



Name: \_\_\_\_\_

Date: \_\_\_\_\_

## Student Exploration: Bohr Model of Hydrogen

**Vocabulary:** absorption spectrum, Bohr model, electron volt, emission spectrum, energy level, ionization energy, laser, orbit, photon

*[Note to teachers and students: This Gizmo was designed as a follow-up to the Bohr Model: Introduction Gizmo. We recommend doing that activity before trying this one.]*

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. What happens to an electron when it absorbs a tiny packet of light called a **photon**?

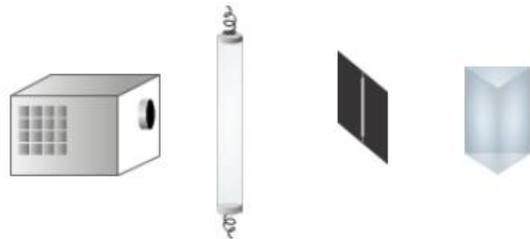
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2. What happens to an electron when it emits a photon? \_\_\_\_\_

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### Gizmo Warm-up

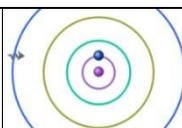
When white light is passed through hydrogen gas and separated by a prism, some wavelengths of light are absorbed by the hydrogen atoms in the gas. This causes black bars to appear in the **absorption spectrum** of hydrogen. An **emission spectrum** is created when hydrogen gas emits light.



The **Bohr model** of the atom was inspired by the spectrum produced by hydrogen gas. The link between light and atomic structure is illustrated by the *Bohr Model of Hydrogen* Gizmo. The Gizmo shows a **laser** pointed at a container of hydrogen gas. After passing through the gas, light from the laser goes through a prism and is detected on a screen.

1. With the **Laser energy** set to 7.0 eV, click **Play** (▶). Observe the blue electron on the ORBITS pane. Do 7.0-eV photons have any effect on the electron? \_\_\_\_\_
2. Click **Pause** (⏏). Set the **Laser energy** to 12.1 eV and click **Play**. What happens to the electron now? \_\_\_\_\_
3. Under **Go to energy level**, select **1**. Notice that a photon is emitted by the electron. What is the energy of the emitted photon? \_\_\_\_\_



<b>Activity A:</b> <b>The spectrum of hydrogen</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>Click <b>Reset</b> (↺).</li> </ul>	
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**Introduction:** The shorter the wavelength of a photon, the greater its energy. We can see photons with wavelengths between 700 nanometers (red) and 400 nanometers (violet), which correspond to energies of 1.8 to 3.1 **electron volts** (eV).

**Question: Which photon energies make up the spectrum of hydrogen?**

- Measure:** Set the **Laser energy** to 0.1 eV. Click **Play**, and slowly increase the energy in 0.1 eV increments so that the **Total absorption spectrum** is filled in. Stop moving the slider when the first photon is absorbed. (Hint: Be sure that *every* energy value is tried.)

  - What is the energy of the absorbed photon? \_\_\_\_\_
  - What effect does this photon have on the electron? \_\_\_\_\_
  - The absorbed photon moves the electron to a higher **orbit**, or **energy level**. Under **Go to energy level**, click **1**. What is the energy of the emitted photon? \_\_\_\_\_
- Measure:** Increase the **Laser energy** by 0.1 eV, and click **Play**. Continue to raise the **Laser energy** until the next photon is absorbed.

  - What is the energy of the absorbed photon? \_\_\_\_\_
  - On which energy level can you find the electron now? \_\_\_\_\_
  - Go back to energy level 1. What is the energy of the emitted photon? \_\_\_\_\_
- Measure:** Increase the **Laser energy** by 0.1 eV, and click **Play**. Use the Gizmo to find the energy of photons that move the electron from the first energy level up to the fourth, fifth, and sixth energy levels. (Remember to move the electron back to energy level 1 each time.)

  - What is the energy of a photon that moves the electron from energy level 1 to energy level 4? \_\_\_\_\_
  - What is the energy of a photon that moves the electron from energy level 1 to energy level 5? \_\_\_\_\_
  - What is the energy of a photon that moves the electron from energy level 1 to energy level 6? \_\_\_\_\_

**(Activity A continued on next page)**



**Activity A (continued from previous page)**

4. Make a rule: How does the energy needed to move an electron to a higher energy level compare to the energy emitted when the electron moves back to the lower energy level?

