The Photoelectric Work Function Of Potassium Is 2.3 EV. Light That Has A Wavelength Of 150 Nm Falls On

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Introduction

The photoelectric effect is a fundamental phenomenon in physics that illustrates the particle-like behavior of light and the interaction between photons and electrons in a material. When light of sufficient energy strikes a metal surface, it can eject electrons, creating a photoelectric current. The energy required to liberate an electron from the surface is known as the work function of the material.

In this context, potassium, a highly reactive alkali metal, has a work function of approximately 2.3 electron volts (eV). Understanding how incident light interacts with potassium is essential for applications ranging from photoelectric cells to photodetectors and quantum physics experiments.

This article explores the scenario where light with a wavelength of 150 nanometers (nm) falls on potassium, analyzing whether it produces the photoelectric effect, and discussing the principles, calculations, and implications involved.

Understanding the Photoelectric Effect and Work Function

What Is the Photoelectric Effect?

The photoelectric effect occurs when photons incident on a metal surface transfer enough energy to electrons to overcome the attractive forces binding them in the metal. If the photon energy exceeds the work function, electrons are emitted with a kinetic energy proportional to the excess energy.

The Work Function

- The work function (ϕ) is the minimum energy needed to eject an electron from the surface of a metal.
- It is expressed in electron volts (eV), where 1 eV = 1.602×10^{-19} Joules.
- For potassium, the work function ϕ = 2.3 eV.

Significance of Wavelength and Energy

The energy of a photon (E) depends on its wavelength (λ) and is given by:

$$ E = \frac{hc}{\lambda} $$

where:
- h is Planck’s constant ($6.626 \times 10^{-34} \, \text{Js}$)
- c is the speed of light ($3 \times 10^{8} \, \text{m/s}$)
- λ is the wavelength in meters

The key question is: Does the photon energy exceed the work function of potassium? If yes, photoemission occurs; if not, electrons remain bound.

Calculating Photon Energy of Light at 150 nm Wavelength

Step 1: Convert Wavelength to Meters

Given $\lambda = 150 \, \text{nm}$:

$$ 1 \, \text{nm} = 1 \times 10^{-9} \, \text{m} $$

So,

$$ \lambda = 150 \times 10^{-9} = 1.5 \times 10^{-7} \, \text{m} $$

Step 2: Calculate the Energy of the Photons

Using the formula:

$$ E = \frac{hc}{\lambda} $$

Substituting the known values:

$$ E = \frac{(6.626 \times 10^{-34} \, \text{Js}) \times (3 \times 10^{8} \, \text{m/s})}{1.5 \times 10^{-7} \, \text{m}} $$

Calculating numerator:

$$ 6.626 \times 10^{-34} \times 3 \times 10^{8} = 1.9878 \times 10^{-25} \, \text{J·m} $$

Dividing by wavelength:

$$ E = \frac{1.9878 \times 10^{-25}}{1.5 \times 10^{-7}} \approx 1.32 \times 10^{-18} \, \text{J} $$

Step 3: Convert Joules to Electron Volts

Recall:

$$ 1 \, \text{eV} = 1.602 \times 10^{-19} \, \text{J} $$

Therefore:

$$ E_{\text{eV}} = \frac{1.32 \times 10^{-18}}{1.602 \times 10^{-19}} \approx 8.24 \, \text{eV} $$

Analyzing the Results

Is the Photon Energy Sufficient to Eject Electrons from Potassium?

- Photon energy $\approx 8.24 \, \text{eV}$
- Work function of potassium $\phi = 2.3 \, \text{eV}$

Since 8.24 eV > 2.3 eV, photons with a wavelength of 150 nm possess enough energy to eject electrons from potassium's surface.

Implications

- Electrons will be emitted with a kinetic energy given by:

$$ KE = E_{\text{photon}} - \phi $$

$$ KE = 8.24 \, \text{eV} - 2.3 \, \text{eV} = 5.94 \, \text{eV} $$

- The photoemission process will be efficient under these conditions.
- The emitted electrons will have significant kinetic energy, which can be utilized in various electronic and photonic devices.

Practical Applications and Significance

Photoelectric Devices Using Potassium

- Photocathodes: Potassium is often used in photocathodes due to its low work function.
- UV Detectors: The high photon energy at 150 nm (deep ultraviolet region) makes potassium suitable for UV detection systems.
- Quantum Physics Experiments: Understanding electron emission helps in studies involving electron microscopy, quantum efficiency, and photoelectron spectroscopy.

