calcium hydroxide affect the rate of chemical reaction for soaking up water and releasing niacin?"

Compare Before and After Nixtamalization

1. Examine our data tables below and on the next page. How is our experiment similar to your nixtamalization experiment? How is our experiment different from your nixtamalization experiment? Record your responses on the next page.

Date Table: Before Nixtamalization

Beaker	How many Kernels	Which Alkaline Substance and How Much (g)	Length Each Corn Kernel (cm)	Width Each Corn Kernel (cm)	Depth Each Corn Kernel (cm)	Volume Each Corn Kernel (cm^3)	How Much Water mL	pH
1	4	None (control)	Kernel 1 1.2 Kernel 2 1.1 Kernel 3 1.2 Kernel 4 1.2	Kernel 1 .8 Kernel 2 .7 Kernel 3 .85 Kernel 4 .8	Kernel 1 .4 Kernel 2 .4 Kernel 3 .3 Kernel 4 .4	Kernel 1 .384 Kernel 2 .308 Kernel 3 .306 Kernel 4 .384 Mean .346	200 mL	6.0
2	4	Juniper Ash 1.25g	Kernel 1 1.25 Kernel 2 1.25 Kernel 3 1.25 Kernel 4 1.3	Kernel 1 .8 Kernel 2 .7 Kernel 3 .7 Kernel 4 .8	Kernel 1 .4 Kernel 2 .4 Kernel 3 .4 Kernel 4 .5	Kernel 1 .400 Kernel 2 .350 Kernel 3 .350 Kernel 4 .520 Mean .405	200 mL	10
3	4	Juniper Ash 4.0g	Kernel 1 1.2 Kernel 2 1.15 Kernel 3 1.25 Kernel 4 1.2	Kernel 1 .8 Kernel 2 .8 Kernel 3 .7 Kernel 4 .8	Kernel 1 .4 Kernel 2 .4 Kernel 3. .4 Kernel 4 .4	Kernel 1 .384 Kernel 2 .368 Kernel 3 .350 Kernel 4 .384 Mean .372	200 mL	13

Date Table: After Nixtamalization

Beaker	Time cooked	Which Alkaline Substance and How Much (g)	Length of Each Corn Kernel (cm)	Width of Each Corn Kernel (cm)	Depth of Each Corn Kernel (cm)	Volume of Each Corn Kernel (cm^3)	How Much Liquid left mL
1	30 min. boiling	None (control)	Kernel 1 1.2 Kernel 2 1.3 Kernel 3 1.2 Kernel 4 1.2	Kernel 1 .8 Kernel 2 .9 Kernel 3. .7 Kernel 4 .8	Kernel 1 .4 Kernel 2 .5 Kernel 3. .5 Kernel 4 .4	Kernel 1 .384 Kernel 2 .585 Kernel 3 .420 Kernel 4 .384 Mean .443	100 mL
2	30 min. boiling	Juniper Ash 1.25g	Kernel 1 1.3 Kernel 2 1.25 Kernel 3 1.25 Kernel 4 1.35	Kernel 1 .9 Kernel 2 .85 Kernel 3 .9 Kernel 4 .9	Kernel 1 .5 Kernel 2 .65 Kernel 3. .6 Kernel 4 .6	Kernel 1 .585 Kernel 2 .691 Kernel 3 .675 Kernel 4 .729 Mean .670	100 mL
3	30 min. boiling	Juniper Ash 4g	Kernel 1 1.3 Kernel 2 1.1 Kernel 3 1.3 Kernel 4 1.4	Kernel 1 1.0 Kernel 2 .9 Kernel 3 1.0 Kernel 4 1.0	Kernel 1 .6 Kernel 2 .7 Kernel 3. .65 Kernel 4 .6	Kernel 1 .780 Kernel 2 .693 Kernel 3 .845 Kernel 4 .840 Mean .790	100 mL

2. Record: How is our experiment similar to your nixtamalization experiment? How is our experiment different from your nixtamalization experiment?

3. Record: Why might several measurements and a mean for each concentration be better than one measurement for each concentration?

Compare Before and After Nixtamalization

Change in Volume: We calculated the percent change in volume of corn kernels after nixtamalization for each concentration. We used this formula to calculate the percent change:

$$\% \text{ Change} = \frac{(\text{Mean Volume After} - \text{Mean Volume Before}) \times 100}{\text{Mean Volume Before}}$$

Change in Niacin: We also calculated the amount of bound niacin released for each concentration. We used data from a scientific paper published by Christianson et al., (1968) to calculate the amount of bound niacin released for each concentration.

