Question Number	Answer	Mark
***1(a)**	(QWC- Work must be clear and organised in a logical manner using technical wording where appropriate.) **Max 4** • Mention of photons **OR** photoelectric (NOT photoelectrons) **(1)** • Idea of one to one relationship from photon to electron **(1)** • Intensity of light relates to number of photons/sec **(1)** • wavelength/frequency is constant **(1)** • photon energy depends on frequency /reference to $E=hf$ **(1)** • Reference to hf = $\Phi + \frac{1}{2}mv^2_{max}$ **and** Φ constant **(1)**	**4**
1(b)(i)	*Use of E=hf* **(1)** E = 3.90×10^{-19} (J) **Or** calculate the minimum frequency for all elements **(1)** Caesium and potassium [independent mark] **(1)**	**3**
1(b)(ii)	**Max 3** Refers to equation *E or* $1/2mv^2 = hf - \Phi$ **(1)** [Do not accept hf = Φ + $1/2mv^2$, equation must be correctly rearranged] *Gradient* **(1)** (All parallel) because gradient = h *Intercept* (-)Φ is intercept on the energy axis /y axis **(1)** **OR** f_0 / threshold frequency/ minimum frequency required to release an electron for the metal is the intercept on the frequency axis **OR** Φ/h is the intercept on the frequency axis potassium will have the smallest Φ **OR** zinc has the greatest Φ **(1)**	**3**
1(b)(iii)	Zinc requires higher frequency /Zinc requires UV/UV dangerous (for students)/UV ionising/Can't get UV filters **(1)** (Do not allow converse argument about Caesium for this mark) Caesium works with visible light **(1)**	**2**
	Total for question	**12**

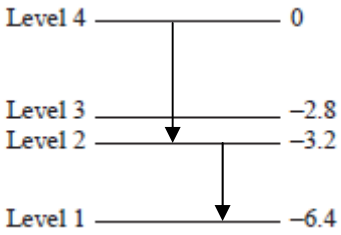
Question Number	Answer	Mark
2(a)	Photon energy is too small / less than work function (**do not** credit the frequency is less than the threshold frequency or electrons have not been given enough energy)	**(1)**
2(b)	**Method 1: Use of intercept x-axis** Use of $E = hf$ with $f = 10 \times 10^{14}$ Hz Divide by 1.6×10^{-19} to convert to eV (this mark can be scored even if wrong frequency used) $\Phi = 4.1$ (eV) Unit given on paper so no ue and ignore reference to J **OR** **Method 2:Use of Photoelectric Equation** Use of $hf = \Phi + E_{max}$ with any pair of values Divide by 1.6×10^{-19} to convert to eV $\Phi = 4.1 - 4.5$ (eV) Unit given on paper so no ue and ignore reference to J	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(max 3)**
2(c)	Gradient of graph is Planck's constant/e (accept just Planck's constant)	**(1)**
2(d)	Graph parallel to original graph cutting X axis with a value less than 10	**(1)** **(1)**
	Total for question	**7**

Question Number	Answer	Mark
3 (a)	A statement which implies only certain energies are allowed e.g. Allowed/possible energy of atom/electron (in an atom) Discrete energy of an atom/electron One of the energies of the atom/electron Energy an atom/electron can have	**1**
(b)	Photon is a (discrete) package/packet/quantum of (electromagnetic) energy/particle of light	**1**

(c)	(energy of) E_2 – (energy of)E_1	**1**
(d)	See $E = h c / \lambda$ **OR** use of $v = f\lambda$ Substitution into $E = h c / \lambda$ **OR** use of $E = hf$ $E = 3.14 \times 10^{-19}$ J or 1.96 eV **Example of answer** $E = (6.63 \times 10^{-34}$ Js $\times 3 \times 10^{8}) \div 6.33 \times 10^{-7}$ m $E = 3.14 \times 10^{-19}$ J	**1** **1** **1**
	Total for question	**6**

Question Number	Answer	Mark
4	Addition of words (order essential) photon metal energy (allow mass, charge, momentum) (photo)electron work function (of the metal)	 **1** **1** **1** **1** **1**
	Total for question	**5**