Wavelength Range for Photoemission from Potassium

- Any light with wavelength shorter than approximately 541 nm can induce photoemission from potassium.

$$ \lambda_{\text{max}} = \frac{hc}{\phi} $$

Calculating:

$$\lambda_{\text{max}} = \frac{1.9878 \times 10^{-25}}{2.3 \times 1.602 \times 10^{-19}} \approx 541 \, \text{nm}$$

Thus, ultraviolet and higher-energy photons (shorter wavelengths than 541 nm) can cause photoemission.

Additional Considerations

Surface Conditions

- Surface cleanliness and roughness affect the work function.
- Adsorbates or oxides can modify the effective work function, influencing photoemission efficiency.

Intensity and Photoelectron Yield

- The number of emitted electrons depends on the intensity of incident light.
- Higher intensity results in more electrons emitted, up to saturation limits.

Quantum Efficiency (QE)

- Quantum efficiency indicates how effectively incident photons produce emitted electrons.
- For potassium, QE varies with wavelength and surface conditions.

Summary and Conclusion

In conclusion, light with a wavelength of 150 nm possesses an energy of approximately 8.24 eV, which is significantly higher than the 2.3 eV work function of potassium. Therefore, when such ultraviolet light falls on potassium, it will induce the photoelectric effect, resulting in the emission of electrons with substantial kinetic energy (~5.94 eV).

This phenomenon underpins many technological applications, including UV photodetectors, photoelectric sensors, and electron emission devices. The ability of potassium to emit electrons under UV illumination makes it a valuable material in photonics and electron emission studies.

Understanding the interplay between photon energy, wavelength, and work function is crucial for designing and optimizing devices that rely on the photoelectric effect. The calculations and principles outlined here serve as a foundation for exploring photoemission phenomena in alkali metals and other materials.

References

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Frequently Asked Questions

What is the photoelectric work function of potassium?

The photoelectric work function of potassium is 2.3 eV.

Given the work function of potassium is 2.3 eV, what is the minimum photon wavelength required to eject electrons from potassium?

The minimum wavelength can be calculated using the relation $\lambda = hc / \varphi$. Substituting $h = 6.626\times10^{-34}$ Js, $c = 3\times10^{8}$ m/s, and $\varphi = 2.3$ eV (which is $2.3\times1.602\times10^{-19}$ J), the minimum wavelength is approximately 540 nm.

Will light with a wavelength of 150 nm cause photoemission from potassium?

Yes, since 150 nm wavelength corresponds to a photon energy of about 8.27 eV, which is much higher than the 2.3 eV work function, so it will cause photoemission.

What is the energy of photons with a wavelength of 150 nm?

The photon energy is given by $E = hc / \lambda$. Substituting $h = 6.626\times10^{-34}$ Js, $c = 3\times10^{8}$ m/s, and $\lambda = 150$ nm (150×10^{-9} m), the energy is approximately 8.27 eV.

How does the photon energy from 150 nm light compare to the work function of potassium?

The photon energy (around 8.27 eV) is significantly higher than the work function of potassium (2.3 eV), ensuring efficient photoemission.

What is the maximum kinetic energy of photoelectrons ejected from potassium when illuminated with 150 nm light?

Using Einstein's photoelectric equation: $KE_{max} = E_{photon}$ - work function, $KE_{max} \approx 8.27$ eV - 2.3 eV = 5.97 eV.

If the wavelength of incident light is decreased, how does it affect the kinetic energy of emitted electrons?

Decreasing the wavelength increases the photon energy, which results in higher maximum kinetic energy of the emitted photoelectrons.

Additional Resources

The Photoelectric Work Function Of Potassium Is 2.3 EV. Light That Has A Wavelength Of 150 Nm Falls On

In the realm of quantum physics and surface science, the photoelectric effect remains one of the most fascinating phenomena, revealing the particle-like nature of light and the intricate electronic properties of materials. Central to understanding this effect is the concept of the work function — the minimum energy needed to liberate an electron from a solid surface. Today, we delve into a specific scenario involving potassium, a metal with a notable work function, and analyze how incident ultraviolet light interacts with its surface.

Understanding the Photoelectric Effect and Work Function

The Photoelectric Effect is the emission of electrons from a material's surface when it absorbs photons—light particles—whose energy exceeds a certain threshold. This phenomenon was pivotal in establishing the quantum theory of light and earned Albert Einstein the Nobel Prize in Physics in 1921.

Work Function (Φ): The work function is a material-specific parameter, representing the energy barrier that electrons must overcome to escape the metal surface. It is typically expressed in electronvolts (eV). For potassium, this value is approximately 2.3 eV.

