DNA Extraction From Strawberries

Set-up:

1. Buy fresh strawberries or thaw frozen strawberries at room temperature (do not heat).
2. Prepare 400mL of extraction buffer by mixing 380mL of water with 20mL dish soap and 10g salt (about 2 teaspoons).
3. Place 190 Proof Spirits (ethanol) in the freezer.
4. Set aside 10mL extraction buffer for each station.
5. Cut cheesecloth into about 6x8" rectangles.
6. Right before activity, set out 5mL ethanol for each station.

Procedure:

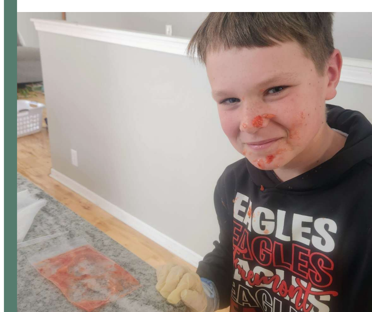
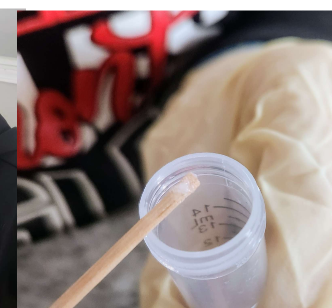
1. Remove green parts from strawberry and place in a Ziplock baggie.
2. Squeeze out air and seal baggie. ***GENTLY*** squash strawberry with hands inside the bag for about 2 min.
3. Add 10mL extraction buffer to bag, reseal, and mix for another 1 min.
4. Hang cheesecloth over cup and pour in strawberry slush so it drips through the cheesecloth and into the cup.
5. Remove cheesecloth and strawberry solids pieces.
6. Carefully pour 5mL of cold ethanol along side of cup so that it layers on top of the strawberry juices.
7. The clear strands of DNA will begin to clump where the two layers meet. Tiny bubbles in the ethanol layer will appear where the DNA precipitates.
8. Slowly rotate the wooden skewer in the ethanol directly above the juice layer to wind (spool) the DNA. Remove skewer and observe the DNA.

Chemical Engineering Applications

Biological Polymers: DNA is a polymer; a giant molecule made of tiny repeating pieces linked like train cars. Chemical engineers use separation techniques to isolate these fragile, long chains from cells to read or safely edit their instructions.

Microscopic Medicine Factories: Chemical engineers can rewrite DNA and insert it into a host cell (a living cell used to grow a product). This transforms the cell into a tiny factory making complex proteins like monoclonal antibodies—"warrior proteins" that fight diseases like cancer.

Green Materials and Sustainability: By designing custom DNA, engineers can reprogram microbes (like bacteria or yeast). Changing their internal instructions trains these organisms to eat industrial waste and recycle it into eco-friendly bioplastics, biofuels, or specialty food ingredients.


Materials

All-In-One Kit: Carolina Biological Supply DNALC Strawberry DNA Extraction Kit (Item# 211338, $83.50, 16 groups of 2 students)

Refill/DIY Items:
Fresh Strawberries, Ziplock Sandwich Bags, Small Plastic Cups, Cheesecloth, Bamboo Skewers, Table Salt, Dish Soap, 190 Proof Spirits, Water (I buy distilled water)

