ADVANCED SCIENCE EXPERIMENTS

For older students to do at home

Welcome to a world of exciting scientific exploration! This guide provides ten advanced science experiments that older students can conduct at home. Each experiment includes clear instructions, scientific explanations, and safety precautions to ensure a fun and educational experience. Get ready to dive into the wonders of science!

1. Chromatography of Leaves

Supplies:

- Fresh green leaves (spinach, kale, or tree leaves)
- Rubbing alcohol (isopropyl alcohol)
- Glass jars or beakers
- Coffee filters or chromatography paper
- Scissors
- Coin or hard object
- Ruler

Directions:

1. Cut the leaves into small pieces and place them in a jar.
2. Add enough rubbing alcohol to cover the leaves.
3. Use a coin to crush the leaves in the alcohol for 2-3 minutes.
4. Cut a strip of coffee filter paper long enough to almost reach the bottom of the jar when suspended.
5. Make a small slit in the center of the paper strip and slide it over a pencil or ruler.
6. Suspend the paper strip in the jar, ensuring the bottom edge is just touching the alcohol (but not the leaves).
7. Wait for the alcohol to travel up the paper. As it does, it will separate the pigments in the leaves.
8. Remove the paper when the alcohol is about 1 inch from the top and let it dry.

Scientific Explanation:

Chromatography is a technique used to separate mixtures based on their different affinities for a stationary phase (the paper) and a mobile phase (the alcohol). Different pigments in the leaves (chlorophyll, carotenoids, xanthophylls) have different solubilities in alcohol and therefore travel at different rates up the paper.

Troubleshooting:

- If the pigments don't separate well, try using fresh leaves or a higher concentration of alcohol.
- Ensure the paper strip doesn't touch the sides of the jar.

Further Exploration:

- Try different types of leaves and compare their pigment compositions.
- Use different solvents (e.g., acetone) and observe the results.

Safety Precautions:

- Rubbing alcohol is flammable. Keep away from open flames.
- Adult supervision is recommended.

2. Building a Simple Electric Motor

Supplies:

- D-cell battery
- Battery holder (optional)
- Enameled copper wire (magnet wire)
- Sandpaper
- Two paper clips
- Strong cylindrical magnet

Directions:

1. Wrap the enameled copper wire around the battery (about 8-10 turns) to form a coil. Leave a few inches of wire free on each end.
2. Remove the coil from the battery and secure the loops by twisting the ends around the coil.
3. Use sandpaper to completely remove the enamel from one end of the wire and *only half* of the enamel from the other end. This is crucial for the motor to work.
4. Bend the paper clips to create stands that will hold the coil. Attach them to the battery terminals (or battery holder terminals).
5. Place the coil in the paper clip stands, so it can spin freely.
6. Position the strong magnet on top of the battery, centered under the coil.
7. Give the coil a gentle push to start it spinning.

Scientific Explanation:

An electric motor works based on the principle of electromagnetism. When current flows through the coil of wire, it generates a magnetic field. This magnetic field interacts with the magnetic field of the permanent magnet, creating a force that causes the coil to rotate. The sandpapering of only half the enamel off one end acts as a simple commutator, switching the current direction to keep the motor spinning.

Troubleshooting:

- If the motor doesn't spin, ensure the enamel is completely removed from one end and only half from the other. This is a common mistake.
- Make sure the coil can spin freely and isn't touching anything.
- Try a stronger magnet or a fresh battery.

Further Exploration:

- Experiment with different numbers of coil turns.
- Investigate the effects of different magnet strengths.
- Build a more sophisticated commutator.

Safety Precautions:

- The wire may get warm during operation. Be cautious when handling.
- Adult supervision is recommended.

3. Building a Mini Wind Turbine

Supplies:

- Small DC motor (generator)
- Cardboard or plastic for blades
- Small LED light
- Wire
- Hot glue gun
- Pencil or dowel (to mount the blades)
- Multimeter (optional)

Directions:

1. Cut out the blades from cardboard or plastic. You can experiment with different shapes and sizes.
2. Attach the blades to the pencil or dowel, ensuring they are angled to catch the wind effectively. Hot glue works well for this.
3. Attach the pencil/dowel with the blades to the shaft of the DC motor.
4. Connect the wires from the DC motor to the LED light. If using a multimeter, connect it in parallel to measure the voltage generated.
5. Place the wind turbine in front of a fan or outside in a windy area.
6. Observe the LED light. If it lights up, your wind turbine is generating electricity.