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5. Interpret: Look at the **Total absorption spectrum**. What do the black bars in the spectrum represent? \_\_\_\_\_

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6. Explore: Move the electron to energy level 1, set the **Laser energy** to 13.3 eV, and click **Play**. What happens? \_\_\_\_\_

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There are several energy levels for hydrogen that are not shown in this Gizmo. The electron is in one of these energy levels.

7. Explore: Under **Go to energy level**, select **6** and then **1**. Set the **Laser energy** to 13.6 eV, and click **Play**. What happens now? \_\_\_\_\_

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The **ionization energy**, or energy required to free the electron completely, is 13.6 eV for hydrogen.

8. Think and discuss: Do you think you have completed the spectrum of hydrogen? Explain.

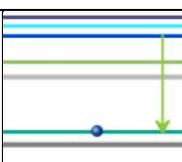
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<b>Activity B:</b> <b>Energy levels</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• If necessary, select energy level <b>6</b>.</li> <li>• Click <b>Reset</b>.</li> <li>• Select the <b>ENERGY LEVELS</b> tab.</li> </ul>	
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**Introduction:** When an electron absorbs a photon, it gains energy. The added energy causes the electron to move to an orbit that is farther from the nucleus. Because each possible orbit is associated with a particular amount of energy, orbits are known as energy levels.

By convention, an energy of 0 eV is assigned to the energy level that is infinitely far from the nucleus. (This is done so that atoms of different elements can be compared from a common starting point.) As a result of this convention, each energy level has a negative energy.

**Question: How do energy levels relate to the spectrum of hydrogen?**

1. List: Look at the graph of energy levels. List the energy of each level ( $n = 1, 2, 3$ , etc.).

n = 1: \_\_\_\_\_      n = 2: \_\_\_\_\_      n = 3: \_\_\_\_\_  
n = 4: \_\_\_\_\_      n = 5: \_\_\_\_\_      n = 6: \_\_\_\_\_

2. Predict: How much energy would an electron have to gain to move from energy level 2 to energy level 3? \_\_\_\_\_

3. Test: Under **Go to energy level**, select **2**. Set the **Laser energy** to the value you think is required to move the electron up to energy level 3, and press **Play**.

- A. What happens? \_\_\_\_\_
- B. What do you see on the **Total absorption spectrum**? \_\_\_\_\_  
\_\_\_\_\_
- C. What do you see on the **Visible absorption spectrum**? \_\_\_\_\_  
\_\_\_\_\_
- D. Select energy level 2. What is the energy of the emitted photon? \_\_\_\_\_

4. Make a rule: In general, how do you calculate the energy of a photon that is needed to move an electron between two energy levels? \_\_\_\_\_  
\_\_\_\_\_

**(Activity B continued on next page)**



**Activity B (continued from previous page)**

5. **Calculate:** Calculate the energy required to move the electron for each transition listed in the table below. Check your answers using the Gizmo.

Transition	Energy (eV)	Transition	Energy (eV)
n1 to n2		n2 to n6	
n1 to n3		n3 to n4	
n1 to n4		n3 to n5	
n1 to n5		n3 to n6	
n1 to n6		n4 to n5	
n2 to n3		n4 to n6	
n2 to n4		n5 to n6	
n2 to n5			

6. **Interpret:** We can see photons that are between 1.8 and 3.1 eV. Based on the table above, how many lines do you expect to appear in the visible absorption spectrum? \_\_\_\_\_

7. **Create:** Based on the table above, use the Gizmo to create the complete absorption spectrum of hydrogen.

When the spectrum is complete, click the **Screen shot** option on the **Tools** menu. Right click and choose "Copy," and then paste the image into a blank document. Label it with your name. You will turn in this document with this sheet.

8. **Explore:** Select the ORBITS tab. On the SIMULATION pane, select **Current**. In this mode, an electrical current passes through the hydrogen.

What is happening on the ORBITS pane? \_\_\_\_\_

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9. **Compare:** The emission of photons results in an emission spectrum. Click **Screen shot** and paste this image below the image of the absorption spectrum. How does the emission spectrum of hydrogen compare to its absorption spectrum?

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