Plasma Globe and Spectra

Part of a Series of Activities related to Plasmas for Middle Schools

Teacher’s Notes

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Preface

This activity, produced by the Contemporary Physics Education Project (CPEP), is intended for use in middle schools. CPEP is a non-profit organization of teachers, educators, and physicists which develops materials related to the current understanding of the nature of matter and energy, incorporating the major findings of the past three decades. CPEP also sponsors many workshops for teachers. See the homepage www.cpepphysics.org for more information on CPEP, its projects and the teaching materials available.

This activity packet consists of the student activity followed by notes for the teacher. The Teacher’s Notes include background information, equipment information, expected results, and answers to the questions that are asked in the student activity. The student activity is self-contained so that it can be copied and distributed to students. Page and figure numbers in the Teacher’s Notes are labeled with a T prefix, while there are no prefixes in the student activity.

The Student Section of this Activity is structured on the BSCS 5E model for Inquiry instruction.

The following description of the 5E model is excerpted from the Introduction to the BSCS text: BSCS Science: An Inquiry Approach

- **Engage**
- **Explore**
- **Explain**
- **Elaborate**
- **Evaluate**

According to the BSCS 5E model, each “E” represents an important part of the sequence through which students progress to develop their understanding. First, students are engaged by an event or a question related to a concept, and they have opportunities to express their current understanding. Then they participate in one or more activities to explore the concept and share ideas with others before beginning to construct an explanation. Following the initial development of an explanation, students have the opportunity to elaborate and deepen their understanding of the concept in a new situation. Finally, students evaluate their growing understanding of the concept before encountering a new one. The combination of the 5E model with a strong assessment-oriented design provides opportunities for learning and conceptual change in students, which leads to an improved understanding of science (Bransford, Brown, & Cocking, 2000).

National Standards addressed by this activity are included at the end of the Teacher’s Notes as Appendix 1.
Plasma Globe and Spectra

Teacher’s Notes

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Introduction:
This Activity has been developed to supplement the Contemporary Physics Education Project chart, *Fusion: Physics of a Fundamental Energy Source*. In the upper right hand corner of this chart there is a graph showing different types of plasmas. Plasmas are the foundation of this activity and through participation in this activity, students should gain a better understanding of plasmas, the atom, and light.

Materials:
Diffraction gratings, prism, colored lights or flashlights, plasma globes, discharge tube and gasses, colored pencils. Set of Duplo, Lego or other blocks. Alternately you or your students could make blocks by cutting cartons, such as milk cartons or by folding up old playing cards. The only requirement is to have square and rectangular blocks that can be put together to form short sets of steps of the same heights and of different heights.

Marbles (small marbles are better)

Engage:
A prism can separate white light into the colors of the rainbow. In the Engage part of this activity, students learn about aspects of color combinations and continuous (rainbow type) spectra.

1. Projectors (or colored flashlights) of primary colors can be used to see how color mixing produces new colors. Students should have access to the three primary colors of light: red, green and blue. Students should be able to mix any two or all three colors at once. It helps if the classroom is dark for this.

2. Students look at spectra from white light passed through a prism either individually or as a demonstration by the instructor. (note: glass prisms work better than plastic prisms and can be found inexpensively from numerous sources). Additionally, the instructor can discuss with the class rainbows. See Appendix 2 for a discussion of what causes rainbows.

Step 1 engages the students by looking at how the primary colors of light can be combined to make other colors and white light.

![Figure 1](image)
Step 2 then engages the students by looking at how light can be broken up into various colors. Figure 1 shows how the colors of light add to form new colors. Note that the way the colors combine is not the same as the way colors of paint would combine! Additionally, the primary colors of light (red, blue, green) are not the same as the primary colors of paint (red, yellow, blue).

In Step 3, students use diffraction gratings. These can be found in a variety of places. Many science education companies sell sheets of plastic that act as diffraction gratings which can be cut up into smaller pieces. One can also find ‘rainbow glasses’ that are cardboard glasses with diffraction grating plastic as the lenses.

3. Students are given diffraction gratings in a room with a variety of light sources including incandescent bulbs, fluorescent tubes, one or more compact fluorescent bulbs and a plasma globe. It will be easiest to view the spectra if only one light source is on at a time. Note the colors of the sources and then the patterns in the diffraction gratings. What are the similarities and differences between the color patterns from one light source to another? Are the patterns continuous or discrete? Note: The instructor will need to give directions on how to orient the grating and where to look.

**Explore:**

Students begin to build a model of how light patterns are characteristic of emission sources and can be used in identification.

