Using Chemistry to Create Everyday Products: Chemical Compositions and 3D Printing

(4-6 weeks)

Authors

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SUBJECT/GRADE LEVEL

Subject Area: Science

Grade Level: Middle School;

7th and 8th Grade

Materials

- Google Site Unit Companion
- Elephant Toothpaste Materials per Group:
    - *Students will be repeating the process and choosing their own amounts; supply plenty of each material listed below to encourage testing.*
    - Hydrogen peroxide (H2O2) solution 3%, at least ½ cup
    - Dry Yeast (catalyst), one package
    - Dish soap, 5 tsp at least
    - Warm tap water, 4 tbsp.
    - Food coloring (optional)
    - Graduated cylinders or measuring cups
    - Collection pan or bowl for overflow
    - Paper towels
    - Plastic or glass bottles; different shapes optional
    - Safety goggles and lab aprons
- Enzyme Lab Activity Materials per Group:
    - Hydrogen peroxide (H2O2) solution 3%, 100mL at least
    - Dry Yeast (catalyst), one package
    - Dish soap, 5 tsp
    - Tap water
    - Food coloring (optional)
    - 4 plastic cups
    - Collection pan or bowl for overflow
    - Paper towels
    - Safety goggles and lab aprons
- Foam items for observation can be but not limited to: yoga mats, packaging peanuts, mattress covers, styrofoam food containers-making sure to have samples of at least polystyrene (#6 plastics such as styrofoam food containers, egg cartons) and polyethylene foams. Here is how to identify different plastics (and know their chemical properties.)
- Chemical formulas list:
    - Yoga Mat: azodicarbonamide (ADA) C2H4O2N4

- PE-Polyethylene (C2H4); chem structure
- PS-Polystyrene (C8H8) #6 plastics; Chem structure ex) packing peanuts, food take out containers, egg cartons
- PP-Polypropylene (C3H6); chem structure
- PU-Polyurethane ($C_{27}H_{36}N_2O_{10}$); chem structure

- Initial Foam Testing Lab
  - Ruler
  - Baseball
  - Camera for slow motion video
  - OR if available: Vernier force plate, Vernier Lab Quest
- Football Helmet Drop
  (3D print the football helmet from link below)
  https://www.thingiverse.com/thing:6133099
  - If no 3D printer available here is a link to a smaller helmet off of Amazon. https://www.amazon.com/Cleveland-Browns-Speed-Football-Helmet/dp/B088W2JRW6/ref=sr_1_6?crid=1QMCO30EQAMV7&keywords=toy+football+helmet&qid=1690396951&sprefix=toy+football+helmet+%2Caps%2C138&sr=8-6
  - Packing tape and clear tape
  - Packing foam, yoga mat, any foam that can be found.
  - Eggs
  - egg carton
  - Kleenex
  - masking tape
  - markers or crayons
  - garbage bags

STANDARDS

Next Generation Science Standards

- MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.
- MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. (density/point of enthalpy/solubility, etc)
- MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
- MS-PS1-5 Develop and use models to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

Mathematics Standards | Common Core State Standards

- CCSS.MATH.CONTENT.7.RP.A.1 Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units.
- CCSS.MATH.CONTENT.7.RP.A.2.A Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.
- CCSS.MATH.CONTENT.7.RP.A.2.B Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.
- CCSS.MATH.CONTENT.8.SP.A.1 Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

English Language Arts Standards | Common Core State

- 8.L.VAU.6 Acquire and accurately use grade-appropriate general academic and domain-specific words and phrases; develop vocabulary knowledge when considering a word or phrase important to comprehension or expression.
- 8.SL.CC.3 Explain a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.
- 8.SL.PKI.4 Present claims and findings in a focused, coherent manner with relevant evidence, valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
- 8.SL.PKI.5 Integrate multimedia components and visual displays in presentations to clarify information, to strengthen claims and evidence, and to add interest.
- 7.L.KL.3 When writing and speaking, choose precise language to express ideas concisely.

Background Knowledge

I. Polyurethane Foam:

- Description: Polyurethane foam is a synthetic material made by reacting polyols and diisocyanates. It can exist in various forms, including flexible and rigid foam.
- Common Uses: Mattresses, cushions, car seats, insulation panels, packaging materials, and soft toys.