Scientific Explanation:

A wind turbine converts kinetic energy from the wind into electrical energy. The wind turns the blades, which rotates the shaft of the DC motor. When the motor is turned, it acts as a generator, producing electricity due to electromagnetic induction. The strength of the generated voltage and current depends on the wind speed and the efficiency of the turbine.

Troubleshooting:

- If the LED doesn't light up, check the connections and ensure the blades are angled correctly.
- Try a stronger wind source.
- Use a multimeter to check the voltage output of the generator.

Further Exploration:

- Experiment with different blade designs and materials.
- Investigate the effect of wind speed on power generation.
- Add a capacitor to store the generated energy.

Safety Precautions:

- Use caution when working with hot glue.
- Ensure the turbine is securely mounted to prevent it from falling.
- Adult supervision is recommended.

4. DNA Extraction from Strawberries

Supplies:

- Strawberries (fresh or frozen)
- Rubbing alcohol (chilled in freezer)
- Dish soap
- Salt
- Water
- Ziploc bag
- Coffee filter or cheesecloth
- Glass or beaker
- Wooden skewer or stirring rod

Directions:

1. Prepare the extraction buffer: Mix 1/2 cup water, 1 teaspoon dish soap, and 1/2 teaspoon salt in a cup.
2. Place the strawberries in a Ziploc bag and gently mash them for 1-2 minutes.
3. Add 1/4 cup of the extraction buffer to the bag. Seal the bag and mash the strawberries for another minute.
4. Pour the strawberry mixture through a coffee filter (or cheesecloth) into a glass or beaker.
5. Gently pour chilled rubbing alcohol down the side of the glass, so it forms a layer on top of the strawberry extract (about the same volume as the strawberry extract).
6. Wait for a few minutes. DNA will precipitate out of the solution and appear as a white, stringy substance at the interface between the alcohol and the strawberry extract.
7. Use a wooden skewer or stirring rod to gently spool the DNA and observe it.

Scientific Explanation:

This experiment demonstrates the basic principles of DNA extraction. Mashing the strawberries breaks down the cell walls. The dish soap disrupts the cell membranes, releasing the DNA. Salt helps the DNA strands clump together. Cold alcohol is used to precipitate the DNA out of the solution because DNA is not soluble in alcohol.

Troubleshooting:

- Ensure the rubbing alcohol is ice cold for best results.
- Avoid vigorous mixing after adding the alcohol, as this can break the DNA strands.
- Use fresh strawberries.

Further Exploration:

- Try extracting DNA from other fruits or vegetables.
- Investigate the effects of different extraction buffers.

Safety Precautions:

- Rubbing alcohol is flammable. Keep away from open flames.
- Adult supervision is recommended.

5. Building a Lemon Battery

Supplies:

- Lemons (4-5)
- Copper electrodes (copper wire or pennies)
- Zinc electrodes (galvanized nails or zinc strips)
- Alligator clips
- Wire
- Small LED light or multimeter

Directions:

1. Roll each lemon on a hard surface to break up the pulp inside and increase juice flow.
2. Insert a copper electrode and a zinc electrode into each lemon, ensuring they do not touch each other.
3. Connect the lemons in series using alligator clips and wires. Connect the copper electrode of one lemon to the zinc electrode of the next.
4. Connect the free copper electrode of the first lemon to the positive lead of the LED light (or multimeter) and the free zinc electrode of the last lemon to the negative lead.
5. Observe the LED light. If it lights up, your lemon battery is generating electricity. If using a multimeter, check the voltage and current.

Scientific Explanation:

A lemon battery is a simple voltaic pile. The lemon juice acts as an electrolyte, allowing ions to flow between the copper and zinc electrodes. The copper acts as the cathode (positive electrode), and the zinc acts as the anode (negative electrode). A chemical reaction occurs, where zinc atoms lose electrons (oxidation) and copper ions gain electrons (reduction), generating an electric current.

Troubleshooting:

- Ensure the electrodes are clean and making good contact with the lemon juice.
- Use fresh lemons.
- Add more lemons in series to increase the voltage.
- Clean the copper and zinc electrodes with sandpaper between uses to ensure a better connection.

Further Exploration:

- Try different fruits or vegetables as electrolytes.
- Investigate the effect of electrode materials on voltage and current.
- Use the lemon battery to power a small electronic device.

Safety Precautions:

- No significant safety precautions are needed, but adult supervision is recommended.

