5) When Light Of Frequency 5.4 X 10 Hz Is Incident Onemitted Electrons Is 1.2 X 1019J. Calculate Thea

5) When Light Of Frequency 5.4 X 10 Hz Is Incident Onemitted Electrons Is 1.2 X 10^19 J. Calculate Thea

Understanding the interaction between light and electrons is fundamental in quantum physics and has vast applications in modern technology. In this article, we will explore the problem involving incident light of a specific frequency and the resulting emitted electrons, guiding you through the necessary calculations to determine the work function (often denoted as 'Φ' or 'Thea' in some contexts). We’ll also delve into the physical principles behind photoelectric emission, the relevant formulas, and practical examples to clarify the concepts.

Introduction to the Photoelectric Effect

The photoelectric effect is a phenomenon where electrons are emitted from a material's surface when it is exposed to light of sufficient energy. Albert Einstein explained this effect in 1905, which played a crucial role in establishing quantum theory. The key points to understand about the photoelectric effect include:

- Electrons are emitted only if the incident photon energy exceeds the material's work function.
- The kinetic energy of emitted electrons depends on the incident light's frequency.
- The number of emitted electrons is proportional to the light's intensity, assuming the photon energy exceeds the work function.

Understanding the Key Concepts and Formulas

Before solving the problem, it’s essential to understand the fundamental formulas involved.

Photon Energy

The energy of a photon (E) is given by Planck’s equation:
\[E = h \times f \]
where:
- \(h \) is Planck's constant (\(6.626 \times 10^{-34} \, \text{Js} \))
- \(f \) is the frequency of the incident light

Photoelectric Equation

The maximum kinetic energy (\(KE_{max} \)) of emitted electrons is related to the photon energy and the work function (\(\Phi \) or 'Thea') by:
\[KE_{max} = E_{photon} - \Phi \]

If we know the total energy emitted as electrons, and the number of electrons, we can find the average kinetic energy per electron.

Analyzing the Given Data

From the problem statement:

- Incident light frequency, \(f = 5.4 \times 10^{14} \) Hz
- Total energy emitted as electrons, \(E_{total} = 1.2 \times 10^{19} \) Joules

Note: The frequency appears to be \(5.4 \times 10^{14} \) Hz, assuming a typo in the original problem statement, as \(5.4 \times 10^{10} \) Hz would be too low for typical photoelectric calculations, but the problem states \(5.4 \times 10 \) Hz, which is likely a typo. Based on context, proceeding with \(5.4 \times 10^{14} \) Hz, a common optical frequency.

Calculating the Energy of a Single Photon

Using the photon energy formula:
\[E_{photon} = h \times f \]

Plugging in the values:
\[E_{photon} = 6.626 \times 10^{-34} \, \text{Js} \times 5.4 \times 10^{14} \, \text{Hz} \]

Calculating:
\[E_{photon} = 6.626 \times 5.4 \times 10^{-34 + 14} \]

$$ E_{photon} = 35.8044 \times 10^{-20} $$
$$ E_{photon} \approx 3.58 \times 10^{-19} \, \text{J} $$

This is the energy of a single photon with the given frequency.

Determining the Number of Emitted Electrons

Total energy emitted as electrons:
$$ E_{total} = 1.2 \times 10^{19} \, \text{J} $$

Number of electrons emitted (n):
$$ n = \frac{E_{total}}{KE_{electron}} $$

But to find n, we need the kinetic energy per electron, which we can derive from the total energy and the number of electrons emitted, or vice versa. Alternatively, if the total kinetic energy is given, the average kinetic energy per electron can be obtained.

Given that the total energy is emitted as electrons, and assuming all photons contribute to electron emission, the total number of electrons emitted is:
$$ N = \frac{E_{total}}{\text{average kinetic energy per electron}} $$

However, since the problem asks to calculate the work function Φ, we need to relate the energy of incident photons and the kinetic energy of the emitted electrons.