II. Polystyrene Foam:

- Description: Polystyrene foam is a lightweight and rigid material created from expanded polystyrene beads. It is often referred to as Styrofoam.
- Common Uses: Disposable food containers, coffee cups, packaging material for electronics, insulation, and craft supplies.

III. Polyethylene Foam:

- Description: Polyethylene foam is a closed-cell foam made from polyethylene resins, resulting in a durable and flexible material.
- Common Uses: Protective packaging for fragile items, sports equipment padding, flotation devices, and insulation.

IV. Neoprene Foam:

- Description: Neoprene foam is a type of synthetic rubber foam known for its excellent resistance to oil, heat, and weather.
- Common Uses: Wetsuits, laptop sleeves, automotive seals, and medical braces.

V. Polyvinyl Chloride (PVC) Foam:

- Description: PVC foam is a closed-cell foam derived from polyvinyl chloride, known for its lightweight and weather-resistant characteristics.
- Common Uses: Boat decks, signage, building and construction applications, and arts and crafts materials.

LESSON OBJECTIVE(S)

Students will gain a better understanding of chemistry by creating a real world product for a specific purpose.

-Discuss everyday uses of foam

-Discuss best practices for laboratory experiments

-Make elephant toothpaste in small groups, record lab results

-Explain catalysts

-Research chemical formulas for materials used in elephant toothpaste

-Model the chemical reaction for elephant toothpaste

-List types of everyday foam, their uses, and chemical and physical properties

-Phet Lab Simulations: Building a Molecule, Molecular Shapes, Balancing Chemical Equations.

-Concussion study

-Foam depression test

-3D Design/Print Helmets if applicable

-Choose 2-3 foams, line the 3D Printed helmet and perform egg drop test

CAREER CONNECTION(S)

Mentor Background: Travis Thornell

Dr. Travis Thornell is a research physical scientist at the US Army Engineer Research and Development Center (ERDC) in Vicksburg, MS. He received his BS in Polymer Science from the University of Southern Mississippi (USM) in 2013 and his PhD in Materials Engineering from Purdue University in 2018. Dr. Thornell joined ERDC as a researcher in 2018 in the Concrete and Materials Branch of the Geotechnical and Structures Laboratory where he plans and conducts research in Military Engineering with internal and external partners. Dr. Thornell was selected for the 2021 American Chemical Society Partners for Progress and Prosperity (P3) award for collaborations with USM on research and academic efforts. My research interests are in the synthesis and characterization of

stimuli-responsive polymers and development of multi-functional composites. By manipulating the temperature, pH, or external magnetic fields, the behavior of polymers can change from being hydrophilic to hydrophobic or flexible to stiff. I also support polymer 3D printing and additive manufacturing by using thermal analysis to understand how the material performs during the printing process.

STEM Careers: Chemist, Engineer, Researcher, Construction, Autocad Tech, Physicist, Biologist

ENGAGEMENT

Brief Description: **Students will be able to begin to make connections with chemistry and everyday objects by watching videos about elephant toothpaste and lab experiences. Students will engage in discussions of foam and their everyday use.**

Procedures:
-Mark Rober Video-Record Breaking-Tallest Elephant Toothpaste
https://www.youtube.com/watch?v=e09xig209cQ

Questioning:
-How can we scale down to a classroom, group size? *Less materials, smaller containers, etc.*
-Why are foams created and how many types do you know?
-What products do you buy that contain foam? Have students enter their responses into a word cloud creator such as https://www.mentimeter.com/features/word-cloud

(Teachers can begin a word wall with chemical names, any elements heard, etc.)

-Kid helmet video: https://www.youtube.com/watch?v=e09xig209cQ
Questioning: What procedures did this student follow? Controls? How were results measured? Guide students the aspect of safety as a necessary place for types of foams.

EXPLORATION

Brief Description: **Make your own foam! Students will create at minimum three trials of elephant toothpaste and document the properties when different amounts of materials are used. Next, students will research and model the chemical formulas and chemical equation of elephant toothpaste. Finally, students will explore samples of everyday foam items, their chemical and physical properties to identify different types of foam.**

Procedures:
1. Make the toothpaste

-Students will spend time with the following materials to create their own elephant toothpaste. Their goal is to try three different combinations of materials, predicting the type of foam for each. Will the foam be tall, dense or full of large bubbles?. Video recording is allowed for evidence. Once each group has successfully tried 1-2 combinations of elephant toothpaste, pause to take a gallery walk.

