

# What Is The Total Energy, In Kj, Of 1.00 Mole Of Photons Of Orange Light Whose Frequency Is 6.751014

## What Is The Total Energy, In Kj, Of 1.00 Mole Of Photons Of Orange Light Whose Frequency Is 6.751014

Understanding the energy contained within photons is fundamental to many areas of physics and chemistry, including quantum mechanics, spectroscopy, and photochemistry. When dealing with light, especially in terms of quantifying energy at the molecular level, it's essential to understand how to calculate the total energy of a given number of photons. This article explores the detailed process of calculating the total energy, in kilojoules (kJ), of 1.00 mole of photons of orange light with a known frequency of  $6.751014 \times 10^{14}$  Hz. We will break down the concepts involved, explain the relevant formulas, and walk through the calculations in a clear, step-by-step manner.

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## Basics of Photons and Energy

Photons are elementary particles, the quanta of electromagnetic radiation, including visible light. They are massless, chargeless particles that travel at the speed of light and carry energy proportional to their frequency.

## Energy of a Single Photon

The energy (E) of a single photon is given by the Planck-Einstein relation:

$$E = h \times \nu$$

Where:

- $E$  = energy of the photon (in joules, J)
- $h$  = Planck's constant ( $6.626 \times 10^{-34}$  Js)
- $\nu$  = frequency of the light (in Hz)

Since frequency is provided as  $6.751014 \times 10^{14}$  Hz, we can substitute this into the formula to find the energy of one photon.

## Number of Photons in a Mole

A mole of photons contains Avogadro's number ( $N_A$ ) of photons:

$$N_A = 6.022 \times 10^{23} \text{ photons/mole}$$

To find the total energy of 1 mole of photons, we multiply the energy of a single photon by Avogadro's number.

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## Step-by-Step Calculation of Total Energy

Let's proceed systematically to compute the total energy in kilojoules for 1.00 mole of photons.

### Step 1: Convert Frequency to Energy per Photon

Using:

$$E_{\text{photon}} = h \times \nu$$

Substitute the known values:

$$E_{\text{photon}} = (6.626 \times 10^{-34} \text{ J}\cdot\text{s}) \times (6.751014 \times 10^{14} \text{ Hz})$$

Calculating:

$$E_{\text{photon}} = 6.626 \times 6.751014 \times 10^{-34 + 14}$$

$$E_{\text{photon}} \approx 44.74 \times 10^{-20}$$

$$E_{\text{photon}} \approx 4.474 \times 10^{-19} \text{ J}$$

So, each photon has approximately  $(4.474 \times 10^{-19})$  joules of energy.

### Step 2: Calculate Total Energy for 1 Mole of Photons

Total energy:

$$E_{\text{total}} = E_{\text{photon}} \times N_A$$

$$E_{\text{total}} = 4.474 \times 10^{-19} \text{ J} \times 6.022 \times 10^{23}$$

Calculating:

$$E_{\text{total}} \approx 4.474 \times 6.022 \times 10^{-19 + 23}$$

$$E_{\text{total}} \approx 26.94 \times 10^4$$

$$E_{\text{total}} \approx 2.694 \times 10^5 \text{ J}$$

Thus, the total energy of 1 mole of these photons is approximately 269,400 joules.

### Step 3: Convert Joules to Kilojoules

Since 1 kilojoule (kJ) = 1,000 joules:

$$E_{\text{total}} = \frac{2.694 \times 10^5 \text{ J}}{10^3}$$

$$E_{\text{total}} \approx 269.4 \text{ kJ}$$

Therefore, the total energy of 1 mole of orange photons with a frequency of  $6.751014 \times 10^{14}$  Hz is approximately 269.4 kJ.

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## Understanding the Significance of the Calculation

This calculation provides insight into how much energy is contained within a mole of photons at a specific frequency. It has practical applications in various scientific fields:

- Spectroscopy: Understanding photon energies helps interpret absorption and emission spectra.
- Photochemistry: Knowing the energy per mole of photons guides the design of photo-reactors and solar energy devices.
- Quantum Mechanics: It exemplifies the particle nature of light and energy quantization.

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## Additional Considerations and Related Concepts

While the calculation above is straightforward, several related concepts and nuances can be considered to deepen understanding.

### Relation Between Wavelength and Frequency

The frequency of light is related to wavelength ( $\lambda$ ) by:

$$c = \lambda \times \nu$$

Where:

- $c$  = speed of light ( $3.00 \times 10^8$  m/s)

Given the frequency, the wavelength can be calculated:

$$\lambda = \frac{c}{\nu}$$

For the given frequency:

$$\lambda = \frac{3.00 \times 10^8 \text{ m/s}}{6.751014 \times 10^{14} \text{ Hz}}$$

$$\lambda \approx 4.44 \times 10^{-7} \text{ m}$$

$$\lambda \approx 444 \text{ nm}$$

This wavelength falls within the visible spectrum, characteristic of orange light.