Data Table: Change in Volume and Change in Niacin Vs. Concentration

Beaker	How Much Alkaline Substance (g)	Mean Volume of Kernels Before (cm^3)	Mean Volume of Kernels After (cm^3)	% Change in Kernel Volume	Amount of Niacin Released
1	Control (None)	.346	.443	28.3	3.0 µg/G
2	Juniper Ash 1.25g	.405	.670	65.4	5.5 µg/G
3	Juniper Ash 4g	.371	.790	112.5	9.3 µg/G

Analyze the Data

4. How does the amount, or concentration, of calcium hydroxide affect the percent change in kernel volume? What trend do you notice? Use data from the table as evidence to support your claim.

5. How does the amount, or concentration, of calcium hydroxide affect the amount of niacin released? What trend do you notice? Use data from the table as evidence to support your claim.

6. Which concentration of calcium hydroxide would you use to release the most niacin? Support your answer with evidence from the table. Also support your answer using evidence from the collisions in the molecular models with the golf balls.

Online Supplemental: Evidence of Student Learning

Figure 1. Student written response demonstrating analysis of percent volume change and niacin release across concentrations.

Compare Before and After Nixtamalization

Change in Volume: We calculated the percent change in volume of corn kernels after nixtamalization for each concentration. We used this formula to calculate the percent change:

$$\% \text{ Change} = \frac{(\text{Mean Volume After} - \text{Mean Volume Before}) \times 100}{\text{Mean Volume Before}}$$

Change in Niacin: We also calculated the amount of bound niacin released for each concentration. We used data from a scientific paper published by Christianson et al., (1968) to calculate the amount of bound niacin released for each concentration.

Data Table: Change in Volume and Change in Niacin Vs. Concentration

Beaker	How Much Alkaline Substance (g)	Mean Volume of Kernels Before (cm^3)	Mean Volume of Kernels After (cm^3)	% Change in Kernel Volume	Amount of Niacin Released
1	Control (None)	.402	.572	41.5	3 µg/G
2	$CaOH_2$ .4g	.404	.677	67.7	5.8 µg/G
3	$CaOH_2$ 1.25g	.427	.818	91.5	8.3 µg/G

Analyze the Data

4. How does the amount, or concentration, of calcium hydroxide **affect the percent change in kernel volume?** What trend do you notice? Use data from the table as evidence to support your claim.

As the concentration of calcium hydroxide increases, the percent change in Kernel volume also increases. According to the data showed that the control had a 41.5% increase in volume, the 0.4g concentration had a 67.7% increase and the 1.25 g concentration had a 91.5% increase. That showed a consistent upward trend. this pattern suggests that higher concentrations of calcium hydroxide caused a greater increase in Kernal volume, and this showed that the reaction is occuring more rapidly or completely at higher concentrations.

5. How does the amount, or concentration, of calcium hydroxide **affect the amount of niacin released?** What trend do you notice? Use data from the table as evidence to support your claim.

By looking at the data I saw that as the concentration of calcium hydroxide increased, the amount of niacin released also increased. The control released 3µg/g of niacin, the 0.4g concentration released 5.8µg/g, and the 1.25 concentration released 8.3µg/g. This showed a clear positive relationship between concentration and niacin release. The trend suggested that increasing the concentration of calcium hydroxide increases the effectiveness of the nixtamalization process in releasing the bound niacin.

6. Which concentration of calcium hydroxide would you use to release the most niacin? Support your answer with evidence from the table.

I would use the 1.25g concentration of calcium hydroxide because it released the most niacin. According to the data table, it released 8.3µg/g of niacin, compared to 5.8µg/g at 0.4g and 3µg/g in the control. The percent change in Kernel volume was also highest at 91.5%, showing that this concentration produced the greatest chemical change. Based on what we learned about collsion theory, increasing the concentration of reacting particles increases the number of collisions between particles. The more collisions there are the more collisions per second that are successful and this increases the reaction rate. This means that the highest concentration would produce the most collisions and the fastest reaction rate and that would cause the greatest release of the niacin.

Figure 1: Evidence of Student Learning from Data Analysis

The students' written responses to the data analysis task demonstrate their ability to identify patterns, apply collision theory, and construct evidence-based explanations. Figure 1. shows one student's complete response to Questions 4–6. The student correctly identified an upward trend in percent change in kernel volume (41.5% → 67.7% → 91.5%) and niacin release (3 µg/g → 5.8 µg/g → 8.3 µg/g) as concentration increased. The student then connected this quantitative pattern to collision theory, explaining that increasing concentration increases the number of particle collisions and therefore increases reaction rate. This response reflects students' ability to apply scientific principles and evidence to explain how changing concentration affects reaction rate (HS-PS1-5).

Figure 2. Student explanation of collision theory using molecular modeling.

Collision Theory Molecular Model

Describe how they used the molecular kit to model how increasing concentration and temperature affect reaction rate (explain using collision theory).

When we did the molecular modeling activity, the golf balls represented Particles in the reaction. The yellow balls represented the Corn molecules and the others colored balls represented the calcium hydroxide Particles. When we added more colored balls, the number of Collisions between the alkaline Particules and the corn Particlues increased. When we shook the container faster, it represented increasing the temperature, which increased kinetic energy.