Why is the work function important?
It determines the threshold frequency and energy of incident photons required

to emit electrons. Any photon with less energy than the work function will not cause electron emission, regardless of the light’s intensity.

The Significance of Potassium’s Work Function of 2.3 eV

Potassium, an alkali metal, has a relatively low work function. This makes it particularly sensitive to ultraviolet (UV) light and suitable for photoelectric applications such as photoelectron spectroscopy and photoemission devices.

- Implication for UV light: Since UV photons carry higher energies compared to visible light, they can induce electron emission from potassium more readily.
- Surface properties: Potassium’s low work function results from its electronic structure, notably its loosely bound valence electrons.

The Incident Light: Wavelength of 150 nm

The scenario involves incident light with a wavelength of 150 nanometers (nm). To understand how this interacts with potassium’s surface, it’s essential to convert this wavelength into photon energy.

Photon Energy Calculation:

Using the relation:
$$ E = \frac{hc}{\lambda} $$

where:
- h = Planck’s constant $(6.626 \times 10^{-34} \, \text{Js})$
- c = speed of light $(3.0 \times 10^8 \, \text{m/s})$
- λ = wavelength in meters

Converting 150 nm to meters:
$$ 150 \, \text{nm} = 150 \times 10^{-9} \, \text{m} = 1.5 \times 10^{-7} \, \text{m} $$

Calculating energy:
$$ E = \frac{6.626 \times 10^{-34} \times 3.0 \times 10^8}{1.5 \times 10^{-7}} $$

$$ E \approx \frac{1.9878 \times 10^{-25}}{1.5 \times 10^{-7}} $$

$$ E \approx 1.325 \times 10^{-18} \, \text{J} $$

Since 1 eV = 1.602×10^{-19} J:
$$ E_{eV} = \frac{1.325 \times 10^{-18}}{1.602 \times 10^{-19}} \approx 8.27 \, \text{eV} $$

Result: The photon energy at 150 nm is approximately 8.27 eV.

Comparing Photon Energy to Work Function

Given that the photon energy (~8.27 eV) exceeds potassium’s work function (2.3 eV), the conditions are more than sufficient to induce the photoelectric effect. Electrons can absorb the photon energy and escape the metal surface, provided that no other surface effects hinder emission.

Key points:

- Threshold: Since 8.27 eV > 2.3 eV, electrons can be emitted.
- Kinetic energy of emitted electrons: The maximum kinetic energy (KE) of the photoelectrons can be calculated using Einstein's photoelectric equation:

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

$$ KE_{max} = 8.27 \, \text{eV} - 2.3 \, \text{eV} = 5.97 \, \text{eV} $$

This means the most energetic photoelectrons will have about 5.97 eV of kinetic energy.

Practical Implications and Applications

The significant excess energy (approximately 6 eV) implies that:

- High-energy photoelectrons: These can be detected easily with standard electron detectors.
- Surface analysis: The emitted electrons provide insights into the electronic structure of potassium.
- Photocathodes: Potassium’s properties make it suitable for use in devices like photomultiplier tubes and image intensifiers, especially when UV sensitivity is required.

Factors Influencing the Photoelectric Emission

While the calculations assume ideal conditions, real-world factors can influence the photoelectric effect:

Surface Purity and Condition:
Contaminants or oxidation layers can increase the effective work function or suppress electron emission.

Temperature:
Higher temperatures can provide thermal energy that assists electron escape but may also cause surface degradation.

Photon Incidence Angle:
The angle at which light strikes the surface can affect absorption and emission efficiencies.

Surface Roughness:
A smooth surface promotes uniform emission, whereas roughness can cause scattering and reduce efficiency.

Broader Context: From Quantum Mechanics to Technology

The analysis of potassium’s photoelectric response to UV light exemplifies the intersection of fundamental physics and technological innovation. Understanding the energy thresholds helps in designing devices like:

- UV photodetectors
- Photoelectron spectrometers
- Electron microscopes

Moreover, the ability to manipulate and measure electron emission underpins advances in materials science and quantum electronics.

Conclusion

In summary, when ultraviolet light with a wavelength of 150 nm (corresponding to approximately 8.27 eV photon energy) falls on potassium with a work function of 2.3 eV, the conditions are ideal for the photoelectric effect to occur. Electrons are emitted with a maximum kinetic energy of around 5.97 eV, enabling various practical applications and deepening our understanding of quantum phenomena.

The interplay between photon energy and work function remains a cornerstone in the study of surface physics, highlighting how fundamental constants and material properties govern the behavior of electrons at the smallest scales. As research continues, the insights gained from such phenomena will drive innovations across spectroscopy, imaging, and quantum information science.

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