unified atomic mass constant,	u	=	1.66×10^{-27} kg
elementary charge	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg

$I = \frac{P}{A}$

$\frac{E}{tA} = \frac{Np(hf)}{tA}$

$I \propto Np$

$P = \frac{E}{t} = \frac{Np(hf)}{t}$

Qns 1(a):

A 1.0 mW laser produces red light of wavelength 663 nm. Calculate how many photons the laser produces per second.

$qV = 1.6\times10^{-19} \times 1V = 1eV = 1.6\times10^{-19}$ J

Qns 1(b):

Visible light has wavelengths spanning from 400 nm (violet) to 700 nm (red). Find the energy, in eV, of (i) a photon of red light and (ii) a photon of violet light.

$1eV = 1.6\times10^{-19}$ J

$E = hf = \_\_ J \div 1.6\times10^{-19} = \_\_ eV$

$10 J \div 1.6\times10^{-19} = \_\_ eV$

Qns 2:

Light of 543 nm is incident on a clean sodium surface. The photoelectrons released are found to have negligible amounts of kinetic energy. Determine the work function Φ for sodium metal in eV.

$qV = (1.6\times10^{-19})(1V) = 1eV$

$= 1 \times (1.6\times10^{-19})$ J

Qns 3:

The maximum kinetic energy of the electrons emitted from a metallic surface is 1 eV when the frequency of the incident radiation is 7.5×10^{14} Hz. Determine

(i) the work function of the metal in eV; $hf = hf_0 + qV$

(ii) the threshold wavelength of this metal.

$qV = 1eV$

$q = 1.6\times10^{-19}$

$hf = 4.9725\times10^{-19}$

$hf_0 = (4.9725\times10^{-19}) - (1.6\times10^{-19}) = 3.3725\times10^{-19}$ J $= 2.1078$ eV

$f_0 = \frac{3.3725\times10^{-19}}{6.63\times10^{-34}} = 5.09\times10^{14}$

Qns 4:

Violet light of 400 nm is incident on the surface of a potassium metal, work function 2.0 eV. Determine the maximum speed of electrons emitted from the surface.

$f < f_0$

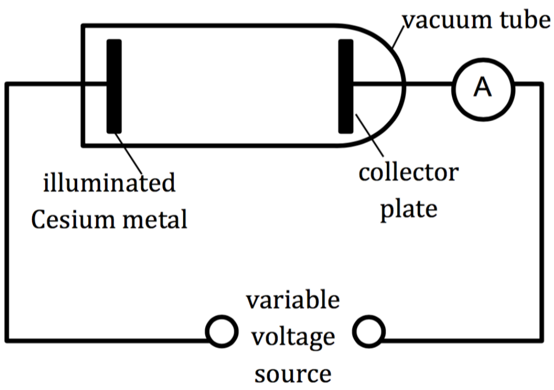
$f \geq f_0$

$hf = hf_0 + KE_{max}$

$hf = \Phi + KE_{max}$

Qns 5:

UV light of wavelength 350 nm falls onto Cesium metal of work function 2.1 eV. Find the stopping potential required for the ammeter to register zero current on the ammeter.



Qns 6:

(a) Explain what is meant by a photon.

(b) The photoelectric effect was important in the development of a photon theory of electromagnetic radiation.

(i) State one observation of the photoelectric effect that cannot be explained using the wave model.

(ii) Explain how the wave theory fails to account for this observation.

(iii) Explain how the photon model can account for this observation.

Qns 7:

When ultraviolet radiation of wavelength 319 nm falls on a metal surface, photoelectrons are emitted. The stopping potential was found to be 0.22 V. The same surface is then illuminated with electromagnetic radiation of wavelength 238 nm. Calculate

(a) the work function of the metal,

(b) the threshold frequency for the metal,

(c) the stopping potential when wavelength is 238 nm,

(d) the maximum speed of the photoelectrons for each wavelength.

(c = 3.00 x 10^{8} m s^{-1}, e = 1.60 x 10^{-19} C, m_e = 9.11 x 10^{-31} kg,
h = 6.63 x 10^{-34} J s)

Qns 8:

Electromagnetic radiation is incident normally on the surface of a metal. Electrons are emitted from the surface and these are attracted to a positively charged electrode, as shown in Fig. 2.1.

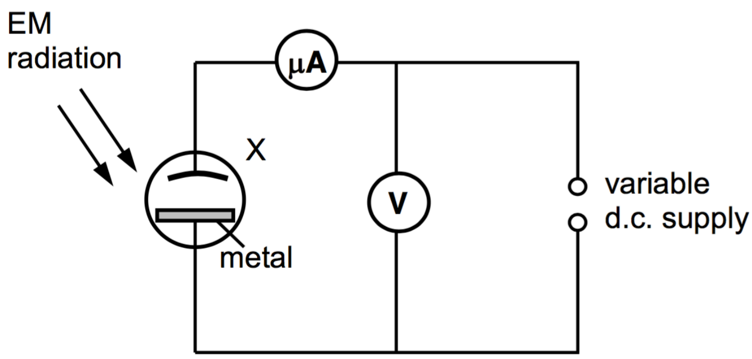


Fig 2.1

(a) Name the effect which gives rise to the emission of the electrons.