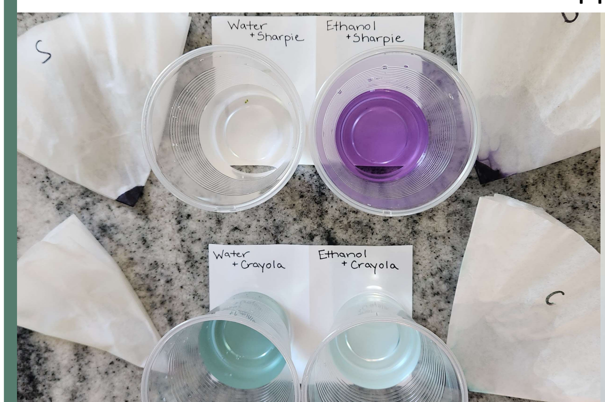
Grade	Primary Concept & Standards	Alternative Relevant Standards	Chemical Engineering Themed Critical Thinking Questions
K–2	**Observable Properties of Matter** (NGSS 2-PS1-1 / IN IAS 2-PS1-1 / OH Grade 2 PS) Mechanism: Biopolymers like DNA can be physically forced out of solution, separated, and classified by their visible, physical properties.	**Inheritance of Traits** (NGSS 1-LS3-1 / IN IAS 1-LS3-1 / OH Grade 1 LS) Concept: Making observations to recognize that plants and animals pass internal traits down to their offspring.	1. We used our hands to smash the strawberries. If a factory needed to do this for thousands of strawberries to make a healthy food or medicine, what kind of machine could we build to smash them safely? 2. The dish soap helped open-up the tiny packages inside the strawberry. What do you think would happen if we forgot to use the soap and only used plain water? 3. What did the strawberry DNA look like when it floated to the top? Is it a solid, a liquid, or something in between?
3–5	**Particles & Scale of Matter** (NGSS 5-PS1-1 / IN IAS 5-PS1-1 / OH Grade 5 PS) Mechanism: Matter is composed of particles too small to be seen; engineers use physical and chemical tools to isolate these hidden structures from a mixture.	**Engineering Design Constraints** (NGSS 3-5-ETS1-1 / IN IAS 3-5-ETS1-1 / OH Grade 3-5 ETS) Concept: Defining a simple design problem with clear criteria for success and constraints on materials, time, or budget.	1. The cheesecloth caught the big chunks of strawberry pulp but let the juice pass through. Why is it important for an engineer to separate the chunks out before trying to collect the tiny DNA particles? 2. In a real manufacturing plant, the cheesecloth would clog up almost instantly and could only be used once. What is another way you could separate a liquid from a solid? 3. The DNA molecules are too small to see until the cold alcohol makes them clump together. Why does an engineer need to know if a product is thick and sticky or thin and watery when designing a factory to make it?
6–8	**Cellular Systems & Membranes** (NGSS MS-LS1-1 / IN IAS MS-LS1-1 / OH Grade 6-8 LS) Mechanism: Accessing intracellular components requires disrupting the protective lipid bilayer membrane using a chemical surfactant (soap).	**Chemical Properties & Interactions** (NGSS MS-PS1-2 / IN IAS MS-PS1-2 / OH Grade 6-8 PS) Concept: Analyzing how the physical state and properties of a solution change when different substances interact.	1. Strawberry cell walls are made of lipids, which are fats and oils. How does the soap act as a chemical tool to break down those greasy membranes and release the DNA? 2. Why does adding freezing-cold alcohol cause the invisible, dissolved DNA molecules to suddenly separate into a solid cloud we can actually see? 3. Imagine you are an engineer running a large bio-manufacturing plant. What factors (like mixing speed, temperature, or amount of soap) would you need to test to get the absolute most DNA out of each batch?
9–12	**Macromolecules & Genetic Coding** (NGSS HS-LS3-1 / IN IAS HS-LS3-1 / OH HS Biology) Mechanism: DNA is a complex biological polymer whose solubility is dictated by the chemical polarity of its surrounding solvent environment.	**Intermolecular Forces** (NGSS HS-PS1-3 / IN IAS HS-PS1-3 / OH HS Chemistry) Concept: Evaluating how the structural properties of a biomolecule determine its behavior, solubility, and phase changes.	1. DNA has a highly polar, negatively charged backbone that dissolves easily in water. How does introducing a less polar fluid like cold alcohol alter the molecular interactions and force the DNA polymer chains to clump together? 2. Processing and separating biological products can make up a huge percentage of a biotechnology company's operating costs. What are the economic and safety trade-offs of using large amounts of alcohol at a real factory scale (Hint: It's flammable)? 3. Once a biochemical engineer safely extracts and purifies a target genetic sequence, what chemical or physical barriers must they overcome so it can successfully enter a patient's cells?

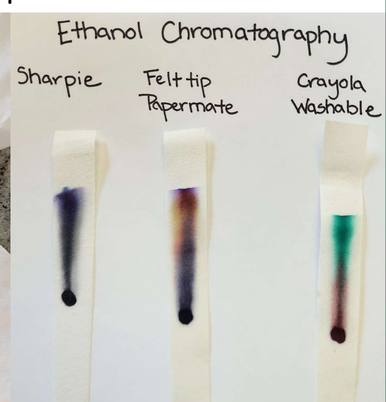
Note on Standards for Michigan, Indiana, and Ohio Teachers: The activities in this session were aligned directly to the Next Generation Science Standards (NGSS), which are adopted verbatim by **Michigan**. If you teach in **Indiana**, these align with the updated 3D Indiana Academic Standards for Science. If you teach in **Ohio**, these activities directly support your grade-level inquiry strands for Chemical/Physical Properties of Matter (Elementary), Matter & Motion (Middle School), and Chemistry/Biology (High School).