## Energy of Photons in Context

- The energy per photon ( $\sim 4.474 \times 10^{-19} \text{ J}$ ) is consistent with the energy of visible photons.
- This energy level is sufficient to excite electrons in certain molecules, leading to various photochemical reactions.

## Implications for Solar Energy

Understanding photon energy at different frequencies informs the development of solar cells, which are designed to convert photon energy into electrical energy efficiently.

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## Summary and Key Takeaways

- The energy of a photon is directly proportional to its frequency, as described by  $E = h \nu$ .
- Calculating the total energy of a mole of photons involves multiplying the energy per photon by Avogadro's number.
- For orange light with a frequency of  $6.751014 \times 10^{14} \text{ Hz}$ , the total energy of 1 mole of photons is approximately 269.4 kJ.
- This calculation underscores the quantized nature of electromagnetic radiation and has practical applications across physics, chemistry, and engineering.

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## Final Thoughts

Mastering the calculation of photon energy and understanding its implications is crucial for scientists and engineers working with light and electromagnetic radiation. Whether analyzing spectral data,

designing photovoltaic devices, or exploring quantum phenomena, these fundamental concepts serve as the building blocks of modern science.

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#### References:

- Tipler, P. A., & Mosca, G. (2008). Physics for Scientists and Engineers. W. H. Freeman.
- Serway, R. A., & Jewett, J. W. (2013). Physics for Scientists and Engineers. Cengage Learning.
- NIST. (n.d.). Fundamental Physical Constants. National Institute of Standards and Technology.

Note: The calculations and constants provided are based on standard scientific values as of October 2023.

## Frequently Asked Questions

### **What is the total energy in kilojoules of 1.00 mole of orange light photons with a frequency of $6.75 \times 10^{14}$ Hz?**

The total energy is approximately 2.69 kJ for 1.00 mole of photons at that frequency.

### **How do you calculate the energy of a single photon of orange light with a frequency of $6.75 \times 10^{14}$ Hz?**

You use the formula  $E = h \times \text{frequency}$ , where  $h$  is Planck's constant ( $6.626 \times 10^{-34}$  J·s). So,  $E = 6.626 \times 10^{-34} \text{ J·s} \times 6.75 \times 10^{14} \text{ Hz} \approx 4.47 \times 10^{-19}$  Joules per photon.

### **What is the significance of knowing the total energy of 1 mole of photons?**

Calculating the total energy helps in understanding the energy transfer involved in light-matter interactions, and is useful in fields like spectroscopy, photochemistry, and energy applications.

### **How is the energy of one photon related to its frequency in the context of orange light?**

The energy of one photon is directly proportional to its frequency, given by  $E = h \times \text{frequency}$ . For orange light with a frequency of  $6.75 \times 10^{14}$  Hz, this yields a specific photon energy.

### **Can you convert the energy of 1 mole of photons into kilojoules?**

Yes, by multiplying the energy of a single photon by Avogadro's number ( $6.022 \times 10^{23}$ ) and converting Joules to kilojoules, you find that 1 mole of orange photons at this frequency has approximately 2.69 kJ of total energy.

# Additional Resources

What Is The Total Energy, In Kj, Of 1.00 Mole Of Photons Of Orange Light Whose Frequency Is  $6.751014 \times 10^{14}$  Hz

Understanding the energy contained within a specific number of photons is a fundamental aspect of quantum physics and chemistry, bridging the microscopic world of particles with macroscopic measurements. When dealing with light, particularly in the context of photons, the concept of energy per photon becomes essential. For a given frequency, the energy of a single photon can be calculated using Planck's equation, and this can then be scaled up to a mole of photons to understand the total energy involved in a large quantity. This article will explore what the total energy, expressed in kilojoules (kJ), of 1.00 mole of photons of orange light with a specified frequency entails, providing a comprehensive breakdown of the physics, calculations, and implications.

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## Understanding Photons and Their Energy

Photons are elementary particles representing quanta of electromagnetic radiation, including visible light. Unlike particles with rest mass, photons are massless entities that travel at the speed of light in a vacuum. Each photon carries a discrete amount of energy directly proportional to its frequency, a relationship derived from quantum theory.

The fundamental equation governing photon energy is:

$$E = h \times \nu$$

where:

- $E$  is the energy of a single photon (in Joules),
- $h$  is Planck's constant ( $6.626 \times 10^{-34}$  J·s),
- $\nu$  (nu) is the frequency of the photon (in Hz).

This relationship highlights that higher frequency photons (like gamma rays) carry more energy, while lower frequency photons (like radio waves) carry less.

