CAIE Physics A-level

22 - Quantum Physics

Flashcards

What are photons?

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Photons are light particles.

They are sometimes referred to as a quantum of energy of EM radiation. ‘A quantum’ in this context just means a set (finite) amount.

True or false? The energy of a photon is directly proportional to the wavelength of the light.

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False.

Energy is directly proportional to the frequency: $E = hf$, and since $f = v/\lambda$, $E = hv/\lambda$.

Therefore energy is inversely proportional to the wavelength of EM radiation.

What is ‘h’ in the equation E = hf? Give units.

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‘h’ is Planck’s constant = 6.63×10^{-34} Js

What quantity can be measured in electron volts (eV)?

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Energy.

Give the equation that allows you to calculate the momentum of a photon.

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$$p = E/c$$

Where ‘p’ is momentum, ‘E’ is energy and ‘c’ is the speed of light ($3x10^{8}ms^{-1}$).

What is the photoelectric effect?

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The photoelectric effect is a phenomenon that occurs when light (of sufficient energy) is shone onto a metal surface, causing it to emit electrons. This effect can cause current to flow.

The electrons emitted are called photoelectrons.

Which features of the photoelectric effect can't be explained if light is a wave?

Which features of the photoelectric effect can't be explained if light is a wave?

If light were a wave, then the energy possessed by released electrons would simply increase proportionally with increasing light intensity. This is not the case. The energy of the released electrons depends on the frequency of the stimulating light. No electrons are released below a certain frequency: the threshold frequency, no matter how intense the light is.

How many photons does each photoelectron absorb prior to emission?

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Only 1.

If it doesn't contain enough energy, the electron will re-emit the energy rather than energy being released.

How does the photon model of light explain the threshold frequency seen in the photoelectric effect?

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Each electron absorbs a single photon. This single photon must have enough energy to cause an electron to be released; If it doesn't the energy is just re-emitted. The electron can't build up energy as it could if light were simply a wave.

What is the name given to the minimum amount of energy an electron requires to leave the surface of a metal?

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The work function (or ‘work function energy’), Φ

Write a word equation relating the energy of an incident photon to the work function and the kinetic energy of released electrons.

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Photon energy = work function + kinetic energy

Write a symbol equation relating the energy of an incident photon to the work function and the kinetic energy of released electrons.

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$$hf = \Phi + \tfrac{1}{2} m v_{max}^{2}$$

True or false? The rate of emission of photoelectrons is proportional to intensity (provided the light is above threshold frequency).

True or false? The rate of emission of photoelectrons is proportional to intensity (provided the stimulating light is above the threshold frequency).

True.

Higher intensity means more photons. This means more electrons can absorb energy and thus be released (leading to a greater current).

Does the maximum kinetic energy of a released electron depend on the intensity of light hitting the surface?

Does the maximum kinetic energy of a released electron depend on the intensity of light hitting the surface?

No.

Energy transferred is due to a one-to-one interaction, and so depends on frequency, not intensity.

What experimental evidence appears to show particles behaving as waves?

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Electron diffraction.

Electrons will diffract if passed through the spaces between atoms in graphite (like a tiny diffraction grating).

This wouldn't happen if electrons were behaving only as particles.

Which equation relates the wave and particle properties of electrons?

Which equation relates the wave and particle properties of electrons?

The de Broglie equation: $\lambda = h/p$

'λ' in the de Broglie equation refers to the de Broglie wavelength: a wavelength associated with a moving particle (wave-property), h = Planck's constant, and p = particle momentum (particle-property).

Should light be considered as a wave or as a collection of moving particles?

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Both,

As explained in this topic, EM radiation displays both wave and particle characteristics in its interactions. Hence both wave-associated and particle-associated terms are incorporated into the de Broglie equation.

What is meant by electron energy levels?

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As electrons orbit the nucleus of atoms, they occupy distinct energy levels. These can be considered analogous to floors on a building; electrons may occupy a distinct energy level (a floor), but cannot settle between energy levels (floors).

What happens when an atom absorbs energy?

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If an atom absorbs energy, it may cause certain electrons to become excited to higher energy levels.

Why do atoms of different elements have distinct absorption spectra?

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The energy levels, which electrons may occupy, are different for different elements. Therefore only distinct energies (and hence frequencies) of light can be absorbed by each element.

Why do atoms of different elements only emit certain light frequencies?

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When no longer subjected to energy influx, electrons fall back down to a lower energy level, emitting photons of the same distinct energies that were originally absorbed. This is useful as it allows us to identify what elements and with what elemental ratios solar bodies are comprised, without needing to sample them.

What is the relationship between the frequency of the emitted light and the fall in energy level of stable electrons?

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$$hf = E_1 - E_2$$

Where 'E_1' is the excited energy level and 'E_2' is the stable electron?