Solvent Extraction of Marker Ink

Set-up (for each station):
1. Cut some of the coffee filters or filter paper into narrow strips (about ½” thick). You will need 3 – 5.
2. Fold 4 whole coffee filters into quarters.
3. Fill 2 cups with alcohol (about 1” deep) and label (A).
4. Fill 2 cups with water (about 1” deep) and label (W).

Procedure:
1. Color the points of two filters with permanent marker/Sharpie and label (S).
2. Color the points of the other two filters with washable marker/Crayola and label (C).
3. Dip one filter point into each cup and swirl for 15 seconds. Remove the filter paper and observe the color of the liquid.
4. ***BONUS:*** Color a thick circle about 1/3 of the way up a thin strip of filter using a marker of your choice. Hold in a cup so the paper bottom touches the liquid but not the circle. Fold the overhanging part of the strip over the cup and let sit for about 5 minutes. Observe what happens to the “black” ink.





Chemical Engineering Applications

Solvent Extraction (Separation Processes): Extraction means using a specific fluid to selectively dissolve and pull a target chemical out of a solid or liquid mixture. When you brew a hot cup of coffee or tea, you are performing liquid extraction! Chemical engineers use this process to pull essential oils (like lavender, mint, or citrus) out of plant matrices so they can be used to scent consumer products like lotions or bath bombs.

Solvent Selection (Maximizing Yield): Knowing which liquid will dissolve a specific molecule is a core chemical engineering skill. Alcohol successfully dissolves permanent ink while water fails. Process engineers carefully choose solvents that are highly attracted to the exact aromatic molecules they want to capture, which allows them to maximize the pure scent while leaving behind unwanted plant components like green chlorophyll or sticky waxes.

Chromatography (Molecular Separation): Chromatography separates a moving mixture by letting its individual components travel through a material (like liquid climbing up filter paper) at different speeds. As the fluid moves, different ink molecules separate into distinct, visible color bands. Chemical engineers scale this up using large columns to isolate and purify life-saving medicines from complex mixtures of cells, ensuring the final injection is perfectly pure and safe for patients.

Materials

- Coffee filters or filter paper
- Small Plastic Cups
- 190 Proof Spirits/Ethanol (First Aid Isopropyl Alcohol or Rubbing Alcohol also works)
- Distilled Water
- Assortment of permanent and washable markers (black or brown have the best effect)