Calculating the Work Function (Φ)

Assuming that the total emitted energy is due to electrons emitted with a certain average kinetic energy, and knowing the number of electrons emitted, the work function can be calculated as:

$$ \Phi = E_{photon} - KE_{electron} $$

But since the total energy is given, and the total number of electrons can be calculated from the total energy divided by the average energy per electron, we need to find the average kinetic energy per electron.

Suppose the total energy emitted as electrons is the sum of all their kinetic energies:
$$ E_{total} = N \times KE_{avg} $$

If we can determine N, the total number of electrons emitted, then:

$$KE_{avg} = \frac{E_{total}}{N}$$

Calculating the Number of Electrons Emitted

In the absence of explicit information about the number of photons or electrons, the most probable interpretation is that:

- The total energy emitted as electrons (1.2×10^{19} J) is due to electrons emitted from incident photons.

- The total number of photons incident is:

$$N_{photons} = \frac{\text{Total incident energy}}{E_{photon}}$$

But the total incident energy is not provided directly. Alternatively, if the problem is asking for the work function Φ based on the given data, perhaps the approach involves calculating the kinetic energy per electron.

Calculating the Kinetic Energy of Emitted Electrons

Key assumption: The total energy of emitted electrons corresponds to the sum of their kinetic energies, which is:

$$E_{total} = N \times KE_{electron}$$

Given the total energy (1.2×10^{19} J) and the energy per photon (3.58×10^{-19} J), we can find the number of photons incident:

$$N_{photons} = \frac{E_{incident}}{E_{photon}}$$

But the incident energy isn't specified directly. If the total energy emitted as electrons corresponds precisely to the energy of the incident photons minus the work function, then:

$$\text{Number of electrons emitted} = N_{photons}$$

Assuming each photon ejects one electron:

$$N_{electrons} = N_{photons}$$

Therefore, the total energy:

$$ E_{total} = N_{electrons} \times KE_{electron} $$

and

$$ KE_{electron} = \frac{E_{total}}{N_{electrons}} $$

But without explicit $N_{electrons}$, perhaps the problem intends to find the work function directly from the relation:

$$ KE_{electron} = E_{photon} - \Phi $$

and the total kinetic energy of all electrons:

$$ E_{total} = N_{electrons} \times KE_{electron} $$

If we assume the total energy emitted is due to the sum of kinetic energies, then:

$$ KE_{average} = \frac{E_{total}}{N_{electrons}} $$

Practical Calculation of Work Function Φ

In typical photoelectric problems, the maximum kinetic energy of emitted electrons is:

$$ KE_{max} = E_{photon} - \Phi $$

Suppose that the total energy emitted as electrons corresponds to the total kinetic energy of the emitted electrons, and the total number of electrons emitted is proportional to the number of incident photons, then:

1. Calculate the energy per photon:

$$ E_{photon} \approx 3.58 \times 10^{-19} \text{ J} $$

2. The total energy emitted as electrons:

$$ E_{total} = 1.2 \times 10^{19} \text{ J} $$

3. The number of electrons emitted:

$$ N_{electrons} \approx \frac{E_{total}}{KE_{electron}} $$

But without the explicit kinetic energy per electron, the problem cannot be directly solved. Alternatively, if the problem intends for us to calculate the work function Φ based on the photon energy and the total emitted energy, then:

$$\boxed{\Phi = E_{photon} - KE_{electron}}$$

and

$$KE_{electron} = \frac{E_{total}}{N_{electrons}}$$

which requires an estimate or assumption about the number of

Frequently Asked Questions

What is the significance of the frequency 5.4 x 10^14 Hz in the photoelectric effect?

The frequency 5.4×10^{14} Hz determines the energy of the incident photons, which influences whether electrons are emitted and their kinetic energy in the photoelectric effect.

How do you calculate the energy of photons incident on a metal surface?

The energy of photons is calculated using $E = h \times f$, where h is Planck's constant (6.626×10^{-34} Js) and f is the frequency of light.

Given the energy emitted by electrons (1.2 x 10^-19 J), how can we find the work function of the material?

The work function (φ) can be found using the photoelectric equation: $KE_{max} = hf - \varphi$. If electrons are emitted, KE_{max} is given, so $\varphi = hf - KE_{max}$.

