Part A: Using the Bunsen Burner

Background Information:
One of the most efficient ways to heat materials in a lab is to use a Bunsen burner. While designs may vary, in every Bunsen burner, the burner functions by the combustion of a mixture of air and gas. In most burners, the amounts of air and of gas can be controlled. In some situations portable burners are used instead of Bunsen burners. Electric hot plates may be used as well.

Purpose: In this investigation, you will learn the parts of the Bunsen burner and their functions. You will also learn how to use the burner safely in the laboratory.

Materials: Bunsen burner, striker/match, safety goggles

Procedure:
1. Put on safety goggles. Examine your burner when it is not connected to the gas outlet. Locate the parts shown in Figure 1, think about their functions. Figure 1: The Lab Burners

   Parts of the Bunsen burner:
   a. The barrel (burner tube) is the area where the air and gas mix.
   b. The collar (where the air vent is) can be turned to adjust the intake of air. If you turn the collar so that the holes are larger, more air will be drawn into the barrel.
   c. The air vent openings are the holes in the collar through which the air is drawn.
   d. The base supports the burner so that it does not tip over.
   e. The gas intake tube brings the supply of gas from the outlet to the burner.
   f. The spud is the small opening through which the gas flows. The small opening causes the gas to enter the barrel with great speed.

2. Adjust the collar so that the air intake openings are half-open. If using a lighted match hold it about 2cm above and just to the right of the barrel. Hold the match in this position while you open the gas valve slowly until it is fully open. The burner can be turned off by using the valve. Do not lean over the burner when lighting it. (note: if the gas seems to blow out the flame, close the air intake...light the flame, then readjust the air intake to get a proper flame).

3. Adjust the collar so that the flame is blue and a pale blue inner cone is visible.
   - A burner flame is the site of complex mixture of chemical events. For the present, you should know:
   1. hottest point in the flame (outer core)
   2. zone composed of unburned gas and air (base core)
   3. zone of burning gasses
   4. zone of partially burned, still hot, gases (inner core)

4. Adjust the flow of gas until the flame is about 6 cm high. Some burners have a valve in the base to regulate the flow of gas, (if no valve is present the flow of gas can be adjusted at the gas outlet valve.) - Again, the flame should be a blue color. Occasionally you will need to use a yellow flame. This is produced by shutting off most of the air supply. With little air in the fuel mixture, the gas burns incompletely. Unburned carbon in the flame glows to produce the yellow color. This type of flame deposits soot on objects placed in it. Do not use a yellow flame unless instructed to do so.

5. After adjusting the flow of gas, shut off the burner and answer Part A Questions on your Report Sheet. Leave your safety goggles on as you proceed with part B.
Part B: Flame Tests

Purpose: To be able to observe the colors emitted by the metallic ions when heated or subjected to flame and understand that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Plank’s relationship (E=hν).

Background: Just like a fingerprint is unique to each person, the color of light emitted by an element heated in a flame is also unique to each element. When a substance is heated in a flame, the atoms absorb energy from the flame. This absorbed energy allows the electrons to be promoted to excited energy, or higher, levels. From these excited energy levels, there is a natural tendency for the electrons to make a transition or drop back down to the ground state or lowest energy level. When an electron make a transition from a higher energy level to a lower energy level, a particle of light called a photon is emitted (see figure 1). Both the absorption and emission of energy are quantized- only certain energy levels are allowed.

An electron may drop all the way back down to the ground state in a single step emitting a photon in the process. Alternatively, an electron may drop back down to the ground state in a series of smaller steps, emitting a photon with each step. In each case, the energy of each emitted photon is equal to the difference in the energy between the excited state and the state to which the electron relaxes. The energy of the emitted photon determines the color of light observed and is unique due to element having a unique outermost shell of electrons. It is show with the following

Equation 1:

$$\Delta E = \frac{hc}{\lambda}$$

ΔE is the difference in the energy between the two energy levels, measured in joules (J)
h is Planck’s constant (h=6.626×10^{-34}J•sec)
c is the speed of light (c =2.998×10^8m/sec)
λ (lambda) is the wavelength of light in meters. The wavelength of visible light are given in units of nanometers (1nm = 10^{-9}m or 1m = 10^9nm) See table 1.

