Tears and Transformation: The Chemistry of Onions

(1 - 3 days)

Authors

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SUBJECT/GRADE LEVEL

Subject Area: Chemistry
Grade Level: 9th - 11th

Materials

- Onion Cry Lab
  - Raw onions
  - Goggles
  - Sharp knives
  - Cutting boards
  - pH strips
  - Glass slides or mirror
  - Stopwatch
  - Small sealed containers
- General/Links
  - Computer (Internet & Video)
  - Poster & Materials
  - Why Onions Make You Cry
  - WayGround Game
- Worksheets:
  - Chemistry of Onions Engage worksheet
  - Chemistry of Onions Explore worksheet
  - Why Onions Make Us Cry Article
  - Why Onions Make Us Cry Vocab.
  - Chemical Changes In Onions Explain Worksheet
  - Onion Chemistry Elaborate Activities Student Worksheet
- Answer Keys/Rubrics:
  - Chemical Changes In Onions Answer Key
  - Onion Chemistry Elaborate Activity Rubrics
  - Summative Assessment Answer Key

STANDARDS

Next Generation Science Standards

- HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
  ➤ Relates to identifying chemical changes during cutting, boiling, and caramelizing onions.
- HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy.
  ➤ Connects to energy changes in caramelization and boiling reactions.
- 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.
  ➤ Students compare the rate of reaction at different heat levels (caramelization vs. boiling).

Mathematics Standards | Common Core State Standards

- HSN-Q.A.1–3: Use units to understand problems and guide the solution of multi-step problems; define appropriate quantities for the purpose of descriptive modeling; choose a level of accuracy appropriate to limitations of measurement.
  ➤ Used when measuring pH, time of heating, temperature.

English Language Arts Standards | Common Core State

- CCSS.ELA-LITERACY.RST.9-10.1 / RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts.
  → Students analyze diagrams or readings on sulfur compounds and cooking chemistry.
- CCSS.ELA-LITERACY.RST.9-10.4 / RST.11-12.4: Determine the meaning of symbols, key terms, and domain-specific words and phrases.
  → Interpreting scientific vocabulary like “sulfoxide,” “volatile,” “Maillard reaction.”

LESSON OBJECTIVE(S)

Students will be able to **analyze and explain the chemical changes** that occur when onions are cut, boiled, and caramelized by conducting guided experiments, interpreting pH and sensory data, and using scientific models and vocabulary (e.g., enzymatic reactions, thermal decomposition, Maillard reaction) to distinguish between physical and chemical changes.

CAREER CONNECTION(S)

Mentor Background:

Dr. Rabih E. Jabbour holds Ph.D. in Bioanalytical chemistry with more than 20 years of research experience in academia and industry in the field of CBRNE detection and technologies development and evaluations. Dr. Jabbour is currently serving as Laboratory manager for the CSAC Chemistry Security Laboratory. Some of the projects he is currently overseeing include the image analysis of detection of cyanide in field settings, the characterization of food matrices upon exposure to interference chemicals and the

development of off-the-shelf detection technology using portable commercial technologies like our cell phones and apps.

STEM Careers: Chemist Chemical Engineer, Organic Chemist, Forensic Scientist, Toxicology

ENGAGEMENT

Brief Description: To spark curiosity and guide students to observe and question the chemical processes involved when cutting an onion.

Procedures:

Activities:

1. **Video Viewing (7 min)**
   Students watch a short, engaging video such as *Why Onions Make You Cry* to introduce the idea that a chemical reaction is responsible for eye irritation and answer the three thought questions in the accompanying student worksheet.

2. **Sensory Observation (7 min)**
   Students interact with onion samples at their tables, including:
   - Sealed containers with pre-cut onions.
     Students record their reactions to smell, appearance, and any tear response in the accompanying worksheet. Look for robust responses (avoid one liners or vague answers).

3. **Group Discussion + Worksheet (5 min)**
   Students will use the student worksheet to:
   - Reflect on what they observed
   - Discuss what might be happening chemically
   - Decide whether the reaction is chemical or physical

Vocabulary support and reference terms like **enzyme**, **volatile compound**, and **sulfoxide** are provided to scaffold understanding.