Make Your Own Foam Lab Sheet

How to Gallery Walk: Students should spend ~2 minutes at each group listening to mini presentations and asking questions. Mini presentations should include the amount of each material used and results/appearances of elephant toothpaste. Students are looking for relationships between the foam that was created in comparison to the type and/or amount of materials used. Imperative that mistakes are shared. Once gallery walks are completed resume the whole group to debrief.
https://www.nsta.org/resources/promoting-discussion-science-classroom-using-gallery-walks

Elephant toothpaste how to:

Materials-

- Elephant Toothpaste Materials per Group:
  - *Students will be repeating the process and choosing their own amounts; supply plenty of each material listed below to encourage testing.*
  - Hydrogen peroxide (H_2O_2) solution 3%, at least ½ cup
  - Dry Yeast (catalyst), one package
  - Dish soap, 5 tsp at least
  - Warm tap water, 4 tbsp.
  - Food coloring (optional)
  - Graduated cylinders or measuring cups
  - Collection pan or bowl for overflow
  - Paper towels
  - Plastic or glass bottles; different shapes optional
  - Safety goggles and lab aprons

Prep Work-

-Wear safety glasses to do this experiment, since hydrogen peroxide can irritate your eyes.

-The elephant toothpaste will bubble up out of the bottle. Do the experiment in a tray or tub (or outside) so it is easy to clean up all the foam.

Instructions-

-Measure the mass of the materials you plan to combine and the container you will use

-Pour 1/2 cup of hydrogen peroxide into the bottle.

-Add a big squirt of dish soap into the bottle, and swirl gently to mix.

-If you want to make your foam a single color, add a few drops of food coloring directly into the hydrogen peroxide, and swirl the bottle gently to mix. If you want to give your foam stripes like some toothpastes, put the drops along the inside rim of the bottle's mouth. Let them drip down the inside of the bottle, but do not mix.

-In a measuring cup, mix together 1 tablespoon of yeast and 3 tablespoons of warm water. Stir for about 30 seconds.

-Pour the yeast mixture into the bottle, then quickly step back and watch your reaction go!

-Measure and record the mass of the containers and materials at the end-compare the beginning data.)

-Questioning throughout the experiment: What do you see? Large or small bubbles-what causes the differences? How long did the reaction last? How does the mass of materials before the lab compare to the mass before (remind students to measure the containers-they always forget!) What happens when the shape of the container changes? Is there a temperature change at the end of the experiment, why does the container feel warm? What is the chemical reaction taking place in the elephant toothpaste experiment? How does the concentration of hydrogen peroxide affect the reaction rate and the amount of foam produced? What role does the dish soap play in the reaction and how does it affect the foam's stability and appearance? How can you test for the presence of gas produced in the reaction?

2. Students will model the chemistry of elephant toothpaste:

-Students should explore enzymes and explain a catalyst. Use the Exploring Enzymes Lab as either a demonstration or in small groups or show this Enzyme Lab video.

3. Explore the types of foam and their physical properties through observation. Types of foam available in the classroom can be but are not limited to: spray foam, upholstery foam, yoga mat, styrofoam, mattress covers, carpet padding, camera case, shipping materials, life jacket. Students can perform physical tests for density (calculating mass, density and volume), rebound (how easily it returns to original shape), cell structure (would the foam be classified as open or closed) and buoyancy (ability to float or absorb water). Chemical properties can be researched online once foam is identified.

Foam type properties: https://foamonline.com/foam-types/

4. Students can begin to label their everyday items with their physical properties such as density/mass/volume, flexibility, hardness, elasticity, tensile strength, transparency, water absorption, etc. To help with chemical/physical properties visit the Crash Course Physical Science: Properties of Matter playlist on youtube.

EXPLANATION

Brief Description: Students will practice creating and modeling chemical formulas as well as balancing chemical reactions to prove the exchange of elements through the law of conservation of mass. Students will then apply those skills to show the formulas necessary for creating types of everyday use foam and the elements involved.

Procedures:

Before students can name and explain the elements and compounds of foam, let's pause to review how compounds are made and the shapes they form. Here is a great place to compare the reaction of table salt (a simple explanation and video) to making foam, discussing how elements combine to form something new with completely different properties.