Both of the changes caused more frequent collisions. When we learned about collision theory, we were taught that rections occur when Particles collide with enough energy. Incresing concentration results in increasing the number of Collisions. Also increasing temperture increases the energy of the collision. This is why higher concentration and temperature increased the rection rate during nixtamalization.

Figure 2: Evidence of Student Learning

Students' written explanations following the molecular modeling activity further demonstrate their understanding of collision theory. Figure 2. shows one student's explanation of how increasing concentration and temperature affect the reaction rate. The student accurately identifies that increasing the number of alkaline particles increases the frequency of collisions and that increasing temperature increases kinetic energy, leading to more successful collisions per second. This explanation reflects students' ability to apply scientific principles and evidence to explain the effects of changing concentration and temperature on reaction rate (HS-PS1-5).

Online Supplemental:
Differentiated Assessments Aligned with NGSS Standard

Name___________________________________

Number of points possible: 10
Level of mastery: 7 / 10

Practice Test: Rate Reactions - Nixtamalization

Alternate Assessment: Understanding Reaction Rates with Corn Cooking

Grade Level: High School *(Modified for Differentiation)*
Standard: HS-PS1-5 – Focus on understanding how concentration affects reaction rate Assessment Points: 10 total

Background

Marta and Jacob wanted to learn how cooking corn with a white powder called calcium hydroxide (lime) changes the corn. When the corn is cooked this way, a vitamin called niacin is released, and the corn gets bigger.

They did an experiment using different amounts of calcium hydroxide but kept everything else the same. After cooking, they measured how much the corn grew in weight.

Data Table

Trial	Calcium Hydroxide Used	Corn Weight Increase
1	**None**	**A little**
2	**A small amount**	**More**
3	**A medium amount**	**Even more**
4	**A large amount**	**A lot**

Part 1: What Did They Change? (2 points)

What one thing did Marta and Jacob change in each trial?

a. Temperature
b. Amount of corn
c. Amount of calcium hydroxide
d. Amount of water

Part 2: What Did They Measure? (2 points)

What did Marta and Jacob measure to see how fast the reaction happened?

a. How much corn was eaten
b. How much the corn's weight increased
c. How hot the corn got
d. How much water was left

Part 3: Draw A Picture (3 points)

Draw a simple picture showing: - Corn and calcium hydroxide before cooking - Corn getting bigger after cooking

(Use stick figures or symbols; no art skills needed!)

Part 4: Explaining The Results (3 points)

Write 1 or 2 sentences explaining why the corn grew more when Marta and Jacob used more calcium hydroxide. Use your drawing from Part 3 to help explain what is happening in the reaction and explain what causes this to happen.

____

Name___________________________________

Number of points possible: 10
Level of mastery: 6 /10

Alternate Assessment: Understanding Temperature and Reaction Rates in Nixtamalization

Grade Level: High School Chemistry (Modified for Differentiation)

Standard: HS-PS1-5 – Understand how temperature affects reaction rate

Assessment Total Points: 10

Background

Angie and Diego wanted to see what happens when they cook corn with a white powder called calcium hydroxide (lime). When they heated the corn in hot water with this powder, the corn grew in size. This means a chemical reaction happened.

They did the experiment using different water temperatures. They wanted to see if higher temperature made the corn grow more.

Part 1: What Did They Change? (2 points)

What one thing did Angie and Diego change in each trial?

☐ The kind of corn

☐ The amount of water

☐ The temperature of the water

☐ The color of the corn

Part 2: What Did They Measure? (2 points)

What did they measure to see how fast the reaction happened?

☐ How much water boiled

☐ How much the corn's weight increased

☐ The smell of the corn

☐ How long it took to cook

Part 3: Draw a Picture (3 points)

Draw a picture of corn: - BEFORE and AFTER cooking in hot water with lime (describe size and hardness).

Label your picture with arrows or words.

BEFORE	AFTER

Part 4:

Explain What Happened (3 points)

Finish the sentence below and write one more sentence:

"When the temperature went up, the corn ______________ because the reaction rate ______________."

Use your picture to help explain why knowing this might be helpful when preparing food?

____

____

____

____

____

Name_________________________________

Number of points possible: 20
Level of mastery: 15 / 10

High-Level Assessment: Investigating Reaction Rates Through Nixtamalization

Grade Level: High School (Advanced Differentiation)
Standard: HS-PS1-5 – Apply scientific principles to explain effects of concentration on reaction rate
Assessment Points: 20 total

Scientific Context

Nixtamalization is the traditional process of cooking corn in an alkaline solution (calcium hydroxide) to make nutrients like niacin more available. The chemical changes during cooking also improve the corn's texture and flavor.