6. Investigating Osmosis with Eggs

Supplies:

- Raw eggs (2)
- White vinegar
- Corn syrup or sugar solution
- Water
- Two glasses or jars
- Ruler
- Scale (optional)

Directions:

1. Gently place the raw eggs in separate glasses or jars.
2. Cover the eggs completely with white vinegar. You'll see bubbles forming on the eggshell.
3. Leave the eggs in the vinegar for 24-48 hours, or until the eggshell dissolves completely. The vinegar's acetic acid reacts with the calcium carbonate in the eggshell, dissolving it.
4. Carefully remove the eggs from the vinegar and rinse them gently with water. You should now have translucent, shell-less eggs.
5. Place one egg in a glass filled with corn syrup (or a saturated sugar solution) and the other egg in a glass filled with water.
6. Observe the eggs over the next 24-48 hours. Note any changes in size, weight (if you have a scale), and appearance.

Scientific Explanation:

This experiment demonstrates osmosis, the movement of water molecules across a semipermeable membrane (the egg membrane) from an area of high water concentration to an area of low water concentration. In the corn syrup, water moves out of the egg into the syrup, causing the egg to shrink. In the water, water moves into the egg, causing it to swell.

Troubleshooting:

- Ensure the eggs are completely submerged in the solutions.
- Use fresh eggs.
- Be gentle when handling the shell-less eggs, as they are fragile.

Further Exploration:

- Try different solutions with varying sugar concentrations.
- Investigate the effects of temperature on osmosis.
- Calculate the percentage change in egg size and weight.

Safety Precautions:

- Handle raw eggs with care to avoid contamination.
- Wash your hands thoroughly after handling raw eggs.

7. Building a Spectroscope

Supplies:

- Cardboard tube (e.g., from a paper towel or wrapping paper roll)
- Diffraction grating film or a CD/DVD
- Razor blade or sharp knife
- Black tape
- Scissors

Directions:

1. Cut a small rectangular hole on one side of the cardboard tube near one end. This will be the viewing slit.
2. At the other end of the tube, use the razor blade or sharp knife to carefully cut a narrow slit (about 1mm wide) directly opposite the viewing hole. This is the entrance slit for the light.
3. If using diffraction grating film, cut a small piece slightly larger than the diameter of the tube. Secure it over the end of the tube with the entrance slit using black tape. The diffraction grating should be positioned so that it will diffract the light.
4. If using a CD/DVD, carefully remove the reflective layer (e.g., using tape). Cut a small piece and secure it over the end of the tube using black tape. The grooved side should face inward.
5. Look through the viewing hole and point the entrance slit towards a light source (e.g., sunlight, incandescent bulb, fluorescent bulb). Adjust the angle to see the spectrum of light.

Scientific Explanation:

A spectroscope is an instrument used to observe the spectrum of light. Light is diffracted (bent) by the diffraction grating or the grooves on the CD/DVD, separating it into its component colors (wavelengths). Different light sources emit different spectra, allowing us to analyze their composition. For example, an incandescent bulb emits a continuous spectrum, while a fluorescent bulb emits a line spectrum.

Troubleshooting:

- Ensure the slits are narrow and clean.
- Experiment with different light sources.
- Adjust the angle of the spectroscope to optimize the spectrum view.

Further Exploration:

- Compare the spectra of different light sources.
- Use the spectroscope to analyze the light emitted by different elements (e.g., by burning salts).
- Research how spectroscopes are used in astronomy and chemistry.

Safety Precautions:

- Use caution when using razor blades or sharp knives.
- Do not look directly at the sun through the spectroscope.

8. Growing Crystals from Borax

Supplies:

- Borax powder
- Hot water
- Glass jar or beaker
- Pipe cleaners
- String or thread
- Pencil or stick
- Food coloring (optional)

Directions:

1. Create a saturated borax solution: In a glass jar, add borax powder to hot water, stirring until no more borax dissolves. A saturated solution means the water can't dissolve any more borax.
2. Add a few drops of food coloring to the solution if desired.
3. Shape the pipe cleaners into desired shapes (e.g., snowflakes, stars, letters).
4. Tie a string or thread to each pipe cleaner shape.
5. Suspend the pipe cleaner shapes in the borax solution, ensuring they are fully submerged and not touching the sides or bottom of the jar.
6. Secure the strings to a pencil or stick placed across the top of the jar.
7. Leave the jar undisturbed for several hours or overnight. Crystals will form on the pipe cleaner shapes as the solution cools and evaporates.

8. Remove the crystals from the solution and let them dry.

Scientific Explanation:

This experiment demonstrates the principles of crystal growth. As the hot borax solution cools, the solubility of borax decreases, meaning the water can no longer hold as much borax in solution. The excess borax precipitates out of the solution and forms crystals on the pipe cleaner shapes. The rate of crystal growth depends on the temperature, concentration of the solution, and the presence of nucleation sites (the pipe cleaners).

