STANDARD OPERATING PROCEDURE:

Demonstrating the flame test using a PET bottle

Note: To be undertaken only by trained personnel in conjunction with a current Safety Data Sheet (SDS) and site-specific risk assessment.

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1. Introduction

A flame test is a routine practical performed across various year levels and areas of science. It demonstrates the specific emission spectrum of a variety of cations. A sample of a cation is introduced into the blue flame of a Bunsen burner and the flame is then observed for any colour change. The flame test identifies a cation by the characteristic colour that it turns the flame of a Bunsen burner.

The emission spectrum of an element is the colour emitted when the heat of the Bunsen flame causes its electrons to absorb energy from the flame and make a transition from a low-energy state to a high-energy state. As these excited electrons then naturally fall back to their low energy state, they emit energy in the form of a particle of light called a *photon*. The colour of the light produced in the flame is determined by the energy of the emitted photon and displays a characteristic wavelength[1]. Each substance has a specific emission spectrum based on their different electron configuration, which allows them to be differentiated from each other.

There have been a number of versions of doing this over the years, from using wire loops, to soaking toothpicks (or similar) in various solutions or solid chemicals, to spraying cation solutions directly into a Bunsen flame. We advise against methods using flammable liquids[2].

Here we describe a method of spraying a cation solution into a Bunsen flame utilising a 2 L PET bottle. The advantage of this method is that the majority of the sprayed cation solution (many of which are hazardous and/or toxic) is contained within the set-up, minimising the spread and inhalation of aerosols in the laboratory environment. This method also allows for the containment and collection of any over spray that can be collected and reused. It also produces a longer lasting colour in the flame for observation with the naked eye or with a spectroscope.

2. Context

- Part A is the method for the construction of the setup for the technician.
- Part B is for the operation of the setup in the classroom to be supervised by experienced teachers and technicians. It can be set up for a teacher/technician demonstration or as stations around the room for students to rotate around

3. Safety notes

Construction

- When using a cutting blade/knife to cut the PET bottle use caution as the knife can slice through quickly once it has started and may not follow the desired path. Ensure that the direction of the knife is away from the person or fingers. Scissors can be used instead once the initial cut has been made.

- Ensure that the bottle is held fairly securely, e.g. tape to a cutting board when drilling the holes as the drill bit may slide off the bottle particularly if the bottle moves.
- Use a drill bit that is smaller than the hole required and then it is easy to enlarge the hole by holding the drill bit in the hole and using the side of the bit to gradually increase it to the required size.
- Label the spray bottle and PET bottle with the cation being tested. Keep them as a pair to avoid the risk of any cross contamination from the other cations interfering with the flame colour.

Classroom

- Ensure that the bottle is held securely with a retort stand and clamp when in use to prevent it from falling over.
- Ensure that the work area around the Bunsen burner is clear of combustible materials.
- Students should be closely supervised when carrying out this activity and appropriate facilities should be available i.e. running water, adequate ventilation and eyewash station.
- Provide relevant Personal Protective Equipment (PPE), i.e. safety glasses.
- Avoid contact with skin and eyes, and avoid breathing in any of the spray.
- For safety, first aid, accident and spill procedures refer to the SDS for each chemical being tested. In all cases, if the chemical gets into the eye, rinse well with water for at least 15 minutes.
- Ensure everybody is aware of when the Bunsen burner is alight as it will be on the blue flame rather than the safety yellow flame.
- Wash hands with soap and water at the completion of the activity

4. Regulations, licences and permits

- Not applicable

5. Equipment

- Bunsen burner (with sufficient length of tubing to comfortably reach the gas tap)
- 15 cm piece of wire (to enable adjustment of the collar of the Bunsen burner from a safety flame to a blue flame once it is in position within the PET bottle)
- 2 L PET bottle (remove original labels and replace with appropriate chemical information)
- 500 mL garden spray bottle with a round nozzle (labelled with the appropriate chemical information)
- 2 cm of plastic tubing (to fit over the nozzle of the spray bottle to allow it to fit into the hole of the PET bottle)
- Piece of copper pipe lagging or silicone bakeware (to wrap around the barrel of the Bunsen burner to allow it to fit snuggly into the neck of the PET bottle)
- Cutting blade/knife such as a box cutter or Stanley knife (to cut an opening in the bottle to fit a Bunsen burner through), scissors can be used after initial cut.
- Electric drill with approximately 10 mm bit (to drill holes in the PET bottle for the Bunsen burner tubing and spray bottle connection)
- Retort stand, boss head and clamp.
- Marking pen
- 1M cation solutions (chloride salts are best) made up with distilled or deionised water
- Heat resistant tape
- Spectroscope (optional)
- PPE: Gloves for cleaning up

6. Operating procedure

See diagram below for a visual of the end product.