In a controlled experiment, Marta and Jacob varied the concentration of calcium hydroxide and observed the resulting changes in the relative weight of the corn, which indicates the extent of the chemical reaction.

Experimental Data

Trial	$Ca(OH)_2$ Concentration (%)	Weight Increase (%)
1	**0.0**	**49**
2	**0.8**	**57**
3	**1.0**	**64**

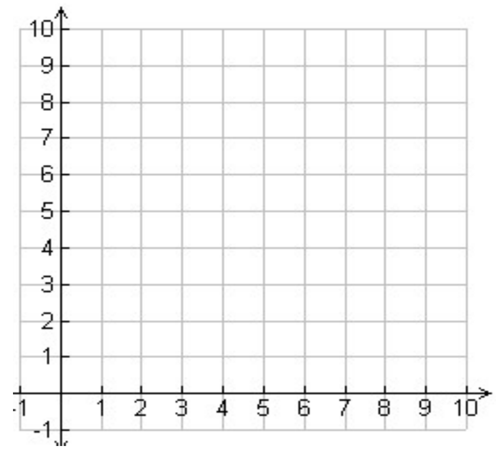
4	**2.0**	**65**

Part 1: Experimental Analysis (6 points)

1. Identify the independent, dependent, and two controlled variables in the experiment.
(3 points)

   - Independent: ___________________________
   - Dependent: ____________________________
   - Controlled(1): __________________________
   - Controlled (2):

2. Plot the data on a graph with $Ca(OH)_2$ concentration on the x-axis and weight increase on the y-axis. (3 points)



Part 2: Scientific Explanation Using Collision Theory (6 points)

Explain how the increase in $Ca(OH)_2$ concentration affects the rate of the reaction. Your explanation should include: - Particle behavior - Frequency and energy of collisions - Formation of new products

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Part 3: Critical Thinking and Evaluation (5 points)

Based on the data, do you think the reaction has reached its maximum rate by Trial 4? Support your answer with reasoning.

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Suggest an additional experiment Marta and Jacob could conduct to test another factor that affects reaction rate.

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Part 4: Reflection (3 points)

Why is it important for food scientists to understand how reaction rates work in processes like nixtamalization? Explain how this knowledge can help improve food quality, safety, or nutrition.

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Name________________________________

Number of points possible: 20
Level of mastery: 16 /10

High-Level Assessment: Temperature and Reaction Rates in Nixtamalization

Grade Level: High School Chemistry (Advanced Differentiation)

Standard: HS-PS1-5 – Apply scientific principles to explain how temperature affects reaction rates

Assessment Total Points: 20

Scientific Background

Nixtamalization is a process where corn is cooked in a solution of water and calcium hydroxide (lime). This reaction helps make nutrients like niacin more available and changes the corn's structure. Angie and Diego investigated how temperature affects the rate of this reaction.

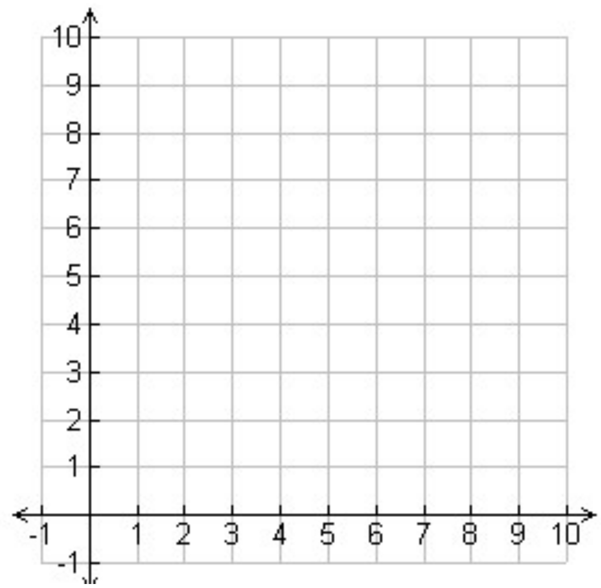
They performed two experiments: one with 1% calcium hydroxide and one with 2%, each at four different temperatures. The corn's weight increase was used to measure the reaction rate.

Part 1: Data Analysis and Graphing (6 points) Use the data provided in both trials to create a graph:

X-axis:

Temperature (°C) Y-axis:

Relative Weight Increase (%)



Plot the 1% and 2% $Ca(OH)_2$ trials on the same graph.

Compare The Trends:

What patterns do you notice?

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Using your observations/data/graph describe how concentration and temperature affect the reaction rate?

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Part 2: Scientific Explanation (6 points)

Use collision theory to explain: - Why the reaction rate increased as temperature rose - How particle movement, energy, and collisions affect the formation of new molecules - The difference in rates between the 1% and 2% calcium hydroxide concentrations.

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Part 3: Critical Evaluation (5 points)

Has the reaction rate plateaued at higher temperatures (e.g., 92°C)? Why or why not? Support your answer using the data.