Question Number	Answer		Mark
5(a)	The (minimum) energy required to remove one/an electron from the surface of the metal (must refer to surface)	**(1)**	**1**
***5(b)**	(QWC- Work must be clear and organised in a logical manner using technical wording where appropriate.) • Increasing the intensity (of light) increases the number of electrons emitted(per sec) **Or** number of electrons emitted(per sec) depends on the intensity (of light) • One photon releases one electron • Intensity determines number of photons **OR** • Increasing the intensity (of light) does not increase the energy/speed of the electrons • One photon releases one electron • Energy of photon determined by/depends on frequency (not intensity) **Or** $E = hf$ **OR** • Below a certain frequency / threshold frequency no electrons emitted **Or** above a certain wavelength no electrons emitted • Energy of photons increases with / depends on frequency **Or** $E = hf$ • Each photon needs a minimum amount of energy / work function **Or** One photon releases one electron **OR** • Electron emission starts at once (even for low intensity) • One photon releases one electron • Wave theory would allow energy to build up **OR** • Increasing the frequency (of light) increases the energy/speed of the electrons **Or** Increasing the frequency (of light) increases the stopping potential • Energy of photon determined by/depends on frequency **Or** $E = hf$ • One photon releases one electron **Or** Wave theory would allow energy to build up (Max one mark for a 2nd or 3rd point if no correct observation given)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
	Total for question		**4**

Question Number	Answer		Mark
6(a)	A statement which implies only certain energy levels are allowed e.g. Allowed/possible energy of atoms/electrons Discrete energy of an atom/electron	**(1)**	**1**
6(b)	Identifies correct pairs of levels, 4 and 2 **AND** levels 2 and 1 Two arrows both showing correct direction [irrespective of identified levels]  	**(1)** **(1)**	**2**
16(c)	**3** Atom/electron gains energy and moves to a higher level **Or** atom/electron becomes excited atom/electron has discrete energies **Or** atom/electron can only move between fixed levels **Or** only certain energy changes are possible atom/electron falls to a lower level By emitting energy in the form of photons **Or** reducing their energy by emitting photons Photons have a specific energy/frequency **Or** reference to $E = hf$ **Or** photon energy $= E_2 - E_1$	**(1)** **(1)** **(1)** **(1)** **(1)**	**3**
6(d)	Use of $E = hf$ with any of the possible energy differences Identifies ΔE as (±) 0.4 ($\times 10^{-19}$ J) $f = 6.0 \times 10^{13}$ Hz <u>Example of calculation</u> Smallest energy difference is 0.4×10^{-19} J $f = 0.4 \times 10^{-19}$ J / 6.63×10^{-34} Js $f = 6.03 \times 10^{13}$ Hz	**(1)** **(1)** **(1)**	**3**
6(e)	Divides an energy by 1.6×10^{-19} Energy = 4.0 (eV) (no ue) <u>Example of calculation</u> Energy = 6.4×10^{-19} J /1.6×10^{-19} C Energy = 4.0 eV	**(1)** **(1)**	**2**
	Total for question		**11**

Question Number	Answer		Mark
7	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **MAX 6**		
	Mention of energy levels (ignore electron shells)	**(1)**	
	Electrons in atoms can only occupy certain (discrete) energy levels	**(1)**	
	Ground state is the lowest energy/level electron(s)/atom can occupy	**(1)**	
	Energy is transferred in the collisions	**(1)**	
	Electrons/atoms move to higher level / become excited (when they gain energy)	**(1)**	
	These electrons return (later) to lower level/ground state	**(1)**	
	By emitting energy in the form of photons / reducing their energy by emitting photons	**(1)**	
	Photons have a specific energy or frequency or reference to $E = hf$ or $E = E_2 - E_1$	**(1)**	**Max 6**
	Total for question		**6**

Question Number	Answer		Mark
8(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Reference to photons (may be descriptive, e.g. quantum of energy / light arrives in small packets / light particles …) Energy of photon greater than or equal to work function (of zinc) / $hf \geq \varphi$ Results in electron being emitted So (electroscope) loses charge / charge decreases (and leaf falls)	**(1)** **(1)** **(1)** **(1)**	**4**
8(b)	Photon energy (for visible light) is less than the work function OR frequency (of visible light) less than threshold frequency	**(1)**	**1**
8(c)	Use of $c = f\lambda$ to find frequency (award if hc/λ used) Use of $hf = \Phi + ½ m v^2$ to find KE Use of ke equation with m_e $v = 8.20 \times 10^5$ m s^{-1} <u>Example of calculation</u> KE = $(6.63 \times 10^{-34} \times 3 \times 10^8)/200 \times 10^{-9} - 6.88 \times 10^{-19}$ KE = 3.07×10^{-19} J $v = \sqrt{(2 \times 3.07 \times 10^{-19})/9.11 \times 10^{-31}}$ $v = 8.20 \times 10^5$ m s^{-1}	**(1)** **(1)** **(1)** **(1)**	**4**
8(d)	No change Photon energy doesn't change (with distance) **Or** photon energy depends (only) on frequency/wavelength	**(1)** **(1)**	**2**
	Total for question		**11**