1. Students are now given spectrum sketching templates and asked to draw the line patterns they see from a few spectrum tubes, including those of helium, mercury and argon. If available, krypton and xenon should be used. Also note the color they see for each tube without the diffraction grating.

2. They are asked to draw the line spectrum that they would expect to see if two of these gases were mixed together and excited to emit light.

Students are asked to make a prediction: “What do you think it would look like if two of the gases were mixed together?” While the answers will vary, some will hopefully predict that the result would look like a combination of the individual gases.

Plasmas globes contain several different gases and thus provide a good source for observing the combination of line spectra for a mixture of gases.

3. Students then observe a set of emission lines from a plasma globe and draw the line pattern that they see.

**Explain:**

In this section background is given so that students can begin to understand why they see line spectra. They first examine the spectra that is produced by the plasma globe and are then introduced to the atom. They are asked several questions as well:
Q: When looking at the plasma globe through the diffraction grating, do you see a rainbow like you would see if the light were white, or do you see line spectra?
A: They will likely see a rainbow but it will contain lines as well.

Q: Examine the lines that you drew after looking at the plasma globe. Can you use these lines to guess what gasses might be in the globe?
Q: Your teacher will show you some line spectra for some other gasses. Do these help you to identify the gasses in the plasma globe?
A: Is it possible that one or more gases in the plasma globe are not in the set of spectrum tubes they observed? Of course it is! After supplying a list of possible gases, have students visit a spectra identification site such as http://jersey.uoregon.edu/elements/Elements.html or http://chemistry.bd.psu.edu/jircitano/periodic4.html and try to identify the gases in each tube by comparison. There is a CPEP video of the spectra of all the gases that might be in a plasma globe (http://viewpure.com/329AOMqJSZk).

Students can make drawings from these and again attempt to identify the gases in a plasma globe. The type of gas in a plasma globe varies but Xenon seems to be the most commonly used commercially. Argon and Neon are also common. See: http://www.powerlabs.org/plasmaglobes.htm#GASES: for a lot of detail.

Possibly offer a prize for the person or group with the most correct. This also allows the opportunity to view a variety of spectral lines for tubes that may not be available.

Q: We say that the electrons have energy. Energy can be stored in different ways, and we give the different ways of storing energy different names. What are some of the names for different ways of storing energy that you can think of?
A: students will answer things such as kinetic (something is moving), energy from food, ‘heat’, etc.

Q: Why do you think that the line spectrum looks different for each type of gas?
A: Each atom has its own set of orbitals where the electrons can be. Since these orbitals differ for each atom, the line spectra will also differ for each atom.

Elaborate:

In this part of the activity students will use blocks to put together their own models of energy levels in atoms. These models will help them to better understand how electron transitions from higher energy levels to lower ones can produce the line spectra that they’ve seen in the previous parts.

To help them get started you should have made an example model that has the basic features that students will need to produce. However, your model will be too simple to represent the production of many different colors in atomic spectra. Your model will have two steps built from blocks, and each step will be of the same height. This model would suggest that only two
energy changes are possible with two energy levels (steps) above the lowest energy level (called
the ground level or the ground state). In reality there would be three different energy changes
possible for an electron that could start at one of the two energy levels above the ground state.
The reason for this is that electron energies don’t increase by the same amount from one energy
level to the next. The largest energy difference between neighboring energy levels is between
the ground state and the first energy level. The next largest is between the first and the second
energy levels. The energy differences continue to increase from level to level.

The basic model that you should build has two equal size steps. If Duplos are used, you won’t
need many blocks. With the usual size Lego blocks it will take a lot of blocks to make steps that
are height enough to be useful. The minimum required height is one from which a marble can
fall and produce an easily heard sound upon impact on a lower level.

The advantage of Legos is the number of colors available, but even Legos don’t normally include
all of the 7 basic colors of the spectrum. The reason that this matters is that it is useful in
keeping track of the energy differences to have the color for each line of the spectrum that would
be produced by an electron (marble in the model) dropping in energy from one step to another.
The color can be put as a vertical column from the top of the higher energy level or step to the
top of the lower energy level. With Legos this vertical column can be made from the Lego
blocks themselves, as indicated. With Dupos or blocks constructed in other ways, the blocks can
be covered in white paper, and colored markers can be used to draw in the colors.

Answers to Questions:

1. If you had a model with 3 steps above the base level, how many different energy changes
could your marble go through?
   
   A: Six – 1 to base, 2 to 1, 2 to base, 3 to 2, 3 to 1 and 3 to base.