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Propose a new experiment to test a different variable (e.g., particle size, cooking time, pH). What would you test?

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What would you predict based on what you've learned?

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Part 4: Industrial Application (3 points)

5. Why is understanding reaction rates important in manufacturing?
Give one example where temperature control impacts production quality or efficiency.

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Explain why temperature and reaction rates are important factors in food production and processing?

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Name______________________________

Number of points possible: 15
Level of mastery: 10 / 15

Practice Test: Rate Reactions - Nixtamalization

Background:
Marta and Jacob wanted to see what happens when they cook corn in an alkaline solution. They researched the process and found that the chemicals are:

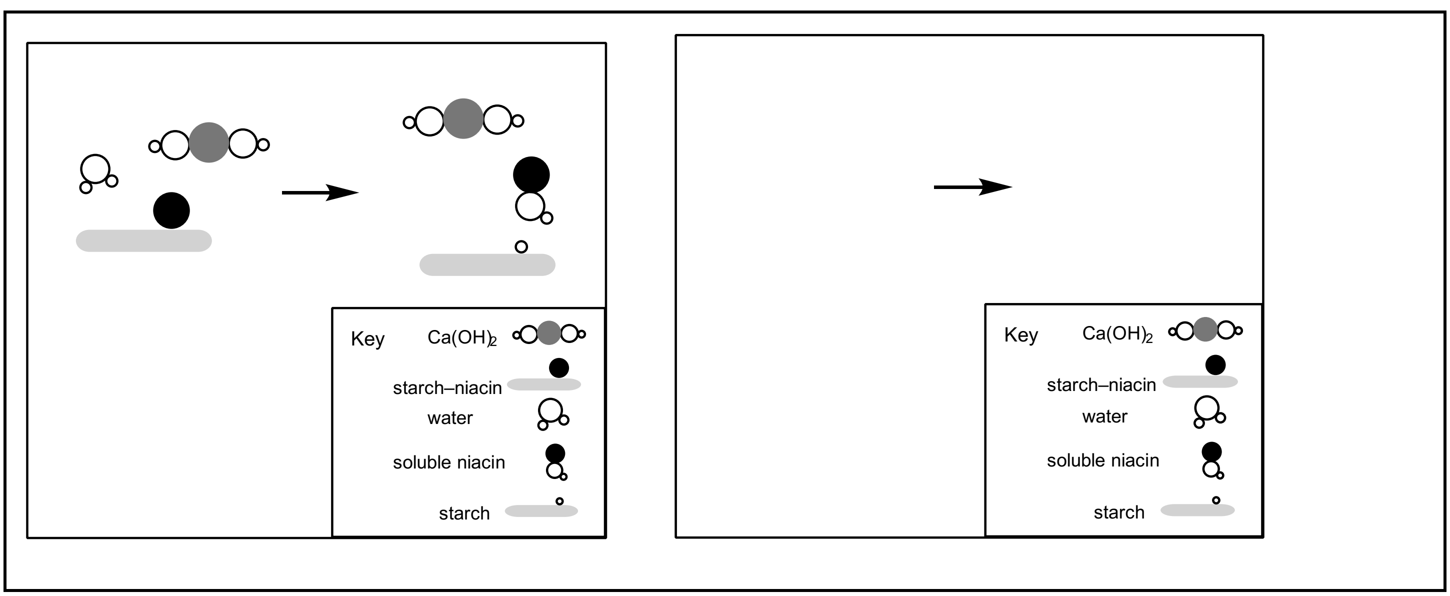
Ingredient	Composition Chemical Formula
Corn	**62% starch (glucose polymer), 19% protein & fiber, 15%water, 4%oil**
Calcium Hydroxide	**CA(OH)$_2$**
Water	**H_2O**

They found an equation for the chemical reaction shown below.

$$\text{Starch–Niacin} + H_2O + Ca(OH)_2 \xrightarrow[\textit{catalyst}]{} \text{Starch–H} + \text{HO–Niacin} + Ca(OH)_2 \textit{ catalyst}$$

They learned that niacin is chemically bound to the starch in corn. Water and calcium hydroxide can react with the bound niacin to form Starch and release soluble Niacin (HO–Niacin).

1. Marta and Jacob found a particle model that represents the chemical process of nixtamalization. Copy the model in the second box. (1 point for each symbol = 5 points). The model shows the rearrangements of atoms into new molecules. Be sure your copy shows the rearrangements of atoms into new molecules like the example does.



Experiment: Varying Calcium Hydroxide Concentration

Marta and Jacob created an experiment to see if different concentrations of calcium hydroxide would cause a change in the relative weight of the corn kernels. The results of their experiment are given below. Examine the information and the data table and answer the questions below.