(b) State a word equation, based on the principle of conservation of energy, which describes this effect.

(c) **(i)** The current recorded on the microammeter is 2.1 μA. Calculate the number of electrons emitted per second from the surface.

(ii) The incident radiation has wavelength 240 nm. Calculate the energy of a photon incident on the surface.

(d) The intensity of the incident radiation is 8.2×10^3 W m^{-2} and the area of the surface is 2.0 cm^2. Calculate

(i) the power of the radiation incident on the surface.

(ii) the number of photons incident per second on the surface.

(iii) Hence determine the ratio

$$\frac{\text{number of electrons emitted per second}}{\text{number of photons incident per second}}$$

(e) If the intensity of the radiation is doubled what will be the effect on

(i) the saturated current

(ii) the maximum kinetic energy of the photoelectrons?

Qns 9:

An excited electron is at the E_2 energy state of a hydrogen atom.

(i) State the number of different possible de-excitation transitions possible.

(ii) Determine the wavelengths of the emitted photons with each possible transition, and identify which part of the EM spectrum these photons lie in.

Qns 10:

(a) Explain how the line spectrum of hydrogen provides evidence for the existence of discrete electron energy levels in atoms.

(b) Some of the electron energy levels in atomic hydrogen are illustrated in Fig. 3.1.

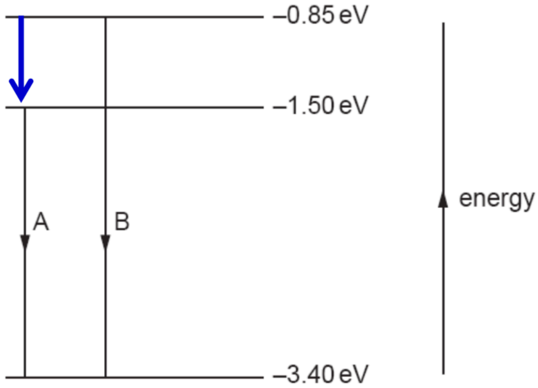


Fig. 3.1

Two possible electron transitions A and B giving rise to an emission spectrum are shown.

These electron transitions cause light of wavelengths 654 nm and 488 nm to be emitted.

(i) On the diagram above draw an arrow to show a third possible transition.

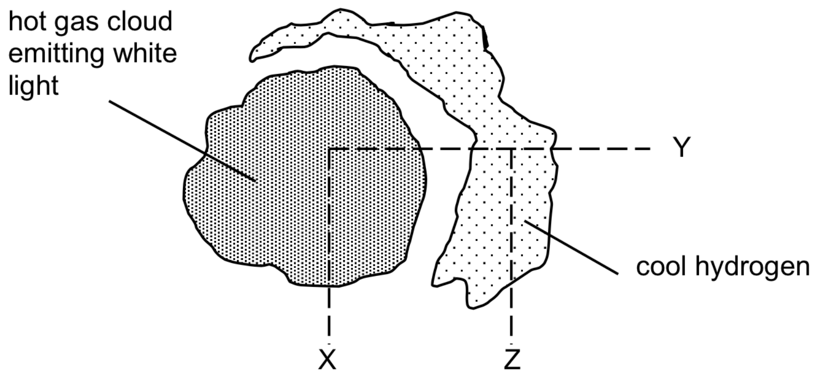
(ii) Calculate the wavelength of the emitted light for the transition in **(i)**

Qns 11:

(a) Explain what is meant by an *energy level* of an electron in an atom.

(b)(i)

A cool region of hydrogen gas surrounds a hot gas cloud emitting white light in outer space. Describe and explain the type of spectrum observed from point X, Y and Z.



(ii) Fig. 4.2 shows some of the energy levels of a hydrogen atom

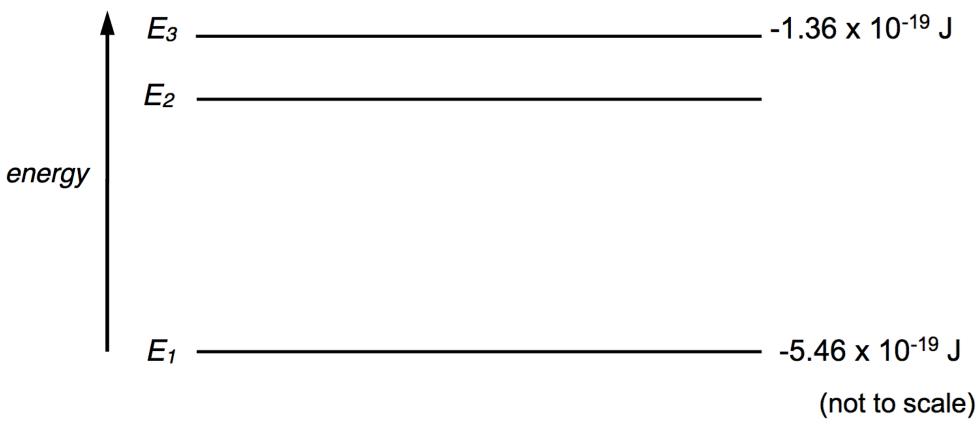


Fig. 4.2

1. Use the values of the energy levels E_3 and E_1 shown in Fig. 4.2 to calculate the frequency of the electromagnetic radiation emitted when an electron makes a transition between energy levels E_3 and E_1.