What is the value of Planck's constant used in calculations related to photoelectric effect?

Planck's constant (h) is approximately 6.626×10^{-34} Joule seconds (Js).

How do we interpret the emitted electron energy of 1.2 x 10^-19 Joules in the context of the photoelectric effect?

This energy represents the maximum kinetic energy (KE_{max}) of the emitted electrons, which can be used to determine the work function of the material.

Can the frequency 5.4 x 10^14 Hz cause photoelectric emission in most metals?

Yes, if the photon energy exceeds the work function of the metal, electrons will be emitted. For many metals, this frequency is sufficient for photoelectric emission.

How do you calculate the number of electrons emitted if the total emitted energy is known?

Divide the total emitted energy (1.2 x 10^-19 J) by the energy of each photon (hf) to find the number of electrons emitted: number = total energy / photon energy.

What is the first step to solve the problem of calculating the work function from the given data?

First, calculate the energy of the incident photons using $E = h \times f$, then compare it with the emitted electron energy to find the work function.

Additional Resources

Photoelectric Effect: Unlocking the Mysteries of Light and Electrons

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Introduction: Exploring the Quantum Realm

In the vast universe of physics, few phenomena have revolutionized our understanding of the nature of light and matter quite like the photoelectric effect. This intriguing process, where light incident upon a material ejects electrons, laid the foundation for quantum theory and earned Albert Einstein the Nobel Prize in Physics in 1921. Today, we delve into a specific problem that illustrates this effect in action — analyzing the energy of emitted electrons when light of a particular frequency strikes a surface.

Imagine a scenario: light with a frequency of 5.4 × 1010 Hz (54 billion Hz) is incident upon a metal surface, causing electrons to be emitted with a total kinetic energy of 1.2 × 1019 Joules. Our goal? To understand what this tells us about the incident light, the work function of the metal, and the fundamental principles governing this interaction.

Understanding the Photoelectric Effect: The Fundamentals

The Photoelectric Equation

The core principle behind the photoelectric effect is encapsulated in Einstein’s photoelectric equation:

$$
K.E._{\text{max}} = hf - \phi
$$

Where:

- $K.E._{\text{max}}$ is the maximum kinetic energy of emitted electrons.
- h is Planck’s constant ($6.626 \times 10^{-34} \, \text{Js}$).
- f is the frequency of incident light.
- ϕ is the work function of the metal (minimum energy needed to eject an electron).

This equation reveals that the energy of incident photons (hf) is partitioned: some is used to overcome the work function ϕ, and the rest manifests as the kinetic energy of the emitted electrons.

Deciphering the Given Data

Let's examine the details provided:

- Frequency of incident light, $f = 5.4 \times 10^{10} \, \text{Hz}$
- Total energy of emitted electrons, $E_{total} = 1.2 \times 10^{19} \, \text{J}$

At first glance, this total energy appears enormous for electrons, which suggests a need to interpret the problem carefully.

Important Note: Typically, in photoelectric problems, the kinetic energy of individual electrons is given, or the total energy is specified in relation to a certain number of electrons. Since the problem states "emitted electrons is 1.2 × 1019 J," it's logical to assume this is the total kinetic energy of all emitted electrons, rather than a single electron.

Calculating the Number of Emitted Electrons

Given the total kinetic energy, we can find the average kinetic energy per electron if we know the total number of electrons emitted. But since the number of electrons isn't directly provided, we can approach this differently.

Step 1: Determine the energy of a single photon of the given frequency.

$$
E_{photon} = hf
$$

Plugging in the values:

$$
E_{photon} = (6.626 \times 10^{-34} \, \text{Js}) \times (5.4 \times 10^{10} \, \text{Hz}) \\
E_{photon} = 6.626 \times 5.4 \times 10^{-34 + 10} \\
E_{photon} \approx 35.7844 \times 10^{-24} \, \text{J} \\
E_{photon} \approx 3.578 \times 10^{-23} \, \text{J}
$$

This is the energy of each photon incident on the surface.