Puma hybrid corn kernels from Monsanto (Semillas y Agroinsumos, México) were heated at a fixed temperature of 92 C. Different concentrations of calcium hydroxide were used measured as weight%. The relative weight increase measures the extent of reaction and is used as a measure of reaction rate. The results are shown in the table.

Data Table

Trial	Corn	H_2O (g)	Water Temperature (°C)	Calcium Hydroxide weight %	Relative weight increase of corn (Reaction Rate)
Trial 1	5.0 g	15.0 g	92	0.0	49%
Trial 2	5.0 g	15.0 g	92	0.8	57%
Trial 3	5.0 g	15.0 g	92	1.0	64%
Trial 4	5.0 g	15.0 g	92	2.0	65%

2. Use the graphic organizer below to identify the following elements of Marta and Jacob's experiment. (4 points)

Identify the
Research Question

CAUSE

Identify the
Independent Variable

Identify the
Dependent Variable

EFFECT

Explanation

Collision Theory
Particles of the reactants must collide with each other in order to react. However, only a few of these collisions are successful. The successful collisions must have the correct relative orientations of the reacting particles, and they must also have enough energy, known as the activation energy, at the moment of impact to break the pre-existing bonds and form all new bonds. This results in the products of the reaction.

3. Support the explanation told above with evidence and reasoning. Your reasoning should include a causal account, or reason, for the varying reaction rates.

Explanation	
Collision theory explains the results of Marta and Jacob's experiment.	
Evidence	
Describe specific evidence from the experiment that helps support the explanation listed in the line above. (3 points)	
Reasoning	

Tell a causal account, or reason, for the varying reaction rates. (3 points)	

References

Anderson, P. (retrieved May 22, 2025) Wonder of Science: Assessments. https://thewonderofscience.com/hsps15#assessments.

Fernández – Muñoz, J.L., Acosta-Osorio, A.A., Gruintal-Santos, M.A., Zelaya-Angel, O. (2011). Kinetics of water diffusion in corn grain during the alkaline cooking at different temperatures and calcium hydroxide concentration. *Journal of food engineering,* 106, 60-64.

Name____________________________________

Number of points possible: 20
Level of mastery: 14 / 20

Summative Assessment: Rate Reactions - Nixtamalization

Background:
Angie and Diego wanted to see what happens when they cook corn in an alkaline solution. They researched the process and found that the chemicals are:

Ingredient	Composition Chemical Formula
Corn	**62% starch (glucose polymer), 19% protein & fiber, 15%water, 4%oil**
Calcium Hydroxide	**$CA(OH)_2$**
Water	**H_2O**

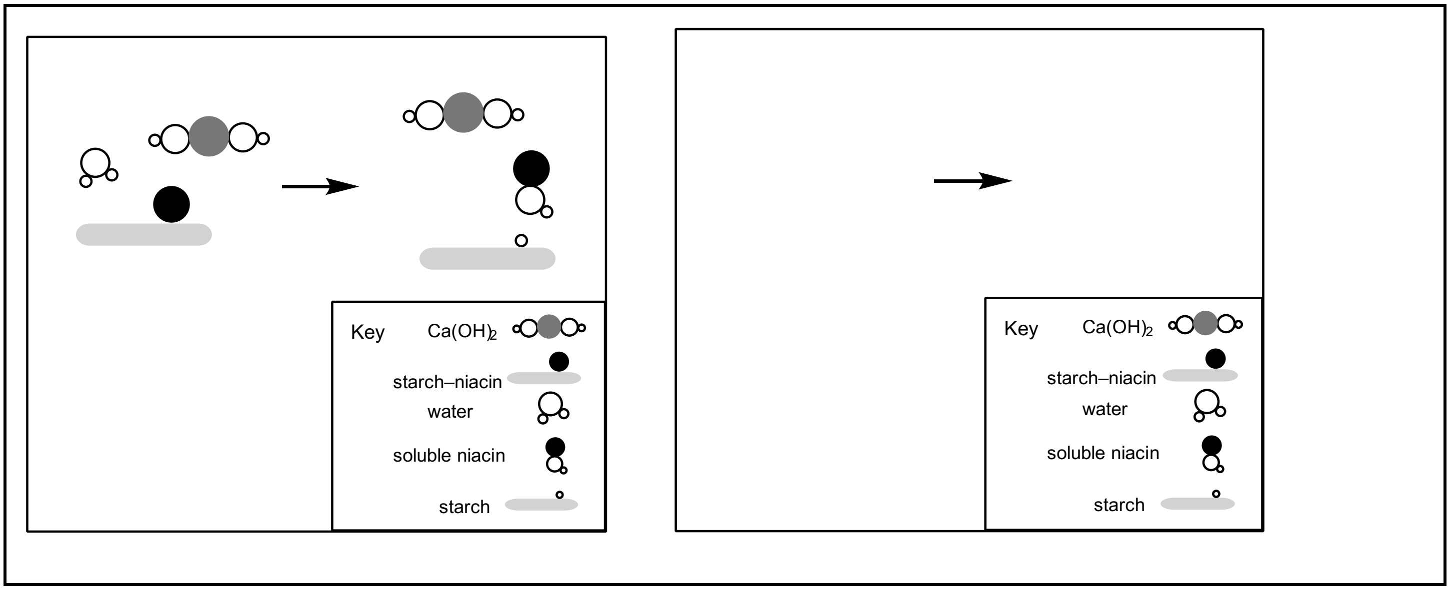
They found an equation for the chemical reaction shown below.