Troubleshooting:

- Ensure the borax solution is saturated.
- Avoid disturbing the jar during crystal growth.
- If crystals don't form, try adding more borax to the solution or leaving it for a longer time.

Further Exploration:

- Experiment with different materials as nucleation sites (e.g., string, rocks).
- Investigate the effects of temperature on crystal growth.
- Grow crystals from other substances, such as sugar or salt.

Safety Precautions:

- Borax can cause skin and eye irritation. Avoid contact and wash hands thoroughly after handling.
- Adult supervision is recommended.

9. Measuring the Speed of Light with a Microwave

Supplies:

- Microwave oven (non-turntable)
- Chocolate bar or marshmallows
- Ruler
- Calculator

Directions:

1. Remove the turntable from the microwave oven.
2. Place the chocolate bar (or marshmallows) on a microwave-safe plate in the center of the microwave.
3. Microwave on high for a short period (e.g., 15-20 seconds) until you see two or three melted spots on the chocolate. Watch carefully to avoid burning.
4. Measure the distance between the centers of the melted spots. This distance represents half the wavelength of the microwaves.

5. The frequency of the microwaves is typically printed on the back of the microwave oven (usually around 2.45 GHz or 2450 MHz). This frequency is in Hertz (Hz) or Megahertz (MHz).
6. Calculate the speed of light using the formula: Speed of Light = Frequency x Wavelength. Wavelength = 2 x Distance between melted spots.

Scientific Explanation:

Microwaves are a form of electromagnetic radiation that creates standing waves inside the microwave oven. The melted spots on the chocolate indicate the locations of maximum energy (antinodes) of the standing waves. The distance between these spots is half the wavelength of the microwaves. Knowing the frequency of the microwaves (provided on the microwave) and measuring the wavelength, we can calculate the speed of light.

Troubleshooting:

- Ensure the microwave oven does not have a turntable.
- Watch the chocolate carefully to avoid burning.
- Measure the distance between the melted spots as accurately as possible.
- If the chocolate doesn't melt evenly, try a different food item or adjust the microwave time.

Further Exploration:

- Compare your calculated speed of light value with the accepted value (299,792,458 m/s).
- Investigate the properties of microwaves and their applications in communication and technology.

Safety Precautions:

- Do not operate the microwave oven without food inside.
- Watch the chocolate carefully to avoid burning.

10. Building a Cloud in a Bottle

Supplies:

- Clear plastic bottle with a narrow neck (e.g., a soda bottle)
- Rubbing alcohol or water
- Air pump (e.g., a bicycle pump or air compressor) with a nozzle that fits snugly into the bottle neck
- Cork or rubber stopper to seal the bottle neck tightly

Directions:

1. Pour a small amount (about a tablespoon) of rubbing alcohol or water into the bottle.
2. Swirl the liquid around to coat the inside of the bottle.
3. Insert the nozzle of the air pump into the bottle neck and seal it tightly with the cork or rubber stopper. It needs to be airtight.
4. Use the air pump to pump air into the bottle, increasing the pressure inside.
5. After pumping for a few seconds, quickly remove the cork or stopper to release the pressure.

6. Observe the bottle. A cloud should form briefly inside the bottle.

Scientific Explanation:

This experiment demonstrates how clouds form in the atmosphere. When you pump air into the bottle, you increase the pressure inside, which also increases the temperature. When you release the pressure suddenly, the air inside the bottle expands and cools rapidly. This rapid cooling causes the water vapor (or alcohol vapor) to condense into tiny droplets around condensation nuclei (e.g., dust particles or alcohol molecules), forming a cloud.

Troubleshooting:

- Ensure the bottle is sealed tightly to prevent air leaks.
- Pump enough air into the bottle to increase the pressure significantly.
- If a cloud doesn't form, try adding more water or alcohol to the bottle.

Further Exploration:

- Investigate the role of condensation nuclei in cloud formation.
- Research different types of clouds and how they form in the atmosphere.

Safety Precautions:

- Be careful when releasing the pressure, as the cork or stopper may pop out forcefully.
- Adult supervision is recommended.

Summary

This guide provides a range of advanced science experiments suitable for older students to conduct at home. Each experiment is designed to be engaging, educational, and safe, promoting hands-on learning and a deeper understanding of scientific principles. Encourage students to explore, experiment, and discover the wonders of science!