2. The frequency of radiation emitted when an electron makes a transition between energy levels E_3 to E_2 is 1.60×10^{14} Hz. Determine the wavelength of the electromagnetic radiation when an electron makes a transition between energy levels E_2 and E_1.

Qns 12

PJC 2008 H2 P3 Q5

(a) In a photoelectric emission experiment, ultraviolet radiation of wavelength 265 nm and intensity 150 W m^{-2} was incident on a rhodium surface in an evacuated tube, so that an area of 14 mm^2 was illuminated.

(i) Calculate the energy of the incident photon. [1]

[7.51×10^{-19} J]

(ii) Determine the rate of photons incident on the rhodium surface. [3]

[2.80×10^{15} s^{-1}]

(iii) Explain what is meant by the 'stopping potential'. [1]

(iv) If light of higher wavelength was used to illuminate the rhodium surface, state and explain how the stopping potential will change. [3]

(b) Fig 1.1 below shows some of the energy levels (measured in electron-volts) of the hydrogen atom.

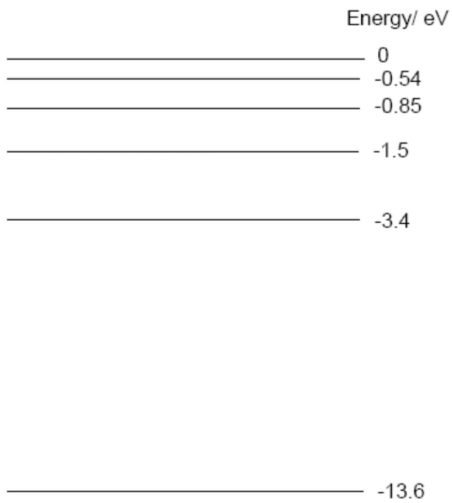


Fig. 1.1

(i) State the value of the ionization energy of hydrogen in joules. [1]

[2.18×10^{-18} J]

(ii) In the emission spectra for atomic hydrogen, the visible red line has a corresponding energy of 1.9 eV. Draw an arrow to show the electron transition that gives rise to this emission line on Fig. 1.1. Label it as **R**. [1]

(iii) On Fig. 1.1, draw arrows to show the electron transitions that will give rise to 2 spectral lines in the ultraviolet region. Label them as **S** and **T**. [1]

Qns 13

In a particular photoelectric emission experiment, the emitter of area 0.45 cm^2 is illuminated with monochromatic radiation of wavelength 300 nm and intensity 180 $W m^{-2}$. The current I in the circuit is measured for various values of the applied potential difference V between the collector and emitter. The variation of I with V is shown in **Fig. 2.1.**

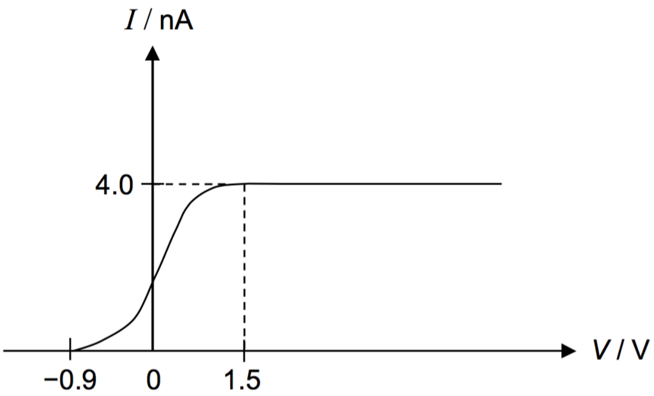


Fig. 2.1

(a) If the intensity of light is now doubled, explain how the current and the maximum velocity of the electrons will be affected by the intensity of light. [2]

(b) From the graph in **Fig. 2.1**, explain why

(i) the current remains at a constant value of 4.0 nA when V is equal or greater 1.5V. [2]

(ii) I is not zero even when V is zero. [2]

(c) **(i)** Calculate the rate of incidence of photons on the emitter. [2]

[1.22×10^{16} s^{-1}]

(ii) Calculate the rate of emission of electrons when V = 1.5 V. [2]

[2.5×10^{10} s^{-1}]

(d) By comparing the values from **(c)**, suggest a reason why the rate of emission of electrons is different from the rate of incidence of photons on the emitter.