$$\text{Starch–Niacin} + H_2O + Ca(OH)_2 \longrightarrow \text{Starch–H} + \text{HO–Niacin} + Ca(OH)_2$$

catalyst *catalyst*

They learned that niacin is chemically bound to the starch in corn. Water and calcium hydroxide can react with the bound niacin to form Starch and release soluble Niacin (HO–Niacin).

1. Angie and Diego found a particle model that represents the chemical process of nixtamalization. Copy the model in the second box. (1 point for each symbol = 5 points). The model shows the rearrangements of atoms into new molecules. Be sure your copy shows the rearrangements of atoms into new molecules like the example does.



Experiment: Varying Temperature

Angie and Diego created an experiment to see if cooking the kernels at different temperatures would cause a change in the relative weight of the corn kernels. The results of their experiment are given below. Examine the information about their experiment and answer the questions below.

Experiment Varying Temperature

Puma hybrid corn kernels from Monsanto (Semillas y Agroinsumos, México) were heated at different temperatures with a fixed 2% Calcium hydroxide concentration. The relative weight increase measures the extent of reaction and is used as a measure of reaction rate.

Trial	Corn	H_2O (g)	Calcium Hydroxide weight %	Water Temperature (°C)	Relative weight increase (Reaction Rate)
Trial 1	5.0 g	15.0 g	2.0	62 °C	36%
Trial 2	5.0 g	15.0 g	2.0	72 °C	45%
Trial 3	5.0 g	15.0 g	2.0	82 °C	53%
Trial 4	5.0 g	15.0 g	2.0	92 °C	65%

Experiment Varying Temperature

Puma hybrid corn kernels from Monsanto (Semillas y Agroinsumos, México) were heated at different temperatures with a fixed 1% Calcium hydroxide concentration. The relative weight increase measures the extent of reaction and is used as a measure of reaction rate.

Trial	Corn	H_2O (g)	Calcium Hydroxide weight %	Water Temperature (°C)	Relative weight increase (Reaction Rate)
Trial 1	5.0 g	15.0 g	1.0	62 °C	34%
Trial 2	5.0 g	15.0 g	1.0	72 °C	44%
Trial 3	5.0 g	15.0 g	1.0	82 °C	51%
Trial 4	5.0 g	15.0 g	1.0	92 °C	64%

References

Anderson, P. (retrieved May 22, 2025) Wonder of Science: Assessments. https://thewonderofscience.com/hsps15#assessments.

Fernández – Muñoz, J.L., Acosta-Osorio, A.A., Gruintal-Santos, M.A., Zelaya-Angel, O. (2011). Kinetics of water diffusion in corn grain during the alkaline cooking at different temperatures and calcium hydroxide concentration. *Journal of food engineering,* 106, 60-64.

2. Use the graphic organizer below to identify the following elements of Angie and Diego's experiment. (4 points)

Identify the
Research Question

CAUSE

Identify the
Independent Variable

Identify the
Dependent Variable

EFFECT

Explanation

Collision Theory
Particles of the reactants must collide with each other in order to react. However, only a few of these collisions are successful. The successful collisions must have the correct relative orientations of the reacting particles, and they must also have enough energy, known as the activation energy, at the moment of impact to break the pre-existing bonds and form all new bonds. This results in the products of the reaction.

1. Support the explanation told above with evidence and reasoning. Your reasoning should include a causal account, or reason, for the varying reaction rates.

Explanation	
Collision theory explains the results of Angie and Diego's experiment.	
Evidence	
Describe specific evidence from the experiment that helps support the explanation listed in the line above. (3 points)	
Reasoning	

Tell a causal account, or reason, for the varying reaction rates. (3 points)	

Summary

3. How could you use the results of your experiment and Angie and Diego’s experiment to improve the nixtamalization process by increasing the rate of the chemical reaction? In other words, what variables would you change to increase the rate of the chemical reaction of nixtamalization? Explain why you would change those variables? (5 points)

Assessment and Scoring Guidance

Student explanations on the differentiated data analysis task and the final written NGSS assessment were evaluated using a three-level rubric (Developing, Proficient, Advanced) aligned to HS-PS1-5. The rubric included criteria for accurate use of quantitative evidence, correct explanation of how concentration and temperature affect collision frequency and reaction rate, identification and interpretation of patterns in percent change and niacin release, and clarity of scientific reasoning.

