Acetylene Gas Lab Grades 6-12

Introduction to Calcium Carbide and Water Reaction:
In the early 20th century, before the widespread use of electric headlights, automobiles relied on acetylene gas to power their headlights. This gas was produced through a chemical reaction between calcium carbide (CaC_2) and water (H_2O). The reaction, which produces acetylene gas (C_2H_2), is highly exothermic and generates enough energy to create a bright flame.

The chemical reaction that occurs is:

$$\mathrm{CaC_2} + 2H_2O \rightarrow \mathrm{C_2H_2} + \mathrm{Ca(OH)_2}$$

When water is added to calcium carbide, acetylene gas is produced, which is highly flammable and burns with a bright, white light. This light was used in early automobile headlights before electric bulbs were developed. The system typically consisted of a carbide generator that contained calcium carbide, and when water was added, it produced acetylene gas, which was then ignited to provide the necessary illumination.
This reaction is a key example of how chemistry was harnessed for practical, everyday uses in the past, specifically in automotive lighting. Through this lab, we'll explore how the reaction between water and calcium carbide can be used to produce acetylene gas, providing insight into the technology that powered early vehicle headlights.

Creating a flame from water and calcium carbide can create a dangerous chemical reaction, so it should only be performed in a controlled, well-equipped laboratory with proper safety protocols in place. If you're working in a chemistry lab, it's crucial to have guidance from a trained professional, like a chemistry teacher or lab technician, and to use appropriate safety equipment.

Next Generation Science Standards:

MS-PS1-3: Gather and synthesize information to describe that synthetic materials come from natural resources and impact society.
MS-PS1-5: Conduct an investigation to provide evidence that the change in the temperature of a substance depends on the type and amount of substance.
HS-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.
HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another.
HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, such as cost, safety, reliability, and aesthetics.

Materials:

1. Calcium carbide (CaC_2) – Ensure you have a small, controlled amount (a few grams).
2. Water (H_2O) – A small amount for the reaction.
3. Beaker or reaction vessel – To contain the reaction safely.
4. Rubber stopper or stopper with tubing – To direct the gas produced into a safer area.
5. Flint Striker – To ignite the acetylene gas (a bigger flame source is not needed, use a flint lighter as opposed to a match or bunsen burner).
6. Safety equipment – Goggles, gloves, lab coat, fume hood, eyewash station, fire blanket and extinguisher.
7. Calcium hydroxide ($Ca(OH)_2$) – As the byproduct of the reaction.

Reaction:

- Acetylene (C_2H_2) is a highly flammable gas that burns with a bright flame.
- Calcium hydroxide ($Ca(OH)_2$) is left behind as a solid byproduct.

Procedure:

1. Safety first: Before starting the experiment, make sure you're wearing proper safety gear (goggles, gloves, lab coat) and are in a well-ventilated area or under a fume hood. Calcium carbide should be handled with care, as it can react with moisture in the air.
2. Prepare the reaction vessel: In a small, heat-resistant container (such as a beaker), place a small amount (a few grams) of calcium carbide. The reaction doesn't require much calcium carbide to generate a flame.
3. Set up the gas collection system: Place the beaker inside a fume hood, and connect a rubber stopper or tubing to the top of the container. This allows any acetylene gas generated to be safely directed to another area (such as an open space, not confined, as acetylene is flammable).
4. Add water: Carefully add a small amount of water to the calcium carbide in the beaker. The reaction will immediately start producing acetylene gas and heat. This will occur rapidly, so don't add too much water at once. Acetylene gas will bubble up through the tube.
5. Ignite the gas: Once the acetylene gas starts bubbling through the tube, strike the flint lighter near the open end of the tube or gas outlet. The acetylene gas will ignite, creating a flame.

Safety Precautions:

- Do not over-pressurize: Make sure the reaction vessel has proper ventilation, as the acetylene gas can build up pressure. Never seal the vessel tightly unless there's an outlet for the gas.
- Flame safety: The flame produced by acetylene is extremely hot and can be dangerous if not handled properly.
- Environmental precautions: Make sure the acetylene does not accumulate in an enclosed area, as it could ignite or explode.

After the Reaction:

Once the reaction is complete and the gas has been consumed, you'll be left with calcium hydroxide, which is a white, powdery solid. Make sure to clean up the equipment properly, as calcium hydroxide is caustic and can cause irritation.

Post-Lab Questions:

1. **Reaction Mechanism:**
   What are the key steps in the reaction between calcium carbide and water that lead to the formation of acetylene gas? Describe the chemical equation and the intermediate steps involved.
2. **Energy Considerations:**
   The reaction between calcium carbide and water is highly exothermic. How does the release of energy influence the reaction, and why is it important for the generation of light in early automobile headlights?
3. **Safety Protocols:**
   Why is it crucial to follow safety protocols when handling calcium carbide and performing this experiment? What could happen if the reaction was not conducted in a controlled environment (such as in a fume hood or with proper ventilation)?
4. **Acetylene Gas Properties:**
   Acetylene is a highly flammable gas. How do the properties of acetylene make it suitable for use in headlights, and why is it no longer used in modern automotive lighting?
5. **Waste Management:**
   After the reaction, calcium hydroxide is produced as a byproduct. How should calcium hydroxide be handled and disposed of to avoid harm or contamination? What are the risks associated with improperly handling this byproduct?
6. **Practical Applications of the Reaction:**
   The reaction between calcium carbide and water powered early automobile headlights. How did this technological innovation impact the development of automobiles and road safety in the early 20th century?
7. **Controlled Reactions:**
   The reaction can become dangerous if over-pressurized or improperly controlled. What factors could lead to an unsafe buildup of pressure in the reaction vessel, and how can these risks be minimized?
8. **Comparison to Modern Lighting:**
   Compare the acetylene lighting used in early automobiles to modern-day headlights that rely on electric bulbs. How have advancements in lighting technology changed the way we use energy and lighting in vehicles?

Bring this lesson to the museum!

Help students connect their learning to real-world contexts by exploring these related vehicles on display at Klairmont Kollections:

- 1909 Hubmobile Model 20
- 1912 Little Roadster
- 1914 Ford Model T Touring