M1.(a) (i) the minimum energy required by an electron✓
to escape from a (metal)surface✓
if refer to atom / ionisation zero marks

2

(ii) the (minimum) energy to remove an electron(from an atom)✓
from the ground state✓

2

(b) (use of $hf = eV$)
$6.63 \times 10^{-34} \times f = 5.15 \times 1.60 \times 10^{-19}$✓
$f = \frac{5.15 \times 1.60 \times 10^{-19}}{6.63 \times 10^{-34}}$ ✓ $= 1.24 \times 10^{15}$(Hz)

if no working and 1.24 × 10^15^(Hz) 1 mark

2

(c) (use of $hf = E_k + \Phi$)
$\Phi = 2.28 \times 1.60 \times 10^{-19} = 3.648 \times 10^{-19}$ (J) ✓
$E_k = 5.15 \times 1.60 \times 10^{-19} - 3.648 \times 10^{-19} = 4.59 \times 10^{-19}$ J ✓✓
3 sig figs
if clearly used 1.2 × 10^15^ then final answer must be to 2 sig. figs. for last mark to be awarded
accept 4.57 in place of 4.59

3

(d) (use of $c = f\lambda$)
$\lambda = \frac{3.0 \times 10^{8}}{1.24 \times 10^{15}} = 2.42 \times 10^{-7}$✓

$v = h / m\lambda = 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 2.42 \times 10^{-7}$
$v = 3010$ m s^{-1}✓✓
first mark minimum working – determination of wavelength
bald answer gets 2 marks
range to 3 sig figs 2900 – 3030

3

[12]

M2.(a) The process involves the ejection of electrons which are negatively charged. ✓

1

Any electrons ejected will only make the positive charge greater. ✓

1

(b) **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. Guidance provided in section 3.10 of the '*Mark Scheme Instructions*' document should be used to assist in marking this question.**

Mark	Criteria	QoWC
6	Both ideas fully analysed, with full discussion of alternatives.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
5	Both ideas analysed with supporting discussion but without alternatives	
4	Both ideas analysed, with one dealt with satisfactorily and the other with some supporting discussion	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
3	Both ideas analysed, with only one dealt with satisfactorily	
2	One idea analysed with some supporting discussion	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
1	One idea analysed, with little supporting discussion	
0	Unsupported combination or no relevant analysis	The student's presentation, spelling, punctuation and grammar seriously obstruct

		understanding.

The following statements are likely to be present.
To demonstrate threshold frequency:
The metal should be kept the same, and the light source varied.
Using any metal, and light sources 1 and 3,
no charge will be lost with light source 1
but charge will be lost with light source 3
because light source three has a greater photon energy and therefore frequency (from E=hf)
and is above the threshold frequency
as the photon energy is greater than the work function of the metal
but light source 1 has a photon energy less than the work function of the metal
so its frequency is below the threshold frequency.
To demonstrate work function
The light source should be kept the same, and the metal varied
Use light source 2 as the other two will either cause all three metals to lose their charge, or none of the metals to lose their charge.
Use each metal in turn, so that zinc loses its charge, due to its low work function, but copper and iron do not lose their charge.

6

(c) Work function in joules = $1.6 \times 10^{-19} \times 4.3 = 6.9 \times 10^{-19}$ J ✓

The first mark is for converting the work function into J

1

Use of hf = work function + KE_{max}

The second mark is for substituting into the photoelectric equation

1

$KE_{max} = hf$ – work function
$= (6.63 \times 10^{-34}) \times (1.2 \times 10^{15}) + 6.9 \times 10^{-19}$ ✓
$= 7.9 \times 10^{-19} – 6.9 \times 10^{-19}$
$= 1.0 \times 10^{-19}$ J ✓

The third mark is for the final answer
Allow 1.1

1

(d) The work function is the minimum amount of energy needed to remove the electron from the zinc surface ✓

Alternative

Reference to max ke corresponding to emission of surface electrons whilst electrons from deeper in the metal will be emitted with smaller ke

1

[12]

M3.D

[1]

M4.B

[1]

M5.C

[1]

M6.(a) energy of photon is constant / fixed OR energy given to electron is fixed ✓
energy required for electron to leave / escape / emit from the surface / metal
OR electron has to overcome work function ✓
maximum kinetic energy is the energy of photon minus the work function ✓
deeper electrons require energy to get to the surface OR have less E_k than surface electrons ✓

mention of energy levels means can only score first mark
photoelectric equation alternative for third mark if φ and hf defined

3 max

(b) (i) (*use of E = hf*)
energy of photon = $6.63 \times 10^{-34} \times 3.0 \times 10^{15}$ ✓ = 1.989×10^{-18} (J)
work function = $hf - E_k = 1.989 \times 10^{-18} - 1.7 \times 10^{-18} = 2.89 \times 10^{-19}$ ✓
work function = $2.89 \times 10^{-19} / 1.6 \times 10^{-19}$ ✓= (1.8 eV)

hf gets first mark even if in wrong equation

3

(ii) work function = hf_0
$f_0 = 1.8 \times 1.6 \times 10^{-19} / 6.63 \times 10^{-34}$ ✓ $= 4.3 \times 10^{14}$ ✓(Hz) ✓(2 sig figs)

2 sig . fig stand alone mark
Accept 4.4×10^{14}

3

(c) (i) decrease the energy of(incident) photons ✓
decrease the maximum kinetic energy of electrons ✓
OR
decrease the energy of(incident) photons ✓
hence fewer deeper electrons escape ✓
OR
below threshold frequency ✓
no electrons emitted ✓
OR
as energy of each photon decreases but intensity is constant (there are more photons / sec) ✓
number of emitted electrons(/sec) must increase ✓

for last two alternatives must get first mark before can qualify for second mark

2

(ii) increase in photons cause increase in (emitted) electrons ✓
double number of electrons / photons OR reference to rate /per second ✓

if refer to energy levels / atoms can only award first mark

2

[13]

M7.(a) Minimum energy to remove an electron

B1

from a (metal) surface

B1

2

(b) Converts 2.28 (e V) to 3.6×10^{-19} (J) / $2.28 \times 1.6 \times 10^{-19}$

C1

Condone minus sign here on energy or

charge

Use of $hf = q\phi_0$

e.g. $f = 2.28 / h$ (will need to see subject)

or $2.28 = 6.6(3) \times 10^{-34} \times f$ or $f =$

$2.28 / 6.6(3) \times 10^{-34}$ (will need to see subject)

Makes f subject or substitutes correctly for h and $q\phi_0$

C1

allow equivalent substitution into $hf = q\phi_0 + KE_{max}$ where $KE = 0$

Penalise minus sign on answer

(f =) $5.5(0) \times 10^{14}$ (Hz) cao

A1

3

[5]