

## 23.1 Photoelectrons, reduced mass and atomic excitation

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

**Total: 10 marks****KEY WORDS** work function • reduced mass

### Objective

Distinguish photoelectric thresholds and characteristic X rays; Apply reduced-mass spectral scaling and many-electron spin filling; Interpret Franck–Hertz energy spacing without inventing new levels. Original public practice; not an ETS paper.

### 1 Key knowledge and worked examples

In the one-photon photoelectric model,  $K_{\max} = h\nu - \phi$  above threshold  $\nu_0 = \phi/h$  and  $eV_s = K_{\max}$ . Increasing intensity at fixed frequency changes available electron count/current, not maximum energy. Below threshold there is no one-photon emission; work function belongs to the surface.

Characteristic X rays are discrete photons from filling inner-shell vacancies. Bremsstrahlung is a continuous background from electron deceleration in nuclear fields; its endpoint follows incident energy. Both can appear together. Do not substitute phonon scattering or electron capture for the characteristic-line mechanism.

Hydrogen-like energies scale as  $-\mu Z^2/n^2$ , with  $\mu = m_e M/(m_e + M)$ ; wavelengths scale inversely with  $\mu Z^2$ . Positronium has  $\mu = m_e/2$ . Many-electron spin needs orbital filling/Hund's rule: occupy degenerate orbitals singly with parallel spins before pairing. Carbon  $2p^2$  and oxygen  $2p^4$  each have two unpaired electrons and  $S=1$ .

Franck–Hertz spacing  $\Delta V$  reveals repeated losses of excitation energy  $e\Delta V$ , not necessarily distinct levels at every peak. Contact/retarding potentials can shift absolute positions. If one return photon carries that energy,  $\lambda = hc/(e\Delta V)$ ; use the spacing and stated apparatus conditions.

#### ■ Worked method

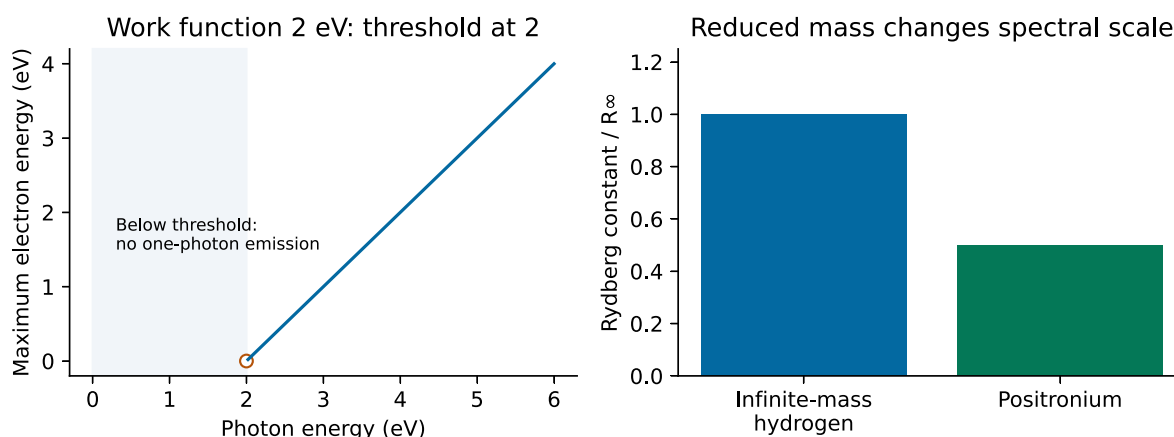
In the one-photon photoelectric effect, use the surface work function  $\phi$ .

$$K_{\max} = h\nu - \phi, \quad eV_s = K_{\max}.$$

For photon energy 4.5 eV and  $\phi = 2.0$  eV,

$$K_{\max} = E_\gamma - \phi = 4.5 \text{ eV} - 2.0 \text{ eV} = 2.5 \text{ eV}.$$

The stopping-potential magnitude is 2.5 V. Higher intensity at the same frequency changes the available electron rate, not this maximum energy.



## 2 Practice

**2.1** Choose one answer. At fixed above-threshold frequency, increasing light intensity in the one-photon photoelectric model mainly changes: [1]

- **A** The surface work function
- **B** Maximum electron kinetic energy
- **C** The photon frequency
- **D** Available photoelectron count/current
- **E** Planck's constant

**2.2** Choose one answer. For neutral oxygen ground configuration  $1s^2 2s^2 2p^4$ , Hund filling gives total electronic spin: [1]

- **A** 0
- **B**  $1/2$
- **C** 1
- **D**  $3/2$
- **E** 2

**2.3** Positronium reduced mass divided by electron mass equals \_\_\_\_\_ (decimal). Show your relation and units. [2]

