Access Tuition

A-Level Physics

Photoelectric Effect

Mark Scheme

Time available: 63 minutes
Marks available: 49 marks

1. (a) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer.**

Mark	Criteria
6	All three areas (as outlined alongside) covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all three areas. If there are several errors or missing parts then 5 marks should be awarded.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed or makes a partial attempt at two areas.
1	One of the three areas covered without significant error.
0	No relevant analysis.

The following statements are likely to be present.

Area A
PEE:
- Is a surface phenomenon.
- Emission of electrons (from a surface) when electromagnetic radiation is incident (on surface).

Area B
Frequency:
- Minimum energy required (work function) to release an electron from the metal surface.
- A photon must supply this energy in one interaction.
- The energy of a photon is directly proportional to its frequency.

Area C
Intensity:

- Increased intensity (at same frequency) results in more photons per second incident on metal.
- Must increase the number of photons (per second) even if frequency increases.
- More electrons released from surface every second so loses charge more rapidly.

6

(b) Use of $E = hf$ or converts their photon energy in J to eV ✓

(E =) 7.96 × 10^{-19} (J) or 4.97 eV

OR

converts 1.1 (eV) to 1.76 × 10^{-19} (J)

Use of $hf = \Phi + E_{k(max)}$ ✓

Φ = 3.9 (eV) ✓

MP2

Condone use of their photon energy (in J or eV) or their $E_{k(max)}$ in J

3

[9]

2. (a) Frequency related to energy (of photon) /$E = hf$ ✓

MP1 is for linking photon energy to frequency

There is a minimum energy (of a photon) required to remove photoelectron; (minimum energy relates to minimum frequency). ✓

MP2 is for explaining what is meant by the work function.

If no other mark awarded, one mark can be given for relevant mention of work function.

Do not credit mention of threshold frequency unless explained

If no mention of a photon, 1 max.

Ignore references to energy levels.

2

(b) Evidence of use of maximum current ÷ charge on electron ✓

1.9 × 10^{14} (electrons per second) ✓

Expect to see 30 × 10^{-6} ÷ 1.6 × 10^{-19}

Condone e for 1.6x10^{-19} in MP1

Allow POT error for current in MP1

Correct answer only for MP2

2

(c) Number of photoelectrons released (per second) depends on intensity of em radiation/number of (incident) photons (per second) (not pd.) ✓

MP1 is for relating the intensity to either the no. of incident photons or released photoelectrons per second

Constant current reached when <u>all</u> photoelectrons released (each second) reach anode (due to anode pd). ✓

MP2 is for linking constant current to all photoelectrons being detected.

Condone 'go round the circuit' for 'reach anode'.

2

(d) MP1 is for range of KE ✓

MP2 for what happens when V is negative in terms of kinetic energy or potential energy or work done on/by electron ✓

MP3 is for link to fewer photoelectrons having necessary KE. ✓

Example statements:

MP1: photoelectrons are released with a range of KE.

MP2: (When V negative) photoelectrons lose KE/gain (E)PE crossing to anode.

MP3: (As V is increasingly negative) fewer of the photoelectrons (released per second) have sufficient (initial) KE to cross to anode (so current decreases).

3

(e) <u>Award each mark independently</u>

If no mention of <u>maximum</u> KE do not award MP1.

Stopping potential related to <u>maximum</u> kinetic energy of photoelectrons/ $KE_{max} = eV_s$ ✓

(Max) KE = energy of photon – work function/ ϕ.

