PHOTOELECTRIC EFFECT

1. (a) The following equation describes the release of electrons from a metal surface illuminated by electromagnetic radiation.

$$hf = k.e._{max} + \phi$$

Explain briefly what you understand by each of the terms in the equation.

hf **Energy of a photon (1)**

$k.e._{max}$ **Kinetic energy of emitted electron/equivalent (1)**

ϕ **Energy to release electron from surface / equivalent (1)**

(3 marks)
[Total 3 marks]

2. A 60 W light bulb converts electrical energy to visible light with an efficiency of 8%. Calculate the visible light intensity 2 m away from the light bulb.

60 W × 8/100 (1)

$\times \frac{1}{4\pi (2\text{ m})^2}$ **(1)**

Intensity = 0.1 W m^{-2}

(3 marks)

The average energy of the photons emitted by the light bulb in the visible region is 2 eV. Calculate the number of these photons received per square metre per second at this distance from the light bulb.

Idea that "N" × 2 → Intensity (1)

Number of photons = 3 × 10^{17} m^{-2} s^{-1} (1)

OR $\frac{\text{Error carried forward } I \text{ Wm}^{-2}}{3.2 \times 10^{-19}\text{ J}}$

(2 marks)
[Total 5 marks]

3. (a) Describe briefly how you would demonstrate in a school laboratory that different elements can be identified by means of their optical spectra

Discharge tube/flame test (1)

Diffraction grating/prism (1)

Each element has its own pattern of lines (1)

(3 marks)

(b) The diagram below is a simplified energy level diagram for atomic hydrogen.

	______________	0 eV
First excited state	______________	–3.4 eV
Ground state	______________	–13.6 eV

A free electron with kinetic energy 12 eV collides with an atom of hydrogen and causes is to be raised to its first excited state.

Calculate the kinetic energy of the free electron (in eV) after the collision.

Kinetic energy = 1.8 eV (1)

Calculate the wavelength of the photon emitted when the atom returns to its ground state.

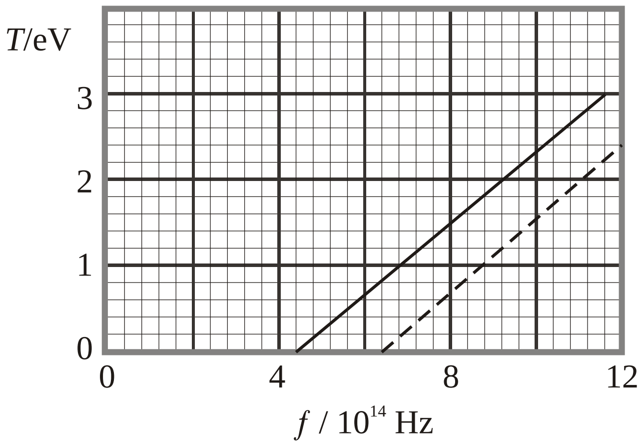
ΔE = 10.2 eV (1)

$\lambda = hc$/Energy value in Joules (1)

Wavelength = 1.2×10^{-7} m (1)

(4 marks)
[Total 7 marks]

4. The graph shows how the maximum kinetic energy T of photoelectrons emitted from the surface of sodium metal varies with the frequency f of the incident radiation.



A parallel line (1)
starting at a higher frequency (1)

Why are no photoelectrons emitted at frequencies below 4.4×10^{14} Hz?

Photon energy too small/less than ϕ (1)

(1 mark)

Calculate the work function ϕ of sodium in eV.

If using $\phi = hf - T$

then a valid pair of points (1)

with both points in the same units (1)

OR

If using $hf_o = \phi$

with $f_o = 4.4 \times 10^{14}$ Hz (1)

Work function = 1.8 eV (1)

(3 marks)

Explain how the graph supports the photoelectric equation $hf = T + \phi$

$T = hf - \phi$ is similar to $y = mx + c$ (1)

Straight line shows *T*/*f* relationship (1)

Negative intercept *T* axis shows ϕ (1)

Any two

(2 marks)

How could the graph be used to find a value for the Planck constant?

From the gradient (1)

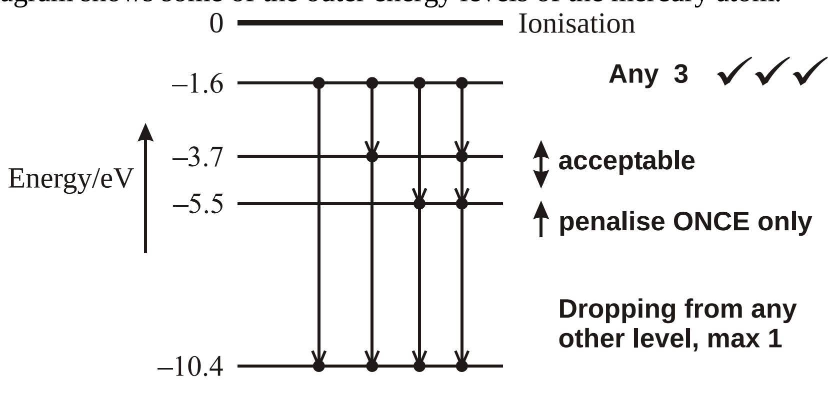
(not necessary to mention conversion factor)

(1 mark)

Add a line to the graph to show the maximum kinetic energy of the photoelectrons emitted from a metal which has a greater work function than sodium. (See graph.)

(2 marks)
[Total 9 marks]

5. The diagram shows some of the outer energy levels of the mercury atom.



Calculate the ionisation energy in joules for an electron in the -10.4 eV level.

any use of 1.6×10^{-19} (1)

Ionisation energy = **$1.66/1.7 \times 10^{-18}$ (J) (1)**
[$-1.66 \times 10^{-18} \rightarrow$ (1 only)]

Any other unit : unit penalty

(2 marks)

An electron has been excited to the –1.6 eV energy level. Show on the diagram all the possible ways it can return to the –10.4 eV level.

(3 marks)

Which change in energy levels will give rise to a yellowish line (λ = 600 nm) in the mercury spectrum?

Substitution in $\frac{hc}{\lambda}$ $\frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9}}$ **(1)**

÷ 1.6 × 10^{-19} (1)

= 2.07 (2 – 2.1) (eV) (1)

Level change -1.6 to -3.7 (1)

[Insist on '-' sign AND on higher → lower level, i.e. NOT -3.7 to -1.6]

Whole thing done backwards ⇒ 591 nm, can get 4/4

(4 marks)
[Total 9 marks]

6. Planck constant
Realise that h is the gradient
Correct attempt to find gradient [but ignore unit errors here]
h = (6.3 to 6.9) × 10^{-34} J s [No **bald** answers] 3

Work function
Use of hf_0 / use intercept on T axis/use of $\phi = hf - T$ **(1)**
ϕ = (3.4 to 3.9) × 10^{-19} J [-1 if –ve] [2.1 to 2.4 eV] **(1)** 2

Stopping potential
$T = 2.3 \times 10^{-19}$ //Use of $T = hf - \phi$ **(1)**
Use of V = their energy ÷ 1.6 × 10^{-19} **(1)**
V = 1.44 V // V = 1.1 – 1.8 V [ignore –ve sign] [ecf h] **(1)** 3

[8]