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, Kmax=h$\nu-\phi$ above threshold ν0=ϕ/h and eVs=Kmax. 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 μ=m_eM/(m_e+M); wavelengths scale inversely with μZ^2. Positronium has μ=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 ΔV reveals repeated losses of excitation energy eΔV, not necessarily distinct levels at every peak. Contact/retarding potentials can shift absolute positions. If one return photon carries that energy, λ=hc/(eΔV); use the spacing and stated apparatus conditions.

■ Worked method

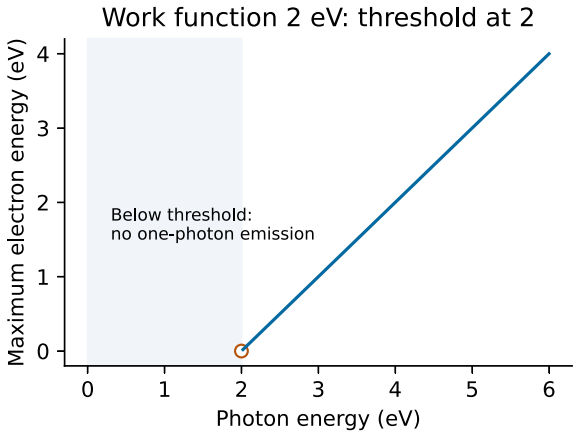
In the one-photon photoelectric effect , use the surface work function phi.

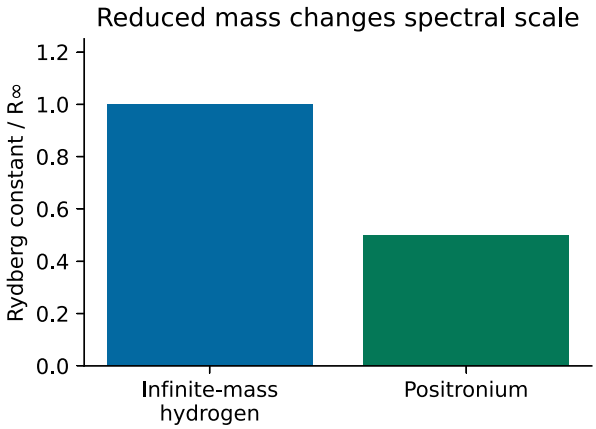
$$K_{max} = h\nu - \phi, \qquad eV_s = K_{max}.$$

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]

2.4 Decide whether this claim is true. Justify it: Equally spaced Franck–Hertz features necessarily identify a different atomic excitation energy at each successive feature. [2]

3 Exam-style questions

3.1 Compare the same hydrogenic transition for nuclear masses M = 10me and M = 20me, with equal Z. Find the ratio of photon frequencies and wavelengths using reduced mass. Explain the infinite-nuclear-mass limit. [4]