1. 'Building a Molecule' simulation at phet lab with worksheet to practice atoms forming molecules, coefficients and subscripts.

2. Students will work with the 'Molecular Shapes: Basics' simulation at phet lab and the worksheet to practice adding elements and how their bonds, angles and geometry of the shape are affected.

3. In the 'Balancing Chemical Equations' phet lab simulation and worksheet will help students recognize that atoms build molecules which create new materials through a chemical reaction

4. What chemicals were used in elephant toothpaste? List them and their chemical formulas. What elements are present? Which elements were combined and how did they rearrange during the reaction? Can we write a chemical explanation of the order we combined the materials and what was produced? Have students draft a chemical equation for elephant toothpaste using known chemical formulas. Students can research the final, balanced equation once drafts are complete. Identify the reactant and the product, label coefficients and subscripts. The chemical equation and reaction information are listed here.

-Relationships can also be made to other reactions we experience daily such as cellular respiration and photosynthesis. These equations can be written on the board in their basic words and any formulas the students may already be familiar with (Photosynthesis: $H2O+CO2+light \rightarrow C6H12O6 + O2$) with later focus being spent on showing how the equation is balanced.

5. Students will physically model the movement of atoms to prove the law of conservation of mass using a kit similar to this or simple items in the classroom to represent molecules. Take pictures for your lab notebook.

6. Students will investigate the compounds responsible for the creation of their everyday foams, label their examples and understand how some foams are manufactured.

Edpuzzle polyethylene, Edpuzzle polystyrene, Edpuzzle polypropylene

ELABORATE

Brief Description: Students will understand how concussions occur and the importance of safety gear, specifically helmets. Students will conduct an initial foam test by selecting multiple combinations of foams and dropping a baseball to test multiple trials of the foam's absorption then choose their most effective combination to be used in the final Helmet Egg Drop Challenge.

Procedures:

1. Concussion study:

-TED-Ed 'What Happens when you have a Concussion?'

-2016 TED-Ed 'Why Helmets don't Prevent Concussions'; shows some excellent technology, data collection and research.

-2021 New York Times Article: 'This Helmet will save Football. Actually, Probably Not.'

-2023 Article 'How to Prevent Concussions in Football? Better Helmets'

Concussion Quizizz

2. Initial Foam Testing Lab:

-Remind the students of the helmet test from the first day of this lesson and the procedures the student followed. Now, students choose types of foam and combine them-testing them by dropping baseball onto the foam.

-Video of controlled density foam test: https://youtu.be/ZAMEhG3WwYI

-Options for collecting data: If available, stack the foam on top of a Vernier Force Plate with Labquest and record the amount of force in Newtons upon impact and record all trials. If this equipment is unavailable, simply using a ruler and a slow motion camera, students should be able to measure the amount of depression made upon impact, and choose their combination that depresses the least.

Lab recording sheet for foam testing lab

EVALUATION

Brief Description: Students will use their final foam combinations and pad a helmet and test which egg survives.

Procedures:

Students will have their football helmets and use their particular combination of foam to line the inside of their helmet. Once everyone has completed lining their helmet it is suggested to start with short drops then gradually increase the distance until either the egg is cracked or the helmet is compromised. The "winner" will be the highest of the combined two variables. Once the results are finalized they are going to present their findings and learnings using a powerpoint style presentation. Lab recording sheet for egg drop.

- Lesson Extension: If 3d Printers are available you could have the students design their own helmet to see if their design could be helpful in the protection of the egg. GIve parameters such as "football player must be able to see, the egg must still fit in the helmet, etc.
- In my example I have 3D printed two of them. One was made out of PLA and the other is from a clear plastic Resin. I made the clear one to show how it could be padded. The foam I am using is a packing material mainly composed from low density conductive polyethylene. The polyethylene is a great example of springy material and dense for packing applications. I also used two rubber bands to keep the "egg" steady in the foam to act as a strap that football players wear.
- You may also want to check out an additional RESET Lesson 'A-head of the Game' for more on concussions and creating helmets.