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## Calculating the Energy of a Single Photon

Given the frequency of the orange light photon as  $6.751014 \times 10^{14}$  Hz, we can compute the energy per photon:

$$E_{\text{photon}} = h \times \nu$$

Plugging in the known values:

$$E_{\text{photon}} = (6.626 \times 10^{-34} \text{ J}\cdot\text{s}) \times (6.751014 \times 10^{14} \text{ Hz})$$

Calculating this:

$$E_{\text{photon}} = 6.626 \times 6.751014 \times 10^{-34 + 14}$$

$$E_{\text{photon}} \approx 44.74 \times 10^{-20}$$

$$E_{\text{photon}} \approx 4.474 \times 10^{-19} \text{ J}$$

Thus, each photon of this orange light carries approximately  $(4.474 \times 10^{-19})$  Joules of energy.

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## Scaling Up to a Mole of Photons

A mole is a standard quantity in chemistry representing  $(6.022 \times 10^{23})$  entities, in this case, photons. To find the total energy for 1 mole of photons:

$$E_{\text{total}} = E_{\text{photon}} \times N_A$$

where:

-  $(N_A)$  is Avogadro's number,  $(6.022 \times 10^{23})$ .

Substituting the values:

$$E_{\text{total}} = 4.474 \times 10^{-19} \text{ J} \times 6.022 \times 10^{23}$$

Calculating:

$$E_{\text{total}} \approx 4.474 \times 6.022 \times 10^{(-19 + 23)}$$

$$E_{\text{total}} \approx 26.93 \times 10^4$$

$$E_{\text{total}} \approx 2.693 \times 10^5 \text{ J}$$

So, the total energy of 1 mole of these orange photons is approximately 269,300 Joules.

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## Converting Joules to Kilojoules

Since energy in macroscopic contexts is often expressed in kilojoules, we convert Joules to kJ:

$$1 \text{ kJ} = 1000 \text{ J}$$

Thus:

$$E_{\text{total}} = \frac{269,300 \text{ J}}{1000} = 269.3 \text{ kJ}$$

Final answer:

The total energy of 1.00 mole of photons of orange light with a frequency of  $(6.751014 \times 10^{14})$  Hz is approximately 269.3 kJ.

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## Context and Significance of the Calculation

This calculation illustrates the quantum nature of light and how the energy contained in a large number of photons, such as a mole, can be substantial despite individual photons having minuscule energies. The process bridges microscopic quantum properties with macroscopic energy measurements, fundamental in fields like spectroscopy, photochemistry, and quantum physics.

Features and Applications:

- Spectroscopy: Understanding photon energies helps interpret absorption and emission spectra.
- Photosynthesis: Quantifies the energy plants harness from sunlight.
- Photovoltaics: Assists in designing solar cells by matching photon energies to material band gaps.
- Quantum Computing and Communication: Precise photon energy calculations are crucial for quantum information processes.

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## Features and Considerations

Pros:

- Accurate scaling: From single photon energy to moles, the calculation is straightforward and precise.
- Fundamental constants: Uses well-established constants, ensuring reliability.
- Applicability: Can be adapted for different wavelengths and frequencies.

Cons:

- Idealized assumptions: Assumes all photons have exactly the same frequency and energy, which may vary in real light sources.
- Does not consider photon interactions: Focuses purely on energy, ignoring other quantum effects or interactions.

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## Additional Insights and Related Topics

- Wavelength Relationship: The wavelength  $(\lambda)$  of light relates to frequency by  $(c =$

$\lambda \times \nu$ ), where  $c$  is the speed of light ( $3.00 \times 10^8 \text{ m/s}$ ). For the given frequency, the wavelength is:

$$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8}{6.751014 \times 10^{14}} \approx 4.44 \times 10^{-7} \text{ m}$$

which is approximately 444 nm, consistent with orange light.

- Energy per photon in electron volts (eV): Since  $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ ,

$$E_{\text{photon}} \approx \frac{4.474 \times 10^{-19}}{1.602 \times 10^{-19}} \approx 2.79 \text{ eV}$$

This energy is typical for photons in the visible spectrum.

- Implication for Photochemical Reactions: The energy per photon can determine whether a photon can initiate certain chemical reactions, especially when bond energies are considered.

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## Conclusion

Calculating the total energy of a mole of photons of orange light provides a clear demonstration of quantum principles applied at a macro scale. The derived value of approximately 269.3 kJ exemplifies how tiny individual photon energies incorporate to produce significant energy quantities when amassed in large numbers. This understanding underpins many technological advances in energy conversion, spectroscopy, and quantum sciences. Recognizing the relationship between frequency, energy, and their practical implications enhances our grasp of the electromagnetic spectrum and the fundamental processes governing light-matter interactions.

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