Estimating the Number of Emitted Electrons

Step 2: Determine the total number of photons incident, assuming all contribute to emission (which simplifies the problem).

If the total kinetic energy of emitted electrons is $1.2 \times 10^{19} \, \text{J}$, and each electron has an average kinetic energy KE, then:

$$
\text{Number of electrons, } N = \frac{\text{Total kinetic energy}}{KE}
$$

But to proceed, we need the kinetic energy per electron. Since this is not specified, perhaps the problem expects us to interpret the total energy as the energy of all emitted electrons collectively, and to find the work function ϕ based on the incident photon energy and the total emitted energy.

Calculating the Work Function and Electron Kinetic Energy

Step 3: Find the kinetic energy per electron.

Suppose the total energy of emitted electrons is from N electrons, each with kinetic energy $KE_{electron}$.

$$
KE_{electron} = \frac{E_{total}}{N}
$$

But without N, this seems circular. Alternatively, perhaps the problem wants us to find the maximum kinetic energy of a single electron, assuming the total energy is from a single electron or a small group.

Alternatively, the problem may be simplified to focus on the maximum kinetic energy of a single emitted electron, which would be:

$$
K.E._{\text{max}} = hf - \phi
$$

And the total energy of all emitted electrons is:

$$
E_{total} = N \times K.E_{electron}
$$

Given the enormous value of $1.2 \times 10^{19} \, \text{J}$, the most logical approach is that this is the energy associated with a large number of electrons emitted.

Revisiting the Problem: Clarification and Assumptions

Because the provided data is somewhat ambiguous, let's clarify possible assumptions:

- The total kinetic energy of all emitted electrons is 1.2 × 1019 J.
- The number of electrons emitted, N, can be calculated if the kinetic energy per electron is known.
- Alternatively, the problem might be simplified to calculating the maximum kinetic energy of a single electron, which is more typical in photoelectric

problems.

Given the context and typical problem structure, this makes sense:

Step-by-Step Solution Approach

1. Calculate the energy of incident photons:

$$
E_{photon} = h f = 6.626 \times 10^{-34} \times 5.4 \times 10^{10} = 3.578 \times 10^{-23} \, \text{J}
$$

2. Determine the maximum kinetic energy of emitted electrons:

Assuming the total kinetic energy of all electrons is $1.2 \times 10^{19} \, \text{J}$, and the total number of electrons emitted is N, then:

$$
K.E._{\text{max, per electron}} = \frac{1.2 \times 10^{19}}{N}
$$

But without N, we have a problem. Instead, considering typical photoelectric effect calculations, the maximum kinetic energy of a single electron is:

$$
K.E._{\text{max}} = hf - \phi
$$

Rearranged to find the work function:

$$
\phi = hf - K.E._{\text{max}}
$$

Estimating the Work Function: A Practical Calculation

Suppose the total kinetic energy corresponds to the energy of a single electron (or a representative electron):

$$
K.E._{\text{max}} = 1.2 \times 10^{19} \, \text{J}
$$

Given that the photon energy hf is extremely small (~3.578×10^{-23} J), but the total kinetic energy is enormous (~10^{19} J), this suggests a mismatch unless the total energy refers to a vast number of electrons.

Therefore, the most logical interpretation is:

- The problem aims to calculate the work function ϕ based on the incident light frequency and the emitted electrons' total kinetic energy.

Final Calculation: Determining the Work Function ϕ

Step 1: Find the energy of one photon:

$$
E_{photon} = 3.578 \times 10^{-23} \, \text{J}
$$

Step 2: Recognize that the total kinetic energy of electrons is 1.2×10^{19} J, which is vastly larger than the energy of a single photon. This indicates that the electrons are not emitted by a single photon, but rather, multiple photons contribute, or the data is perhaps symbolic.

Step 3: Since the total energy is so large, perhaps the problem expects us to find the maximum kinetic energy of an individual electron emitted by a photon of known energy.

Using the photoelectric equation:

$$
K.E._{\text{max}} = hf - \phi
$$

Assuming that the maximum kinetic energy of an emitted electron is approximately equal to the total kinetic energy divided by the number of electrons emitted

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