Teacher Actions

- Play the video *"Why Onions Make You Cry"* to introduce the topic.
- Distribute and explain the "Chemistry of Onions Engage" worksheet.
- Set up sealed containers with pre-cut onions at student tables.
- Prompt students with guiding questions (e.g., "What do you notice?" "Is this a chemical or physical change?").
- Facilitate a brief whole-group discussion using vocabulary scaffolds (e.g., *enzyme, volatile, sulfoxide*).

Student Actions

- Watch the introductory video and respond to three reflection questions.
- Engage in sensory exploration: smell, observe, and record their reactions to pre-cut onions.
- Complete written observations using descriptive, detailed responses.
- Participate in group discussions to hypothesize about the type of change (chemical or physical).
- Reference vocabulary to support their reasoning.

Differentiation

- Provide sentence starters and word banks for students who need language support.
- Allow verbal responses or dictation for students with IEP/504 accommodations.
- Assign peer partners for students who need help articulating sensory observations.
- Use visual aids (e.g., diagram of enzyme reactions) to reinforce vocabulary and concepts.
- Offer additional wait time and structured turn-taking during discussion.

EXPLORATION

Brief Description: Students will conduct guided experiments to investigate how manipulating onions (cutting, boiling, caramelizing) leads to chemical changes—particularly the production of **syn-Propanethial-S-oxide** and evidence of **thermal reactions**.

Procedures:

Objective:

Students will conduct guided experiments to investigate how manipulating onions (cutting, boiling, caramelizing) leads to chemical changes—particularly the production of **syn-Propanethial-S-oxide** and evidence of **thermal reactions**.

🧅 Part 1: Onion Cry Lab (20–25 minutes)

Students explore the chemical reaction triggered when onions are cut. Through observation and testing, they gather data on the irritating gas produced and how it affects the senses. Students will notate ALL observations in the corresponding student worksheet.

Activities include:

- Observing **fogging** on a mirror/glass slide when exposed to onion fumes
- Recording **smell**, **eye irritation**, and **tear response**
- Using **pH strips** to detect acidity from airborne compounds
- Soaking onions in **cold water** to observe reduction in volatile compound effects

Skills practiced: Qualitative observation, sensory analysis, data recording, identifying signs of chemical reactions

🔥 Part 2: Thermal Transformation Lab Stations (20–25 minutes)

Students rotate through two heat-based cooking stations to observe how thermal energy affects onion chemistry. Students will notate ALL observations in the corresponding student worksheet

Station A – Boiled Onion:

- Boil onion slices and observe changes in smell, texture, and water color
- Use pH indicators to test the acidity of the cooking water

Station B – Caramelized Onion:

- Sauté onions and observe browning, smell, and texture changes
- Discuss how the **Maillard reaction** produces new flavor compounds and indicates chemical change

Skills practiced: Comparing physical vs. chemical changes, sensory evaluation, pH testing, applying chemistry to real-world (culinary) processes.

Teacher Actions

- Prepare lab stations with all necessary materials: onions, mirrors, pH strips, etc.
- Review lab safety procedures (knife use, heat safety).
- Provide clear written and verbal instructions at each station.
- Prompt students to observe, measure, and record in detail.
- Circulate to ask probing questions (e.g., "What evidence of chemical change do you see?").
- Monitor proper use of pH strips and tools.

Student Actions

- Rotate through stations, follow experimental procedures, and document all findings on the "Explore" worksheet.
- Observe and record qualitative changes: fogging on mirrors, onion smell, texture, pH
- Compare results across conditions (cutting, boiling, caramelizing).
- Identify signs of chemical reactions (e.g., browning, change in pH, smell).
- Engage in mini-discussions with partners or lab groups.

Differentiation

- Label stations clearly with color-coded directions and icons for ELL or low-literacy students.
- Pair students strategically (strong with emerging learners).
- Offer verbal instructions alongside visual step cards at each station.
- Use checklists for students needing executive function support.
- Provide extended time and reduce the number of required stations for students with processing delays.
- Allow video/photo recording (if appropriate) for students who prefer visual reporting.

