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Modern
Photoelectric Effect Lab

Essential Questions
1. What happens if a material absorbs a photon?
2. Does the number of photons absorbed equal the number of photons emitted?
3. What does "certainty" mean on the atomic scale?
4. Does humankind benefit more from fission or fusion?

Enduring Understanding - Modern physics studies the smallest particles in nature in order to develop a deeper understanding of fundamental processes.

Background

Physics had explained all observable phenomena as of 1900 except for: blackbody radiation, photoelectric effect and atomic spectra. It was believed, once these were explained, the study of physics would be complete. This assumption was wrong and led to a new branch of physics known today as quantum mechanics.

Max Planck developed the idea that light was a packet of energy called a photon. His formula, **E = hf**, relates the energy of a photon to its frequency. The constant, "h", Planck's constant, is named in honor of Max Planck. Albert Einstein won the Nobel Prize in 1921 for his explanation of the photoelectric effect.

This card game will investigate the photoelectric effect. The photoelectric effect is the ejection of electrons from a metal when light of a certain frequency shines on its surface.

Keywords

Photon – A photon is a particle of light; a bundle of energy. Light is now considered to be a particle, not a wave. The energy of a photon is given by the equation **E = hf**.

- **E** is energy measured in either joules (J) or electron-volts (eV)
- **h** is Plank's constant and equals 6.63 X 10^{-34} Js or 4.14 X 10^{-15} eVs
- **f** is frequency

$$E = hf$$

Energy of a Photon

Work Function, W

The work function is the **MINIMUM** energy needed to eject an electron from an atom.

- Photons with energy less than the work function **DO NOT** eject electrons.
- Photons with energy greater than or equal to the work function **DO** eject electrons.

Photoelectric Effect Activity

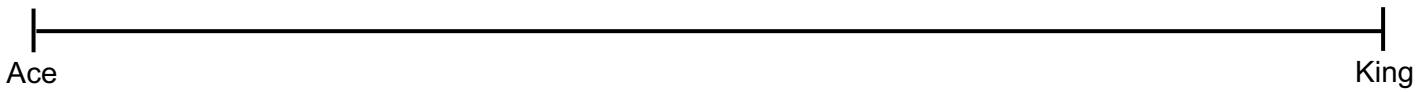
Part 1 – Cards are Energies - What ejects?

1. On a large piece of clean paper turned portrait, draw the nucleus of an atom along the bottom edge (short side).
2. Near the nucleus, about 10 cm above, draw a line parallel to the short side of the page and label it **work function**.
   - Label the area between the line and nucleus - "Does NOT eject"
   - Label the area between the line at top of the page – "Does eject"
3. Get 1 deck of cards from your teacher.
4. Shuffle the deck until the cards are mixed well.
5. Draw one card face up on top of the line labeled **work function**. Draw again if the card's a value is not between 6 and 10. The value of this card represents the **work function**.
6. Deal the remaining cards, one at a time face down, to each student.

Your **work function** card was **W** =_____

The face value of the players' cards represents the energy of photons. Aces are low; Kings are high.

7. Each player, one at a time, turns one of their cards over and places it in either the "Does NOT eject" or "Does eject area until all cards have been played.
8. Draw a card line (i.e. number line) and identify the positon of the work function. Color all energies/numbers that don't eject red and energies/number that do eject green. **DO NOT COLOR THE PLAYING CARDS.**



9. After completing your card line, call your teacher over for a follow up question(s).

Part 2 – Threshold Frequency

The threshold frequency is the **MINIMUM** frequency that will eject an electron. The relationship, **E = hf**, can be rewritten to calculate the threshold frequency. Recall the MINIMUM energy needed to eject an electron is called the **work function, W**. The previous **E = hf** equation can be rewrite as $\mathbf{W = hf_t}$

- **W** = work function
- **h** is Plank's constant and equals 6.63 X 10^{-34} Js or 4.14 X 10^{-15} eVs
- $\mathbf{f_t}$ = thresh old frequency

1. Calculate the following: (Recall *ace – 1 eV,2 = 2 eV, . . . 10 = 10 eV, jack = 11 eV, queen = 12 eV and king = 13 eV)*

A frequency that **does not** eject an electron using **E = hf**.	The threshold frequency of your atom using $\mathbf{W = hf_t}$.	A frequency that **does** eject an electron using **E = hf**.

2. Record your answers on your card line (i.e. number line) on the previous page.

Part 3 – Check Your Understanding.

1. In terms of energy, when will a photon eject an electron?

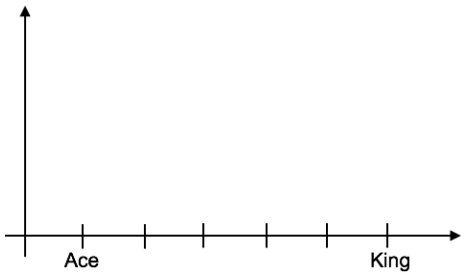
$$E \square W$$

2. In terms of frequency, when will a photon eject an electron?

$$f \square f_t$$

Part 4 – What do you think?

1. If a photon ejects an electron, what happens to the extra energy? For example, the work function is an eight, the photon is a king; what happens to the energy between the 8 and king? How would you graphically represent your answer?



2. What does the intensity of the photons effect? In other words, does how fast you played the Photoelectric Effect Activity effect how the electrons were ejected?

Part 5 – Ejection Battle

1. Shuffle the deck until the cards are mixed well.
2. Place one card face up on top of the line labeled **work function**. The card's value should be between 6 and 10.
3. Deal the remaining cards, one at a time face down, to each student.
4. All players at the same time play their top card.
   - If none of the cards played eject an electron, all the cards remain on the table.
   - If one or more cards played eject an electron, the player with the highest card takes all the cards on the table.
   - If there's a tie for highest card, the tying players will continue to turn cards over one at a time until there is one player with the highest card. The player with the highest card takes all the cards on the table.
5. Repeat step 4 until one player gathers all the cards.