Grade	Primary Concept & Standards	Alternative Relevant Standards	Chemical Engineering Themed Critical Thinking Questions
K–2	**Material Performance & Choice** (NGSS 2-PS1-2 / IN IAS 2-PS1-2 / OH Grade 2 PS) Mechanism: Different solvents interact with pigments uniquely; chemical choice determines whether a substance dissolves and moves or stays fixed.	**Comparing Design Solutions** (NGSS K-2-ETS1-3 / IN IAS K-2-ETS1-3 / OH K-2 ETS) Concept: Testing and comparing two different tools or liquids designed to solve the same practical problem to see which works better.	1. Why did the Sharpie ink stay stuck on the paper in the water cup, but change the liquid color in the alcohol cup? 2. If you accidentally got permanent marker on your shirt, would you use a water-based soap or an alcohol-based spray to get it out? Why? 3. If an engineer wants to collect a sweet scent out of orange peels to put into a bath bomb, should they pick a liquid the scent loves to dissolve in or ignores? 4. Look at your bonus paper strips. Did the "black" ink stay completely black? Do the strips using different marker types match?
3–5	**Identifying Material Properties** (NGSS 5-PS1-3 / IN IAS 5-PS1-3 / OH Grade 5 PS) Mechanism: Complex mixtures can be identified and systematically separated by testing how their individual components dissolve in different fluids.	**Visualizing Hidden Particles** (NGSS 5-PS1-1 / IN IAS 5-PS1-1 / OH Grade 5 PS) Concept: Using a model to show that matter is made of particles too small to be seen moving through a physical matrix.	1. The Crayola marker dissolved in water, but the Sharpie required alcohol. How does an engineer use this idea to extract pure lavender oil from a plant without accidentally collecting smelly and sticky plant waxes? 2. On your bonus strip, why do you think some colors traveled all the way to the top of the paper while other colors got stuck near the bottom? 3. A factory accidentally mixed a blue ink that dissolves in alcohol with a yellow ink that dissolves in water. Based on our experiment, how could you separate them back out? 4. Swirling one paper filter at a time is a slow process. If an engineer needed to extract medicine from thousands of tropical plants what would you recommend instead?
6–8	**Properties of Solutions & Mixtures** (NGSS MS-PS1-2 / IN IAS MS-PS1-2 / OH Grade 6-8 PS) Mechanism: Components separate based on a physical partition coefficient—their relative affinity for a mobile solvent versus a stationary surface.	**Evaluating Engineering Options** (NGSS MS-ETS1-2 / IN IAS MS-ETS1-2 / OH 6-8 ETS) Concept: Systematically evaluating a process to determine how well it meets specific manufacturing criteria and operational constraints.	1. When you swirled the marker in the cup, you performed a liquid extraction. Why is choosing a highly selective solvent critical when trying to isolate natural vanilla or mint flavors for foods and lotions? 2. In chromatography, components separate because they travel at different speeds. If a pharmaceutical engineer wants to isolate a pure vaccine from a messy mixture of cells, how could they use this "speed difference" to separate the good medicine from the waste? 3. If we changed the solvent on your chromatography strip to a 50/50 mix of water and alcohol, how do you predict the separation bands of the black ink would change?
9–12	**Polarity & Electrical Forces** (NGSS HS-PS1-3 / IN IAS HS-PS1-3 / OH HS Chemistry) Mechanism: Molecular separation is driven by competitive intermolecular forces (hydrogen bonding vs. London dispersion forces) between the solute, solvent, and matrix.	**Optimizing Industrial Solutions** (NGSS HS-ETS1-3 / IN IAS HS-ETS1-3 / OH HS ETS) Concept: Evaluating real-world technical solutions based on safety, environmental regulations, material costs, and chemical efficiency constraints.	1. Based on your extraction results, analyze the relative chemical polarities of the Sharpie pigments versus the Crayola pigments. What does this tell you about their affinity for polar vs. less-polar solvents? 2. Industrial chromatography columns purify life-saving medicines like insulin at a massive scale. What process variables (fluid flow rate, temperature, or column material) must a chemical engineer control to ensure the final product is 100% pure and safe for a patient? 3. While organic solvents like alcohol or hexane are great at extracting nonpolar molecules, they can be toxic or highly flammable. How does an engineer balance high chemical efficiency with safety and environmental regulations in a production plant?

Chemical Engineering of Bath Bombs

Materials

- 2 cups baking soda
- 1 cup citric acid
- 1 cup corn starch
- 1 cup Epsom salt
- Coconut or olive oil
- Food coloring
- Essential oils
- Soap molds or muffin tins
- Quart sized sandwich bags

Procedure & Tips

1. Premix dry ingredients in a large bowl.
2. Scoop about a half cup of dry mix into a Ziplock bag. Squeeze out air and seal tightly.

Preparing the dry mix too far in advance or leaving it out in humid air will cause the ingredients to clump into solid rocks.

3. Allow each student to select their scent and color preference. Add 2 drops of each to the bag.
4. Add ¼ teaspoon of oil and ¼ teaspoon of water to the bag.
5. Gently knead each bag until the mixture lightly clumps together like kinetic sand or sandcastle beach sand.
6. Lightly coat mold in oil and a bit of dry ingredient mix. (Like flouring a pan for baking a cake)
7. Firmly press the scented mix into the mold. Bath bombs assemble better if cured overnight.

Quick drying method: Preheating an oven to 150°F, place packed metal molds inside, turn oven off, and let molds dry inside for 1hr.

8. Remove from mold and store in foil or plastic bag until ready to use.

Chemical Engineering Applications

Chemical Kinetics (Controlling Reaction Speed): Chemical engineers don't just start reactions; they control how fast or slow they happen. By tweaking a chemical recipe, an engineer can design a bath bomb to fizz slowly for a relaxing five minutes or optimize the chemistry inside an automotive air bag so it inflates in a split second during a crash.

Process Scale-up (From Bowls to Factories): Making a few bath bombs in a small kitchen bowl is easy, but a manufacturing engineer must design giant automated mixing plants. They calculate how to blend thousands of pounds of dry powder uniformly without letting the humidity in the room ruin the chemical reaction before the product gets packed into a box.