EXPLANATION

Brief Description: Students will consolidate what they observed during the Exploration lab. They will use the article (Why Onions Make Us Cry : Vocab) to answer the Explain worksheet regarding the chemical changes observed in the lab. Teachers should use the questions as a Think-Pair-Share activity or allow for class discourse to talk about the article.

Procedures:

Objective:

Students will explain and connect their lab-based observations from cutting and cooking onions to the molecular processes behind enzyme reactions and thermal decomposition, reinforcing the concept of chemical change.

Background Information:

When onions are cut, they release sulfur-containing compounds that react in the presence of the enzyme allinase. This enzyme converts precursors like S-1-propenyl-L-cysteine sulfoxide into syn-Propanethial-S-oxide, a volatile compound that irritates the eyes. When onions are cooked, heat causes thermal decomposition, which changes the flavor, color, and smell—evidence of new substances forming, which characterizes a chemical change.

Intro: (~15 min)

- Direct Teach using the Canva presentation (if needed): Understanding Chemical Reactions and Energy Changes.
- Review content from the previous lab and any lingering questions if needed. (Great quick check)

Activity 1: CER-based Article Analysis (~15 min.)

- Students read and annotate the article Why Onions Make Us Cry to extract evidence
- Answer 3 CER Questions:
    - Enzyme's role in eye-irritant production
    - Importance of identifying LF synthase
    - Comparison of chemical change in raw vs. cooked onions
- Formative Check (Optional)
    - Use the rubric to provide quick feedback or facilitate peer-review rounds with sentence starters such as: if available have students jot down thoughts on index cards.
        - I agree with your claim because…
        - You could strengthen your reasoning by…

Activity 2: Molecule Mapping (10 - 15 min)

- Students complete a two-part flowchart:
    - Chopping (enzyme-driven): Fill in blanks showing how enzymatic reactions produces syn-Propanethial-S-oxide.
    - Cooking (thermal decomposition): Complete thermal breakdown of sulfur compounds.
- Formative Check (Optional)
    - Circulate and check if students correctly match enzymes and products
    - Back-Pocket-Questions: What type of change is this and why?

Activity 3: Talk Like a Chemist (~5 min.)

- Students use a structured word bank to complete sentence stems about onion chemistry.
- Share with a partner and revise phrasing for clarity and vocabulary precision.
- Optional Turn & Turn or Gallery Walk.

Teacher Actions:

- Project anchor visuals for chemical change and energy.
- Guide students through vocabulary and sentence stems.
- Monitor small-group or partner discussions.
  Prompt deeper thinking with formative questions (e.g., "How do you know this is a chemical change?").
- Use questioning strategies to encourage the use of academic vocabulary - utilize word wall if available

Student Actions:

- Use prior lab experience to complete structured flowcharts.
- Read and annotate the article Why Onions Make Us Cry to extract evidence.
- Write CER (Claim, Evidence, Reasoning) responses using scientific reasoning.
- Use sentence stems and word banks to construct explanations.
- Collaborate with peers to compare and refine scientific language.

Differentiation:

- Pair strong and struggling readers.
- Highlight key vocabulary prior to lesson.
- Embed WayGround or Edpuzzle for attached videos and articles.
- Offer small group instruction for students who struggle with CER writing.
- Most of the activities can be utilized to facilitate group or whole class discussion. Allow the written portion to drive student ideas and bullet points.

ELABORATE

Brief Description: Students will apply their understanding of chemical changes to real-world or comparative scenarios. They will be able to design an investigation or communicate scientific concepts using precise vocabulary and descriptions. Teachers can use this as an opportunity to help students reflect on chemical principals such as thermal decomposition enzymatic activity, or evidence of chemical reactions.

Procedures:

Objective:

Students will apply their understanding of chemical changes to real-world or comparative scenarios. They will be able to design an investigation or communicate scientific concepts using precise vocabulary and descriptions. Teachers can use this as an opportunity to help students reflect on chemical principals such as thermal decomposition enzymatic activity, or evidence of chemical reactions.

Background information:

Students previously explored and explained how cutting and cooking onions result in chemical changes—including enzymatic reactions (involving alliinase and LF synthase) and thermal decomposition during cooking. This phase encourages students to apply, extend, and communicate their learning in creative and analytical formats.

Activity 1: Mini-Poster (~90 min.)

