

Exercise walk-through

21.1

Photons and the photoelectric effect

International Baccalaureate · IB Diploma · Physics · HL

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

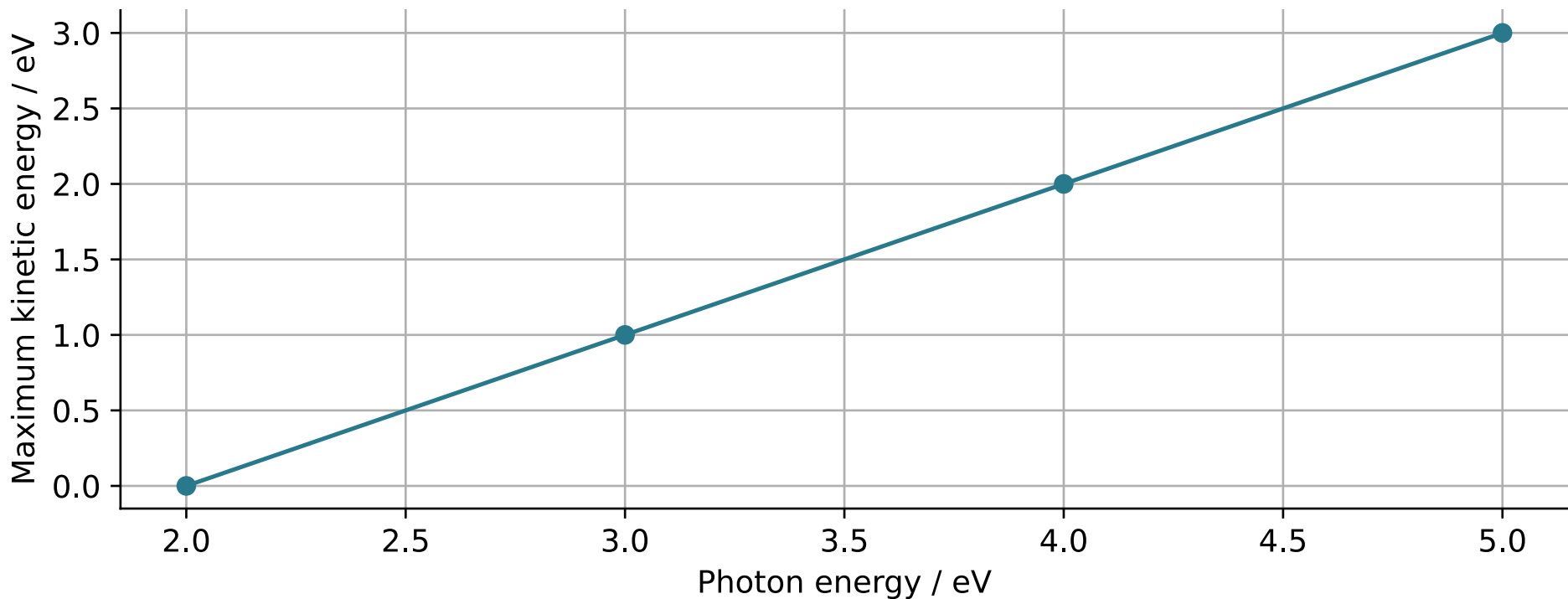
■ What would explain this observation?

- 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.

Exercises 2.1·2.3

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]

Exercises 2.1·2.3

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]

2.1 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 Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy. Show the relation, substitution and units. [2]

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

2.3 Decide whether this claim is true and justify: Doubling light intensity doubles each photon energy at fixed frequency. [2]

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.

Exercises 2.4·3.1

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]

Exercises 2.4·3.1

2.4 A quantum of electromagnetic radiation: write the technical term. [1]

3 Exam-style questions

2.4 photon. photon means A quantum of electromagnetic radiation.

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]

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} .