

**Teacher’s Guide**

 **The Photoelectric Effect**

***February 2022***

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Activate students’ prior knowledge and engage them before they read the article.

[Reading Comprehension Questions](#_Student_Reading_Comprehension) 3

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer 5](#_Graphic_Organizer)

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 9](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

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# Anticipation Guide

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

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Einstein discovered the photoelectric effect.
 |
|  |  | 1. Electromagnetic radiation includes visible light as well as X-rays and radio waves.
 |
|  |  | 1. The color of light determines whether electrons will be knocked loose from a metal.
 |
|  |  | 1. Red light has more energy than blue light.
 |
|  |  | 1. If the minimum threshold frequency is reached, increasing the brightness of light will cause the dislodged electrons to move faster.
 |
|  |  | 1. The photoelectric effect led Einstein to develop the concept of photons.
 |
|  |  | 1. Photoelectric sensors must be in put in vacuum-sealed containers.
 |
|  |  | 1. Infrared radiation has lower energy than visible light.
 |
|  |  | 1. Night-vision goggles can work in complete darkness.
 |
|  |  | 1. The intensity of the light has no effect on the number of electrons emitted in the photoelectric effect.
 |

# Student ReadingComprehension Questions

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

**Directions**: Use the article to answer the questions below.

1. Explain how the photoelectric effect works.
2. What are photoelectrons?
3. What type of charge to electrons have?
4. Define frequency in terms of light.
5. Once the minimum threshold frequency is reached, if the frequency of light is increased, what happens to the number of electrons emitted?
6. What type of light is typically used in photoelectric sensors in automatic grocery store doors?
7. What must occur to remove an electron from an atom?
8. Explain how photoelectrons differ from other electrons.
9. Once the minimum threshold frequency is reached, if the frequency of light is increased, what happens to the movement of electrons?

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Explain how the structures in night vision goggles contribute to their function of helping someone see in low light.
2. When examining the electromagnetic spectrum, what is the relationship between energy and wavelength?
3. The article mentions that the photoelectrons come from the surface of a metal. Perform research to identify at least two metals that can be used to achieve the photoelectric effect.
4. Select a photoelectric technology that is not already explained in the article. Create a diagram to demonstrate your understanding of how the process works within that product.
5. Use your understanding of the photoelectric effect to propose a new use for the technology. Explain how an existing device or a new invention would incorporate the photoelectric effect.

# Graphic Organizer

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

**Directions**: As you read, complete the graphic organizer below to describe important terms related to the photoelectric effect.

|  |  |  |
| --- | --- | --- |
| **Term** | **Definition in your own words** | **Relationship to photoelectric effect** |
| **Frequency** |  |  |
| **Electromagnetic****Radiation** |  |  |
| **Photons** |  |  |
| **Night-vision goggles** |  |  |

**Summary:** On the back of this sheet, write a one-sentence summary (18 words or less) of the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **Explain how the photoelectric effect works.**

*The photoelectric effect is when electrons are released from the surface of a metal that is bombarded by light.*

1. **What are photoelectrons?**

*Photoelectrons are electrons that are released from a metal when its surface is bombarded by light.*

1. **What type of charge to electrons have?**

*Electrons have a negative charge.*

1. **Define frequency in terms of light.**

*Frequency is how frequently a wave is vibrating.*

1. **Once the minimum threshold frequency is reached, if the frequency of light is increased, what happens to the number of electrons emitted?**

*The number of electrons emitted stays the same.*

1. **What type of light is typically used in photoelectric sensors in automatic grocery store doors?**

*Invisible infrared radiation is typically used in photoelectric sensors in grocery store doors.*

1. **What must occur to remove an electron from an atom?**

*Energy must be applied to overcome the attraction between the protons and the electrons in the atom.*

1. **Explain how photoelectrons differ from other electrons.**

*Photoelectrons are different because they are released from the surface of a metal because of light, otherwise, they are identical to other electrons.*

1. **Once the minimum threshold frequency is reached, if the frequency of light is increased, what happens to the movement of electrons?**

*The electrons move faster because the energy of the light is changed to kinetic energy.*

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. **Explain how the structures in night vision goggles contribute to their function of helping someone see in low light.**

*Light hits a photocathode, which causes electrons to be released from the metal. Those electrons enter a photomultiplier which causes more electrons to be released. All of these photons then come into contact with a phosphor screen which excites them and causes them to emit visible light.*

1. **When examining the electromagnetic spectrum, what is the relationship between energy and wavelength?**

*Waves with shorter wavelengths have more energy.*

1. **The article mentions that the photoelectrons come from the surface of a metal. Perform research to identify at least two metals that can be used to achieve the photoelectric effect.**

*Student responses will vary but should list two metals that are used to elicit the photoelectric effect.*

1. **Select a photoelectric technology that is not already explained in the article. Create a diagram to demonstrate your understanding of how the process works within that product.**

*Student responses will vary but should exhibit an understanding of the photoelectric effect.*

1. **Use your understanding of the photoelectric effect to propose a new use for the technology. Explain how an existing device or a new invention would incorporate the photoelectric effect.**

*Student responses will vary but should exhibit an understanding of the photoelectric effect.*

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# Additional Resources

**Labs and demos**

[Demonstrate the Photoelectric Effect:](https://www.arborsci.com/blogs/cool/electroscope-photoelectric-effect) This video demonstrates the use of an electroscope in explaining the photoelectric effect.

**Simulations**

[Photoelectric Effect PhET](https://phet.colorado.edu/sims/cheerpj/photoelectric/latest/photoelectric.html?simulation=photoelectric): In this PhET simulation students are able to modify light intensity and various metals to study the photoelectric effect.

[Photoelectric Effect Gizmos](https://gizmos.explorelearning.com/index.cfm?method=cResource.dspDetail&resourceID=491): Students can use this online simulation to explore the photoelectric effect by adjusting both the type of metal and wavelength of light.

**Lessons and lesson plans**

[Introduction to PES](https://teachchemistry.org/classroom-resources/introduction-to-pes): This lesson can be used to help students learn how to interpret photoelectron spectroscopy spectra through using their knowledge of electron configurations, periodic trends, and Coulomb’s law.

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Electrons
* Electricity
* Electromagnetic spectrum

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

|  |
| --- |
| **HS-PS4-3.**  Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.  |

**Disciplinary Core Ideas:**

* PS.4.A: Wave Properties
* PS4.B: Electromagnetic Radiation

**Crosscutting Concepts:**

* Cause and effect
* Energy and matter
* Systems and System Models

**Science and Engineering Practices:**

* Constructing explanations and designing solutions

**Nature of Science:**

* Science models, laws, mechanisms, and theories explain natural phenomena.

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students how they think automatic sensors that open doors or turn on water faucets work. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
	+ As they read, students can find information to confirm or refute their original ideas.
	+ After they read, ask students what they learned about the photoelectric effect.
* After students have read and discussed the article, ask students how they will use the information from the article in the future.
	+ What other practical uses can they think of for the photoelectric effect besides those that were mentioned in the article?