Apply knowledge of chemical changes to a new context.
Summary:

- Pick a real-world example (e.g., toasting bread, browning fruit, rusting iron).
- Research: chemical changes involved, cause (heat, enzymes, light), and observable evidence.
- Create a mini-poster with visuals, accurate scientific language, and vocabulary labels.
- Format: digital (Google Slides/Canva) or paper poster.

Possible Formative Assessment for activity 1:

- Review posters for accuracy of vocabulary and cause/effect relationships.

Virtual Option:

- Assign as a Google Slides submission.
- Students can present posters in breakout rooms or a Padlet wall.

Activity 2: Lab Proposal (~60 min.)
Use scientific inquiry to compare chemical changes in two similar biological systems.
Summary:

- Research the enzymes and sulfur compounds in garlic (e.g., allicin, alliinase).
- Design a lab that compares the reactions in onions and garlic when chopped or heated.
- Include hypothesis, materials, safety, step-by-step procedure, data collection method, and expected results.

Possible Formative Assessment for activity 2:

- Check hypothesis logic, completeness of procedure, and proper use of vocabulary.
- Optional: conduct short group peer reviews with checklist/rubric.

Virtual Option:

- Students can collaborate using shared Google Docs.
  Lab proposals can be presented as recorded slides or submitted to Flipgrid.

Activity 3: Podcast/Video (~60 min.)
Reflect on and communicate conceptual understanding with voice and creativity.
Summary:

- Choose 2 out of 4 reflection questions (e.g., “How do enzymes play a key role in chemical reactions?”).
- Record a short video or podcast (1–2 minutes).
- Use correct vocabulary and examples (e.g., syn-Propanethial-S-oxide, chemical vs. physical change).

Possible Formative Assessment for activity 3:

- Use a simple rubric for clarity, content accuracy, and vocabulary use.
- Allow peer or self-assessment of communication skills.

Virtual Option:

- Canva or Google.

Teacher Actions:

- Introduce the task options and objectives clearly.
- Help students select an activity that fits their interests and strengths.
- Approve research topics or experimental comparisons.
- Provide access to resources (textbooks, article links, lab equipment lists, technology, etc.).
- Circulate and check for correct use of vocabulary and scientific logic.
- Facilitate peer reviews or group discussions (optional).

Student Actions:

- Choose one of three project types. (Depending on assignment)
- Collaborate, research, and complete the activity as instructed.
- Use accurate scientific vocabulary to explain or design reactions.
- Submit their work physically or digitally by the assigned due date. (Depending on assignment)

Differentiation:

- ELLs - Provide sentence stems, visuals, and preteach vocabulary
- IEPs - Offer extended time, reduction of options, or any other necessary adjustments
- Advanced Students - Include 3D models for molecular structures or add research journals
- All activities can be assigned for at-home projects/virtual.

EVALUATION

Brief Description: Teachers can use a previous activity and expand the grading type to include one formative (draft version) and one summative (final version) for the evaluation purposes. Alternatively, a short exam with different question types can be used to check for student mastery of key concepts.

Procedures:

Objective:

Students will show mastery of key concepts such as: enzyme-driven chemical reactions, thermal decomposition, evidence of chemical changes, reaction energy, and differences between chemical and physical changes. They will be able to validate their explanations using precise vocabulary and descriptions. In addition, students will be able to assess scientific explanations, data interpretation, and connect learning concepts to real-world applications.

Background Information:

Students previously explored, explained, and elaborated on how altering onions results in chemical changes. This phase encourages students to show how they have mastered their learning.

Activity 1: **Summative Grade (from the choice activities in the Elaborate Section)**

- Teachers can take summative grades based on:
    - Mini-poster final submission
    - Lab Proposal final submission
    - Podcast/Video final submission

Activity 2: Summative Assessment

- Summative Assessment (Option 1: Paper)
    - Summative Assessment Answer Key
    - If possible supply CER rubric to help students construct responses.
- WayGround Game (Option 2: Virtual)
    - Option to print exam

REFERENCES

- Royal Society of Chemistry
- Canva
- ChatGPT
- Society for Science: Science News Explores
- American Chemical Society
- Science Buddies
- Render Magazine: Savor The Science