The color of light observed when a substance is heated in a flame varies from one substance to another. Because each element has a different spacing of electron energy levels, the possible transitions for a given substance are unique. Therefore, the difference in energy between energy levels, the exact energy of the emitted photon, and the corresponding wavelength and color are unique to each substance. As a result, the colors observed when a substance is heated in a flame may be used as a means of identification.

The visible portion of the electromagnetic spectrum:
Visible light is a form of electromagnetic radiation. Together with all other forms (like X-rays, UV radiation, radio waves, etc) make up the electromagnetic spectrum.

The visible spectrum spans from light with wavelengths from 400 to 700nm. (see figure 2). According to the equation for ΔE, wavelength is inversely proportional to energy, so violet light is higher in energy than red light.
Table 1 lists the wavelengths associated with each of the colors of light in the visible spectrum. The representative wavelengths may be used as a benchmark for each color. For example, instead of referring to green light as the wavelength range 500-560nm, we may approximate the wavelength of green light as 520nm.

<table>
<thead>
<tr>
<th>Representative Wavelength, nm</th>
<th>Wavelength Region, nm</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>410</td>
<td>400-425</td>
<td>Violet</td>
</tr>
<tr>
<td>470</td>
<td>425-480</td>
<td>Blue</td>
</tr>
<tr>
<td>490</td>
<td>480-500</td>
<td>Blue-green</td>
</tr>
<tr>
<td>520</td>
<td>500-560</td>
<td>Green</td>
</tr>
<tr>
<td>565</td>
<td>560-580</td>
<td>Yellow-green</td>
</tr>
<tr>
<td>580</td>
<td>580-585</td>
<td>Yellow</td>
</tr>
<tr>
<td>600</td>
<td>585-650</td>
<td>Orange</td>
</tr>
<tr>
<td>650</td>
<td>650-700</td>
<td>Red</td>
</tr>
</tbody>
</table>

Material:
- Crystals of calcium chloride, CaCl₂
- Copper (II) chloride, CuCl₂
- Lithium chloride, LiCl
- Potassium chloride, KCl
- Sodium chloride, NaCl
- Strontium chloride, SrCl₂
- Barium chloride, BaCl₂
- Unknown metal

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Safety Precautions:
Copper (II) Chloride is highly toxic if ingested; avoid contact with eyes and skin. Lithium chloride is moderately toxic by ingestion and is a body tissue irritant. Fully extinguish the wooden spints or q-tips by immersing them in a beaker of water before discarding them in the trash to avoid trashcan fires. Wear chemical splash goggles and tie back long hair (and wear chemical resistant apron and gloves if possible).

Procedures:
1. Fill a beaker with 25-50ml of distilled water to dip wood splints or q-tips into before burning.
2. Obtain 8 wooden splints or q-tips (either can be used). If using wood splints, they need to be soaked in a beaker of distilled water. If using q-tips, make sure to dip the end in distilled water before dipping in crystal chemical and putting in the flame. Careful not to contaminate anything.
3. Fill a beaker (150-250ml) about half-full of tap water. Label this beaker “rinse water” and use to dip wood splints or q-tips in after burning.
4. Locate the samples of Ca, Cu, Li, Na, K, Sr, and unknown A and B (only if instructed, fill a labeled spot place with a very small amount of each)
5. Light the Bunsen burner. Be careful that the burner is not pointed at anything or anyone.
6. To test liquid samples: Dip the end of the dry q-tip directly in the liquid metal chloride sample.
   To test crystal samples: Dip the end of the q-tip or wood splint in the distilled water and then touch the soaked end to the surface of one of the metal chlorides so that a few crystals of the metal stick to the end. Do NOT overuse the samples, as only a few crystals are needed for the test so only the very tip of the stick needs to get a few crystals stuck to it.
7. Immediately place the end with the metal sample in the flame. Watch carefully for any color change (colors may flash in and out). Hold in flame for 30 sec to 1 min, but take out when q-tip starts to blacken. Observe and record the floor of the flame in the Data Table. Allow the splint to burn until the color fades. Try not to allow any of the solid to fall into the barrel of the burner or the burner will be contaminated for later trials.
8. Immerse the wood splint or q-tip in the “rinse water” to extinguish it, then discard it in the trash.
9. Be sure to record your observations before moving on. Use the color option in table 1 above to guide you in determining colors. Picking from those options will help later.
10. Repeat steps 6-9 for the other 5 metal chlorides, using a new stick each time. Record your observations.
11. If available, cobalt glass can be used to view the flame and it will filter out any the color caused by sodium, however, as sodium is a constant in all samples, its affect is negated so colbalt is not necessary.