2. We can only see light from red to violet or light made of mixtures of some of the colors
   from red to violet. But atoms can radiate something like light with less energy than red.
   This is known as “infrared” radiation. Some atoms can also radiate something like light
   with more energy than violet. This is known as “ultraviolet” radiation. How could you
   modify one of your step heights to have an energy difference that would model the
   production of infrared radiation? How could you make a step drop in your model that
   would model the production of ultraviolet radiation?
   
   A: Step heights that model the production of infrared radiation will be less than the
   smallest height you used for red. Step heights that model the production of ultraviolet
   radiation will be greater than the largest height you used for violet.

3. Your answer to number 1 suggests that the number of spectral lines for any atom that has
   many energy levels should be very large. Why don’t we see more than a few spectral
   lines for many atoms?
   
   A: Most of the possible energy changes that result in radiation from atoms will produce
   either infrared or ultraviolet radiation that can’t be seen with the unaided eye.
After students produced line drawings with arrows for energy changes:

Answers to Questions:

1. So far your models don’t say anything about the actual range of energies in visible light. In fact to make the physical models that you built work, we have to pretend that the energy range of visible light is a little bigger than it really is. The ratio of energy of the most energetic violet light to the least energetic red light is just under a factor of 2. Pick one of the shorter arrows in your drawing to represent the lowest energy red line. How many of the arrows that you drew are less than twice the length of this arrow? These would be the arrows for visible light.

   A: This will vary from drawing to drawing, but it will likely be in the range of 5 to 10 out of a possible 15.

2. How many of the arrows you drew are too short or too long to be for visible spectrum lines? How many would be in the infrared part of the spectrum? How many would be in the ultraviolet spectrum?

   A: Total that are too short of too long will be 15 minus the answer to #1. The next two answers depend on the particular drawing.

3. In real atoms the radiation emitted when an electron drops from the first step above the base step to the base is often not visible. Use your model to explain this.

   A: This is typically the biggest step or largest energy change, and the resulting radiation will be in the ultraviolet range.

4. What features of real atoms do your models get right?

   A: Only particular energy transitions are possible (as a marble can’t float between steps, electrons can’t have energies between energy levels). The larger the step size, the greater the energy change and the greater the energy of the light emitted. There is a lowest possible energy for the electron. Energy transitions can take place between the higher electron energies and many of the lower ones.

5. What features of real atoms do your models get wrong or not explain?

   A: In real atoms there are many more energy levels than can be indicated in either a physical model or a line model. The model is mostly one-dimensional, and atoms are three-dimensional. The physical model doesn’t explain the basis of the different energy levels or why the steps get smaller as they get farther from the base or lowest energy.
**Evaluate:**

In this part students compare their models to the ideas that atoms can undergo only definite changes in energy and that this results in line spectra of stimulated gases.

They will also compare their models to the understanding of how low energy light is emitted by phosphors that have absorbed higher energy light.

Students should then discuss how the results of this activity could be applied to determining the compositions of systems such as stars (including our sun) and nebulae, even though we can’t get instruments to these objects.

An additional discussion that could form the basis of a take-away, is to explore the discovery of helium.
APPENDIX 1
National Science Standards Addressed

NSS M.A. Science as Inquiry – Science as inquiry requires students to combine process and scientific knowledge with scientific reasoning and critical thinking to develop their understanding of science.

M. A. 1 (NS 5-8.1) As a result of activities in grades 5-8, all students should develop abilities necessary to do Scientific Inquiry.
   a. Identify questions that can be answered through scientific investigations.
   b. Design and conduct a scientific investigation.
   c. Use appropriate tools and techniques to gather, analyze, and interpret data.
   d. Develop descriptions, explanations, predictions, and models using evidence.
   e. Think critically and logically to make the relationships between evidence and explanations.
   f. Recognize and analyze alternative explanations and predictions.
   g. Communicate scientific procedures and explanations.
   h. Use mathematics in all aspects of scientific inquiry.

M. A. 2 (NS 5-8.1) As a result of activities in grades 5-8, all students should develop understandings about scientific inquiry.
   a. Different kinds of questions suggest different kinds of scientific investigations.
   b. Current scientific knowledge and understanding guide scientific investigations.
   c. Mathematics is important in all aspects of scientific inquiry.
   e. Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.

NSS M.B. Physical Science – Physical science focuses on science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use.

M. B. 3 (NS 5-8.2) As a result of activities in grades 5-8, all students should develop an understanding of the transfer of energy.
   a. Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical.
   b. Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).