Lab 11. Atomic Structure and Electromagnetic Radiation: What Are the Identities of the Unknown Powders?

Introduction

According to our current theory about the structure of atoms, electrons are found around the nucleus in regions called orbitals (see Figure L11.1). Orbitals represent the potential position of an electron at any given point in time. Orbitals are located at different distances from the nucleus and have different energy levels associated with them. Each orbital, however, can only hold two electrons. The electrons of an atom fill low-energy orbitals, which are the ones closer to the nucleus, before they fill higher-energy ones.

Electrons are in a ground state when under stable conditions. When the electrons in an atom are bombarded with energy from an outside source, however, they absorb that energy and jump temporarily to a higher energy level. The electrons are said to be in an excited state when this happens. When those electrons release that energy, it is emitted in the form of electromagnetic radiation. If that electromagnetic radiation falls between 400 and 700 nanometers (nm) in wavelength, it is given off in the form of visible light.

Many common metal ions, such as Li+, Na+, K+, Ca2+, Ba2+, Sr2+, and Cu2+, produce a distinct color of visible light when they are heated. These ions emit a unique color of light because they consist of atoms that have a unique electron configuration. Chemists can therefore identify these elements with a flame test. To conduct a flame test, a clean wire loop or a wooden splint that has been soaked in distilled water is dipped into a powder or solution and then placed into the hottest portion of a flame (see Figure Lll.2).

The unique color that we observe during a flame test is actually mixture of several different wavelengths of visible light. Chemists can use a spectroscope to identify these various wavelengths. This technique is known as spectroscopy. A spectroscope splits light to form an emission line spectrum. The emission line spectrum for hydrogen is provided in Figure L11.3. The emission line spectrum for hydrogen consists of four different wavelengths of light (410 nm, 434 nm, 486 nm, and 656 nm). In this investigation, you will have an opportunity to conduct a flame test and use a spectroscope to identify four unknown powders.

FIGURE L11.1

Each of the three p orbitals (top row) and all three together on the same atom (bottom)

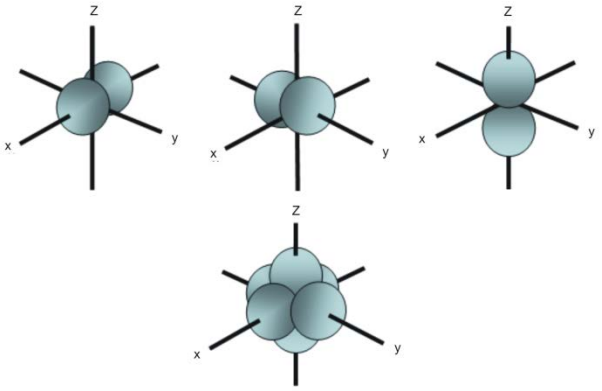


FIGURE L11.2

Flame test

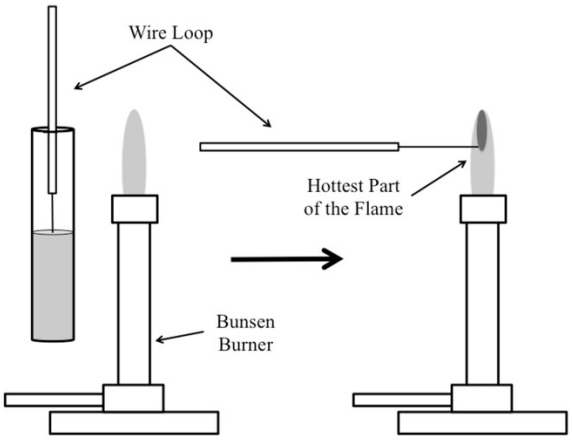
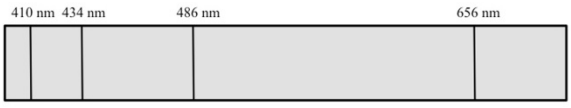


FIGURE L11.3

The hydrogen emission spectrum with wavelength labels



Your Task

Use a flame test and a spectroscope to determine the emission line spectrum of six different powders. Then determine the identity of four unknown powders using a flame test, a spectroscope, and the emission line spectra from the six known powders.

The guiding question of this investigation is, **What are the identities of the unknown powders?**

Materials

You may use any of the following materials during your investigation:

Consumables	**Equipment**
• Calcium chloride, $CaCl_2$ • Copper(II) chloride, $CuCl_2$ • Lithium chloride, LiCl • Potassium chloride, KCl • Sodium chloride, NaCl • Strontium chloride, $SrCl_2$ • 4 unknown powders	• Beakers • Bunsen burner • Wooden splints • Spectroscope

Safety Precautions

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Use caution when working with Bunsen burners. They can burn skin, and combustibles and flammables must be kept away from the open flame. If you have long hair, tie it back behind your head.
- Handle all glassware with care.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and conduct an investigation. To accomplish this task, you must determine what type of data you need to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about the following questions:

- How will you be able to identify a substance based on a flame test?
- What type of measurements or observations will you need to record during your investigation?

To determine *how you will collect the data*, think about the following questions:

- How often will you collect data and when will you do it?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data*, think about the following questions:

- What type of data table could you create to help make sense of your data?
- What types of calculations will you need to make?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

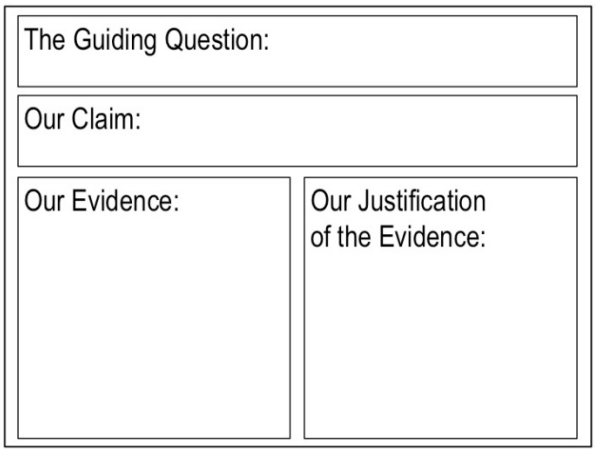
- the importance of identifying patterns,
- how system models contribute to understanding science,
- the difference between laws and theories in science, and
- the importance of imagination and creativity in your investigation.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure Lll.4.

FIGURE L11.4

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might therefore need to ask the presenter one or more follow-up questions, such as:

- How did your group collect the data? Why did you use that method?
- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- What did your group do to analyze the data, and why did you decide to do it that way?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!