Product Formulation (Designing the Perfect Mix): Combining active chemical ingredients with filler materials to get a specific texture or shape is called formulation engineering. This is the exact process engineers use to create everyday consumer goods, like crunchy dishwasher pods, smooth cosmetics, or timed-release vitamin tablets that dissolve slowly in your stomach.

Grade	Primary Concept & Standards	Alternative Relevant Standards	Chemical Engineering Themed Critical Thinking Questions
K–2	**Irreversible Changes via Mixing** (NGSS 2-PS1-4 / IN IAS 2-PS1-4 / OH Grade 2 PS) Mechanism: Mixing specific dry and wet ingredients triggers an irreversible chemical change that generates a gas and cannot be easily undone.	**Form & Functional Design** (NGSS K-2-ETS1-2 / IN IAS K-2-ETS1-2 / OH K-2 ETS) Concept: Developing a physical model or mold to illustrate how the shape of an object helps it function to solve a practical problem.	1. When we mixed the dry white powders together, they just sat there quietly. Why did adding water suddenly make them wake up and fizz? 2. What would happen to our dry ingredients if we forgot to dry our hands before packing them into the mold? Why must a bath bomb factory stay completely dry inside? 3. We used our hands to squeeze the mixture into a round mold. If a factory wanted to make thousands of star-shaped bath bombs every single minute, what kind of machine would you invent to do that?
3–5	**Chemical Reactions & New Products** (NGSS 5-PS1-4 / IN IAS 5-PS1-4 / OH Grade 5 PS) Mechanism: An acid-base neutralization reaction produces an entirely new substance—carbon dioxide gas—evidenced by rapid effervescence.	**Conservation of Matter** (NGSS 5-PS1-2 / IN IAS 5-PS1-2 / OH Grade 5 PS) Concept: Measuring and tracking material quantities to demonstrate that total weight is conserved during a chemical or physical change.	1. The bubbles we see are a brand-new gas called carbon dioxide. Where did that gas come from if we started with only solid powders and liquid oils? 2. If we doubled the amount of cornstarch (which doesn't fizz) but kept the baking soda and acid the same, how do you think it would affect the fizzing time in the water? How does an engineer find the perfect recipe balanced between speed and cost? 3. When you make one bath bomb, you can feel if it's too wet or dry with your hands. How could a factory engineer measure and control the moisture of a giant 500-pound mixer without touching it?
6–8	**Rearrangement of Atoms** (NGSS MS-PS1-5 / IN IAS MS-PS1-5 / OH Grade 6-8 PS) Mechanism: Dry crystals have limited molecular mobility; adding a liquid water medium allows ions to dissolve, diffuse, collide, and react.	**Evidence of Chemical Change** (NGSS MS-PS1-2 / IN IAS MS-PS1-2 / OH Grade 6-8 PS) Concept: Analyzing data from properties before and after an interaction to verify if a genuine chemical transformation has occurred.	1. What specific evidence tells you that a chemical reaction is taking place when the bath bomb hits water, rather than just something dissolving like sugar? 2. In their dry crystal forms, the baking soda and citric acid molecules cannot move freely to collide and react. How does water act as a medium that unlocks this reaction? 3. Making one bath bomb in a small bowl is easy. If you are scaling up to mix tons of dry powder in a giant factory blender, what problems might you face if the heavy machinery creates friction and heats up the powder bed?
9–12	**Reaction Kinetics & Collision Theory** (NGSS HS-PS1-5 / IN IAS HS-PS1-5 / OH HS Chemistry) Mechanism: The rate of a reaction is constrained by mass transfer and physical state; hydration lowers the activation energy barrier by facilitating rapid ionic collisions.	**Breaking Down Complex Problems** (NGSS HS-ETS1-2 / IN IAS HS-ETS1-2 / OH HS ETS) Concept: Designing an industrial solution to a complex, multi-scale problem by breaking it down into smaller, managed process control stages.	1. Use collision theory to explain why the reaction rate between dry citric acid and baking soda is practically zero, but becomes almost instantaneous the moment water is added. 2. Imagine you are designing a storage hopper for bulk mixed bath bomb powder. If the plant's humidity control system fails, what process safety hazards arise from gas generation in a closed tank, and what safety relief designs would you add? 3. How would you establish a control system for an industrial compression press to ensure that each bath bomb is packed tightly enough so it won't crumble during truck shipping, but loosely enough that it still dissolves quickly in the consumer's tub?

Water + Washable Marker	**Alcohol + Washable Marker**
Water + Permanent Marker	**Alcohol + Permanent Marker**