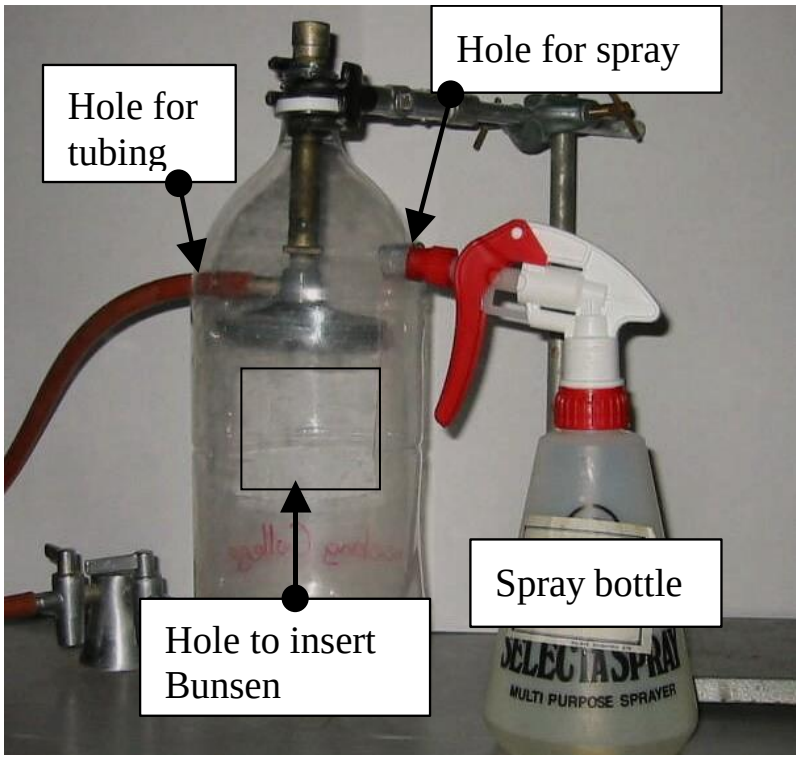
Part A: construction

1. Mark and cut an opening in the PET bottle – about 7 x 6 cm and 10 cm from the bottom of the bottle.
2. Place the garden spray bottle beside the drink bottle.
3. Mark and drill (or cut) a hole at the height of the spray bottle nozzle in the PET bottle to connect the spray bottle nozzle. The hole should be made on the RHS of the Bunsen insertion hole when it is facing you. Attach a short 2 cm piece of plastic tubing that fits on the nozzle as a connector. (NB: do not use a longer piece of connection tubing, as it will interfere with the spray and produce a stream rather than a mist which will not enter the Bunsen flame.)
4. Mark and drill (or cut) a hole opposite the one made for the spray bottle so the Bunsen tubing can be inserted. This should be at a height so the level of the spray bottle nozzle is at the same level as the air intake of the Bunsen burner.
5. Wrap some packing (lagging from copper hot water pipes or some silicon from bakeware) around the barrel of the Bunsen burner and tape it into position.
6. Push the Bunsen burner tubing through the small hole and attach it to the Bunsen burner. Push the Bunsen through the rectangular hole and poke the barrel into the neck of the bottle. Check that the Bunsen holds steady, if not add more lagging or tape.
7. Label the PET bottle and spray bottle with the particular cation being tested. Keep them as a pair.
8. Repeat steps 1–8 for the number of sets required (this is based on the number of cations being tested plus one for an unknown).
9. Fill the spray bottle with 200 mL of the labelled aqueous solution. Use 1M solutions of chloride salts made up with deionised or distilled water.

Part B: Set up and operation in the laboratory

1. Set up a retort stand and clamp the neck of the PET bottle to hold it and the Bunsen assembly stable.
2. Adjust the spray of the matching spray bottle to a fine mist, and attach it to the corresponding hole of the PET bottle with the 2 cm plastic tubing connector piece. Keep this tubing to the smallest length possible or the mist spray may catch it and come through as a stream not a mist.
3. Adjust the air intake valve of the Bunsen with the wire (if necessary) to the fully open position to obtain a blue flame. Connect the tubing to the gas supply and light the flame.
4. Squeeze the trigger of the spray bottle once or twice allowing the fine mist to enter the air intake hole of the Bunsen. The flame will display the corresponding colour for the cation for about 10–20 seconds. This is long enough for students to use spectroscopes to observe the emission. Dim the lights in the laboratory for a clearer result.
5. When the activity is complete, any over spray that is contained in the PET bottle, can be collected and poured back into the spray bottle to be reused.
6. Rinse the PET bottle with tap water. The washings can be emptied down the sink, as only trace amounts of the salts are present. Include rinsing the air intake and gas jet of the Bunsen burner in this process to prevent clogging up of the gas jet.
7. It is also recommended to remove and rinse the spray mechanism from the spray bottle to avoid blockages prior to storage.

