

21.1 Photons and the photoelectric effect

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS photon • work function

Objective

Photons and the photoelectric effect. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

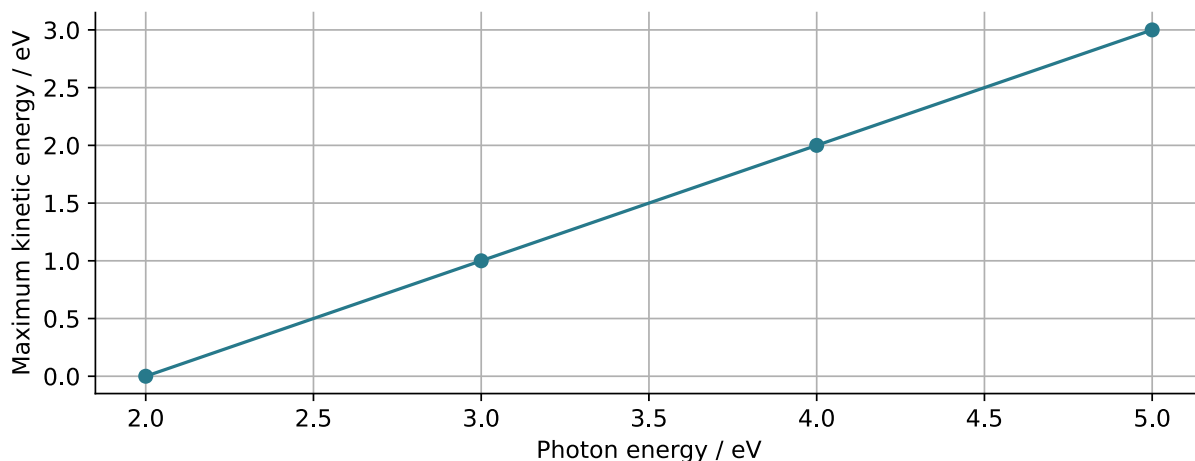
1 Key knowledge and worked examples

■ What would explain this observation?

- Bright low-frequency light can fail to eject electrons while dim higher-frequency light succeeds. **Photon** energy depends on frequency, not intensity alone.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- A photon has energy proportional to frequency. The **work function** is the minimum energy needed to release an electron from a surface. Above threshold, excess photon energy can become electron kinetic energy.
- photon: A quantum of electromagnetic radiation; work function: Minimum surface energy needed to release an electron.



■ **Choose evidence that can test it**

- Use photon energy = Planck constant $\times$ frequency. Maximum kinetic energy = photon energy - work function. Increasing intensity at fixed frequency increases photon arrival rate, not individual photon energy.
- Read axes carefully on a stopping-potential or kinetic-energy graph. Identify threshold frequency from the zero-energy intercept. State the metal and experimental conditions because work function is material-specific.

■ **Work from known quantities**

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: photon energy is 5.0 electronvolts and work function is 2.0 electronvolts. Maximum kinetic energy = photon energy - work function = $5.0 - 2.0 = 3.0$ electronvolts. A 1.5 electronvolt photon cannot cause emission from that surface in this model.

Example:

Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ **Check the conclusion and its limits**

- Electrons do not accumulate many sub-threshold photons in the elementary single-photon model. Do not confuse photon number with photon energy.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Doubling light intensity doubles each photon energy at fixed frequency. This claim is false: Electrons do not accumulate many sub-threshold photons in the elementary single-photon model. Do not confuse photon number with photon energy.

Key:

Photons and the photoelectric effect: Use photon energy = Planck constant $\times$ frequency. Maximum kinetic energy = photon energy - work function. Increasing intensity at fixed frequency increases photon arrival rate, not individual photon energy.

2 Practice

2.1 At fixed above-threshold frequency, increasing intensity mainly increases what? Choose one answer.

- **A** Photon energy
- **B** The number of emitted electrons per time
- **C** Work function

[1]

2.2 Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy. Show the relation, substitution and units.

[2]

2.3 Decide whether this claim is true and justify: Doubling light intensity doubles each photon energy at fixed frequency.

[2]

2.4 A quantum of electromagnetic radiation: write the technical term.

[1]

3 Exam-style questions

3.1 A surface has work function 2.5 eV. Compare 2.0 and 4.0 eV photons and predict what doubling intensity changes in the one-photon model. [4]

Solutions

2.1 B Use photon energy = Planck constant $\times$ frequency. Maximum kinetic energy = photon energy - work function. Increasing intensity at fixed frequency increases photon arrival rate, not individual photon energy.

2.2 $K_{\max} = \text{photon energy} - \text{work function} = 4.8 - 2.1 = 2.7 \text{ eV}$.

2.3 False. Electrons do not accumulate many sub-threshold photons in the elementary single-photon model. Do not confuse photon number with photon energy.

2.4 photon. photon means A quantum of electromagnetic radiation.

3.1 2.0 eV cannot cause emission; 4.0 eV gives maximum kinetic energy 1.5 eV. Above threshold, greater intensity supplies more photons, not more energy per photon. It does not raise $K_{\max}$.