OR (max) KE increases as (work function is lower and) radiation same ✓

(max) KE increases, so stopping potential increases. ✓

Alternative

Reference to Einstein equation in the form: $hf = \phi + eV_s$ ✓

rearranged to

$$V_s = \frac{hf - \phi}{e}$$ ✓

So lower work function,(with hf and e constant,) gives higher Vs. ✓

3

[12]

3. (a) Idea that atoms gains energy (from beta particle) eg atoms excited or atoms/electrons moved to higher energy levels ✓

Idea that atom loses energy by emission of light/photons eg atoms de-excite or electrons move to lower energy levels ✓

Allow ionisation as named process

2

(b) Use of $E = \frac{hc}{\lambda}$ **OR** use of $c = f\lambda$ and $E = hf$ ✓

Condone POT error for λ

3.2×10^{-19} (J) ✓

Allow 3.1×10^{-19} (J) if 6.6×10^{-34} used

2

(c) Use of $W = QV$ **OR** determines pd = 750 V ✓

1.2×10^{-16} (J) ✓

2

(d) Max 3 from: ✓ ✓ ✓

Attempt to count squares **OR** calculate unit area **OR** Statement that area under curve = charge flow

1 small square = 2×10^{-12} (C) ; 1 large square = 5×10^{-11} (C)

Counts number of squares/Determines area

Converts number of squares to charge

Accept 140 to 180 small or 5.5–7 large squares

Accept $\frac{1}{2}$ base × height for triangle of base 12–16 ns and height 50 mA

Divides their total charge by 1.60×10^{-19}

2×10^{9} ✓

Allow 1 sf answer

4

[10]

4. (a)

Transition	Ultraviolet	Visible	Infrared
A			✓
B		✓	
C	✓		

all correct 1 mark

1

(b) EITHER

energy needed for electron to move to higher level/orbital ✓

OR

for a transition/excitation/change of levels an exact amount of energy is needed ✓

all the photon's energy absorbed(in 1 to 1 interaction) ✓

electron can transfer part of its energy (to cause a transition/excitation)/ continues moving/ lower kinetic energy/ lower speed ✓

Any implication of photoelectric effect max 1

Accept one energy level to another

1
1
1

(c) (use of $\varphi = hf_0$)

$\varphi = 6.63 \times 10^{-34} \times 5.1 \times 10^{14}$ ✓ (= 3.38×10^{-19})

$\varphi = 3.38 \times 10^{-19}/1.6 \times 10^{-19} = 2.1(1)$ (eV) ✓

OR

$\varphi = 6.63 \times 10^{-34} \times 5.1 \times 10^{14}$ ✓(= 3.38×10^{-19})

energy in J $10.2 \times 1.6 \times 10^{-19} = 1.63 \times 10-18$ ✓

OR

energy levels in J = $10.2 \times 1.6 \times 10^{-19} = 1.63 \times 10^{-18}$ ✓

photons frequencies giving this energy= 2.46×10^{15} ✓

If see 2.1 get these first two marks

1
1

2 → 1 / C possible ✓

Last mark dependent on previous 2

1

(d) (use of hf = $\varphi + E_k$)

$12.1 \times 1.6 \times 10^{-19} = 2.1 \times 1.6 \times 10^{-19} + E_k$ ✓

$E_k = 1.6 \times 10^{-18}$(J) ✓

v = $\sqrt{(2 \times 1.6 \times 10^{-18}/9.11 \times 10^{-31})}$ ✓(= 1.9×10^6 m s^{-1})

Photoelectric equation must be used

Ecf for third mark their calculated kinetic energy having used photoelectric equation even if not converted eV to J or frequency to J

Correct answer gets (1.9 × 10^6 m s^{-1}) full marks

1
1
1

[10]

5. (a) Photons of light incident on the metal surface cause the emission of electrons ✓

The electrons emitted are those near the surface of the metal✓

2

(b) Use of = hc / λ condone errors in powers of 10✓

5.2×10^{-19}J✓

Converts their energy in J to eV or work function to J

photon energy = 3.3 eV or work function = 3.7×10^{-19}J✓

Compares the two values and draws conclusion✓

4

(c) Diffraction effects (spreading of light) when light passes through a single slit

OR

interference patterns (light and dark fringes) using two slits or diffraction grating✓

Only waves diffract and interfere✓

2

[8]