Quizizz Chemical Formulas

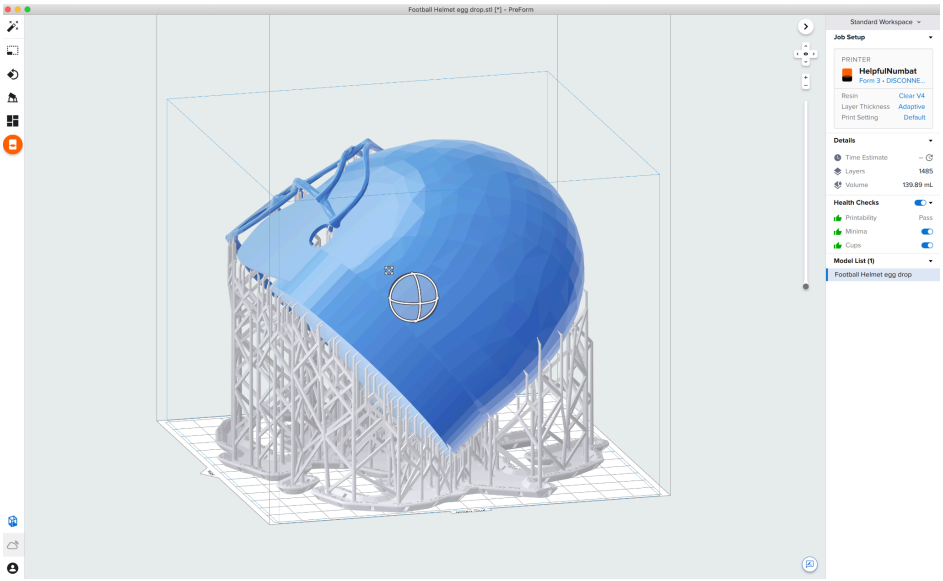
https://quizizz.com/admin/quiz/5aca31e167bf32001a11ae66?source=quiz_share

https://quizizz.com/admin/quiz/632dca188798a0001ddb04ce?source=quiz_share

Quizizz for Law of Conservation of Mass

https://quizizz.com/admin/quiz/5e5e99158fdb3c001b81acd0?source=quiz_share

https://quizizz.com/admin/quiz/5bc6294abc0e78001a6e6a8a?source=quiz_share


Football Helmet egg drop.stl [*] - PreForm
Standard Workspace
Job Setup
PRINTER
HelpfulNumbat
Form 3 - DISCONNE...
Resin
Clear V4
Layer Thickness
Adaptive
Print Setting
Default
Details
Time Estimate
Layers
1485
Volume
139.89 mL
Health Checks
Printability
Pass
Minima
Cups
Model List (1)
Football Helmet egg drop







REFERENCES

- Google Site Unit Companion
- Here is how to identify different plastics (and know their chemical properties.)
- PE-Polyethylene (C2H4); chem structure
- PS-Polystyrene (C8H8) #6 plastics; Chem structure ex) packing peanuts, food take out containers, egg cartons
- PP-Polypropylene (C3H6); chem structure
- PU-Polyurethane ($C_{27}H_{36}N_2O_{10}$); chem structure
- (3D print the football helmet from link) https://www.thingiverse.com/thing:6133099
- If no 3D printer available here is a link to a smaller helmet off of Amazon. https://www.amazon.com/Cleveland-Browns-Speed-Football-Helmet/dp/B088W2JRW6/ref=sr_1_6?crid=1QMCO30EQAMV7&keywords=toy+football+helmet&qid=1690396951&sprefix=toy+football+helmet+%2Caps%2C138&sr=8-6
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- Kid helmet video: https://www.youtube.com/watch?v=e09xiq209cQ
- Make Your Own Foam Lab Sheet
- https://www.nsta.org/resources/promoting-discussion-science-classroom-using-gallery-walks
- **Elephant toothpaste how to:**
- Exploring Enzymes Lab
- show this Enzyme Lab video
- Foam type properties: https://foamonline.com/foam-types/
- Crash Course Physical Science: Properties of Matter playlist on youtube.
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- Lab recording sheet for egg drop.
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- https://quizizz.com/admin/quiz/632dca188798a0001ddb04ce?source=quiz_share
- Quizizz for Law of Conservation of Mass
- https://quizizz.com/admin/quiz/5e5e99158fdb3c001b81acd0?source=quiz_share
- https://quizizz.com/admin/quiz/5bc6294abc0e78001a6e6a8a?source=quiz_share

Extension Possibilities

- Address the environmental impact of foam production and potential alternatives to foam;
- alternative materials to make foam/polymers out of;
- biodegradability of foam types;
- starch based packing peanuts and bioplastics