Scoring Rubric for HS-PS1-5

Reaction Rate Explanation Task

Performance Levels

Criteria	Developing	Proficient	Advanced
Use of Quantitative Evidence	Mentions data but does not clearly identify trend or uses data inaccurately.	Correctly identifies trend in percent change or niacin release and references numerical evidence.	Accurately identifies trends in multiple data columns and integrates specific numerical comparisons to support claim.
Application of Collision Theory	Mentions collisions but explanation is incomplete or lacks mechanism.	Correctly explains that increasing concentration or temperature increases collision frequency and reaction rate.	Provides mechanistic explanation connecting collision frequency, kinetic energy, and successful collisions per second.
Use of Crosscutting Concept (Patterns)	Recognizes that values change but does not clearly interpret pattern.	Identifies upward trend and connects pattern to causal explanation.	Explicitly describes pattern across concentrations and uses pattern as evidence of causality.
Clarity and Scientific Reasoning	Explanation is partially clear but lacks coherence or precise vocabulary.	Explanation is logically organized and uses appropriate scientific vocabulary.	Explanation is coherent, precise, and clearly integrates data, mechanism, and scientific terminology.

Safety Plan: Nixtamalization and Reaction Rate Chemistry Investigation

Overview

This lab activity involves cooking corn in varying concentrations of calcium hydroxide ($Ca(OH)_2$) and Hardwood Ash *(fine residue left after the combustion of hardwoods)* solutions at different temperatures to investigate how these variables affect reaction rate. Though calcium hydroxide is food-safe in culinary use, its lab application requires clear safety protocols. This activity involves chemical handling and heat sources, requiring full adherence to district and NSTA safety guidelines.

Hazard Analysis

Substance/Procedure	Risk	Precaution
Calcium Hydroxide Hardwood Ash (solid/powder)	Mildly caustic; irritates skin, eyes, and respiratory tract	Wear gloves and goggles when handling dry powder
Heated solutions	Burn risk; potential for spills or splatter	Use hot plates, supervise heating, wear heat-resistant gloves
Glassware and cooking pots	Breakage or burn hazard	Use heat-safe containers and tongs; avoid open flame
Disposal of chemical solution	Improper disposal can affect plumbing or violate policy	Neutralize with vinegar if required; follow district policy

Required Personal Protective Equipment (PPE)

- Chemical splash goggles (ANSI Z87.1-compliant)
- Nitrile or latex gloves
- Lab aprons
- Closed-toe shoes

Engineering Controls

• Work in a well-ventilated area
• Keep eyewash stations and first aid kits accessible
• Ensure hot plates are placed on stable, heat-resistant surfaces away from traffic flow

Safe Procedures

- Do not allow students to directly handle hot beakers or pots
- Carefully measure calcium hydroxide using dedicated utensils - never by hand
- All solutions should be mixed under teacher supervision
- Label all containers with concentration and hazard warnings
- Do not allow eating, tasting, or smelling of any materials

Emergency Procedures

Incident	Action
Eye contact with solution	Use eyewash station immediately for 15 minutes and notify instructor
Skin contact with solution	Rinse with cool water for several minutes; remove contaminated clothing
Inhalation of powder	Move to fresh air and notify instructor immediately
Burn from hot surface	Run under cool water; report to school nurse
Chemical spill	Cover with absorbent material while wearing PPE; dispose per school policy

Disposal Procedures

- Calcium hydroxide solution should be neutralized (if required by district) using a dilute acid (e.g., vinegar) before disposal
- Solid waste (e.g., corn residues) should be collected in labeled bins and disposed of according to food/chemical waste separation guidelines
- All waste handling must follow school district environmental protocols

Instructional Controls

- Pre-lab safety briefing required
- Students must sign a Science Lab Safety Contract (on file)
- Teacher must inspect all PPE use and lab stations before initiating activity
- Students with respiratory or skin sensitivities should be assigned non-handling roles (observation, recording, analysis)

Documentation and Compliance

- This activity complies with the NSTA Safety in the Science Classroom recommendations (2015)
- Risk Management signed off by [Teacher/School Lab Supervisor Name]
- A copy of this safety plan is available in the submitted supplemental materials and is on file with the school science department

References

National Science Teaching Association. (2015). *Safety in the science classroom: A position statement of the National Science Teachers Association.* Arlington, VA: NSTA.

Roy, K., & Love, J. (2017). *Safer Science: A guide to improving secondary science safety.* Arlington, VA: National Science Teaching Association.

American Chemical Society. (2016). *Safety in academic chemistry laboratories: Best practices for first- and second-year university students* (8th ed.). Washington, DC: American Chemical Society.

Flinn Scientific. (2022). *Science safety contract and laboratory safety guidelines.* Batavia, IL: Flinn Scientific, Inc.

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Authors

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