Image of the finished product showing the location of the holes to insert the Bunsen and its tubing and the plastic tubing connecting the spray bottle. (Image courtesy of Dale Carroll)



To watch a video demonstrating the set-up in operation see:

'Demonstrating metal ion flame tests using a PET bottle laboratory rig', YouTube (7:26 min) https://youtu.be/kzWbIcpZUi8

There are many cations that can be tested. The following list is a suggestion. Chloride salts are generally used. Permanganates, nitrates and chlorates should be avoided due to hazardous products when burned[3]. All solutions are made with distilled or deionised water to reduce any contamination.

Table of colours for chemicals[1]

Dominant colour	Approximate wavelength (in nm*)	Compound
Red	701	Lithium chloride (LiCl)
Crimson-Red	700	Strontium chloride ($SrCl_2$)
Orange	609	Calcium chloride ($CaCl_2$)
Orange-Yellow	597	Sodium chloride (NaCl)
Yellow-Green	577	Barium chloride ($BaCl_2$)
Green-Blue	492	Copper chloride ($CuCl_2$)
Violet	423	Potassium chloride (KCl)

***Wavelength values here are given for the mid-range of the colour indicated.

7. Trouble shooting/emergencies

First aid: See latest SDS for more detailed information on chemicals used

- **If swallowed:** Do not induce vomiting. Rinse mouth with water, and then give water to drink. Seek medical attention if symptoms persist
- **If in eyes:** Hold open and irrigate with a copious quantity of water for at least 15 minutes. Seek medical attention if symptoms persist
- **If on skin/clothes:** Wash affected area with copious quantities of water immediately. Remove contaminated clothes and wash before reuse. If swelling, redness, blistering or irritation occurs seek medical attention.
- **If inhaled:** Remove to fresh air and seek medical attention if symptoms persist.
- **If toxic to the environment:** Avoid release to the environment.
- For further advice contact the Poisons Information Centre on 131126
- **For burns**: In the event of a burn, hold the burnt area under cold running water for 20 minutes.

Any health concerns should be referred to the school first aid officer for assessment, accompanied by the relevant latest SDS if applicable. Follow your school's accident and incident policy and reporting procedures.

Set up:

- Check that the nozzle of the spray bottle is not blocked. It is best removed and cleaned at the end of each activity.
- Make sure that the plastic tubing connecting the spray bottle to the PET bottle is not too long, as the spray needs to be a 'mist' going into the PET bottle and not a stream.
- Cleaning of the Bunsen burner is recommended at the end of the activity to prevent it from becoming blocked. Periodic, thorough cleaning may be required.

Limitations of flame tests[4,5]

- They are a qualitative, not a quantitative technique. They only detect the presence of a certain element and not how much is present.
- They cannot detect low concentrations of most ions.
- Contaminating substances can mask the flame colour and affect the results.
- Sodium is a common contaminant and its orange-yellow spectrum can dominate over others. Looking through blue glass can filter out this impurity.
- The test cannot differentiate all elements. Some can produce the same colour in the flame and some will not change the colour of the flame.
- Accuracy can be improved by viewing though a spectroscope.
- The colour of the flame is subjective.

8. Waste disposal

- Any unused chemical contained within the set-up can be returned to the spray bottle for future use. The water used to rinse the bottle at the completion can be washed down the sink with water, as it will only contain trace amounts of the salts tested.

9. Related material

- A site specific Risk Assessment should be conducted.

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[2] 'Safety Alert Rainbow Demonstration' American Chemical Society website. https://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/safety-alert-rainbow-demonstration.html (Accessed June 2016)

[3]'Flame tests using metal salts', LearnChemistry, Royal Society of Chemistry website, http://www.rsc.org/learn-chemistry/resource/res00001875/flame-tests-using-metal-salts?cmpid=CMP00004546 (Accessed May 2016)

[4]'Chemistry tutorial: Flame tests', Aus-e-tute website, http://www.ausetute.com.au/flametest.html (Accessed May 2009)

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