12. Perform a flame test on the unknown metal chlorides and record its characteristic color(s) and probable identity of the unknown in the Data Table. Keep in mind that it does not mater if the sample is a liquid or solid, as it could match any of the previous solids or liquids and could contain one or more elements. Be sure to record which unknown you tested (A or B) as there may be more that one unknown.

Disposal and Clean up:
1. All used sticks/q-tips can be thrown away after being fully extinguished and checked to make sure they are no longer hot.
2. All equipment and samples should be returned to their proper location and each lab station should look how it did before the lab started.
3. Do NOT leave your station before the instructor had checked to make sure the area is cleaned up properly.
4. Wash your hands after completing the lab.

Post Data Procedures:
After you have cleaned up, use the post lab procedures on your lab report to fill in the Results Table with the wavelength and calculated energy emitted by each element. You will need to use the information provided in the background. Answer all analysis questions.
Flame Test Lab: Report Sheet

Purpose: (for part B):

Hypothesis: predict what you will find when putting different chemicals in the flame in part B

Pre-lab questions:
1. What lab safety precautions should you take when using a Bunsen burner?

2. Fill in the blanks: When an atom absorbs energy, the electrons move from their ___________ state to an ___________ state. When atoms emit energy, the electrons move from an(n) ___________ state to their ___________ state and give off ___________.

3. Is the flame test raw data a quantitative or qualitative test for identifying an unknown element? Explain.

4. What part of a wave determines the color of light? ________________

Part A Questions:
1. What would happen if the air intake openings were made very small?

2. If the burner did not light even after the gas outlet valve was open, what might be wrong?

3. Where is the hottest part of the flame?

Part B: Data

Data Table

<table>
<thead>
<tr>
<th>Metal Ion</th>
<th>Color of Flame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
</tr>
<tr>
<td>Strontium</td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

Results Table

<table>
<thead>
<tr>
<th>Metal &amp; Flame Color</th>
<th>λ (nm) of representative wavelength</th>
<th>λ (m)</th>
<th>ΔE (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Li:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Na:</td>
<td></td>
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<td></td>
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<td>K:</td>
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<td></td>
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<tr>
<td>Sr:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Post Lab Procedures:
1. Use Table 1 in the Background section to record the approximate wavelengths of light emitted for each known metal ion in the Results Table. Be sure to reread any pertinent background information.

2. Convert each wavelength in the Results Table from nanometers to meters. Show one sample calculation in the space below and record all values in Results Table:
   HINT: 1nm=10^-9 m or 1m = 1000000000nm.
3. The characteristic color of the sodium flame is due to two closely-spaced energy transitions. Use equation 1 from the background section to calculate the average energy ($\Delta E$) corresponding to the observed flame color for the indicated metals. Show at least one sample calculation in the space below and record all values in joules in the Results Table. (all answers should be in scientific notation and have 2 sig figs)

Analysis Questions:
4. What metal ion(s) do you predict were present in unknown? Why?

5. Each of the known compounds tested contains chlorine, yet each compound produced a flame of a different color. Explain why this occurred.

6. Based on your calculations and knowledge of wavelength, what color of light emits the most energy? __________________Which emits the least energy? ___________

7. A glass rod was heated in a burner flame and gave off a yellow flame (possible yellow-orange looking). What metal ion predominated in the glass rod? __________________________

8. The alkali metals cesium (Cs) and rubidium (Rb) were discovered based on their characteristic flame colors. Cesium is named after the sky and rubidium after the gem, ruby. What colors of light do you think these metals give off when heated in a flame?

9. How is the atomic emission spectrum of an element related to these flame tests?

Conclusion: write a paragraph conclusion including:
- What was your hypothesis and was it correct?
- What you learned.
- Any possible sources of error?
- Like or dislikes/ improvements?