Applecross Senior High School
Year 12 Physics
Waves, Photons & Quantum Sets Validation Test

/25

Name: Solutions

1. A typical microwave oven has an electrical power rating of 1100 W, but produces 700 W of microwaves at a frequency of 2450 MHz.

(a) Explain the difference in the two power ratings given. (1 mark)

Oven is not 100% efficient. Electrical energy is changed into heat energy (waste)

(b) Calculate the wavelength of the radiation produced. (1 mark)

$f = 2450 \times 10^6\ Hz$

$c = 3 \times 10^8\ ms^{-1}$

$\lambda = ?$

$c = f\lambda$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.45 \times 10^9} = 0.122\ m$

$= \underline{\underline{12.2\ cm}}$

(c) What is the energy of each photon produced? (1 mark)

$E_{ph} = hf = 6.63 \times 10^{-34} \times 2.45 \times 10^9$

$= \underline{\underline{1.62 \times 10^{-24}\ J}}$

(d) A cup of water is heated in this microwave oven for 2 minutes, 20 seconds in preparation for making a cup of coffee How many photons are produced by the oven in this time? (2 marks)

$t = 140\ sec$

Total $E = P \times t$

$= 700 \times 140$

$= 98\,000\ J$

No. of photons $= \frac{\text{Total Energy}}{\text{Energy per photon}}$

$= \frac{98000}{1.62 \times 10^{-24}}$

$= \underline{\underline{6.05 \times 10^{28}\ \text{photons}}}$

2. The threshold frequency for aluminium is 1.25 x 10^{14} Hz.

(a) calculate the work function of aluminium in both joules and electron-volts. (2 marks)

$f_0 = 1.25 \times 10^{14}\,Hz$ $W = hf_0 = 6.63\times10^{-34} \times 1.25\times10^{14}$

$\frac{8.29\times10^{-20}}{1.6\times10^{-19}} = 0.518\,eV$ $= \underline{\underline{8.29\times10^{-20}\,J}}\ (\underline{\underline{0.518\,eV}})$

An aluminium surface was then irradiated with violet light with a frequency of 7.10 x 10^{14} Hz and the resultant emitted electrons analysed.

Calculate, showing all working:

(b) The wavelength of the incident violet light. (1 mark)

$c = f\lambda$ $\lambda = \frac{c}{f} = \frac{3\times10^{8}}{7.1\times10^{14}}$

$= \underline{\underline{4.23\times10^{-7}\,m}}$

(c) The energy of the incident photons in both joules and electron-volts. (2 marks)

$E_{ph} = hf = 6.63\times10^{-34} \times 7.10\times10^{14}$

$= \underline{\underline{4.71\times10^{-19}\,J}}$

$E(eV) = E(J) \div 1.6\times10^{-19}$ $= \underline{\underline{2.94\,eV}}$

(d) The maximum kinetic energy of the emitted photo-electrons. (1 mark)

E_K electron $= E_{ph} - W$

$= 4.71\times10^{-19} - 8.29\times10^{-20}$

$= \underline{\underline{3.88\times10^{-19}\,J}}$ (or $2.42\,eV$)

(e) The maximum velocity of the emitted photo-electrons. (1 mark)

$E_K = \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2E_K}{m}}$

$= \sqrt{\frac{2\times3.88\times10^{-19}}{9.11\times10^{-31}}}$

$= \underline{\underline{9.23\times10^{5}\,ms^{-1}}}$

3. An experiment is conducted where the surfaces of both platinum and sodium are irradiated with blue light of wavelength 465 nm. Photoelectrons are found to be emitted from the sodium surface but not the platinum surface.

(a) Explain why this different effect has occurred with the two metal surfaces. (1 mark)

The blue light has a photon energy above the work function of Sodium, but below the work function of platinum.

Question 3. Continued.....see previous page.

(b) Explain the effect each of the following changes would have on the photoelectric current for **each** of the **metals**;

(i) The intensity of the incident beam is increased. (1 mark)

Sodium - will increase the photoelectric current (will eject more electrons)

Platinum - no change

(ii) The blue light was replaced with a light of much longer wavelength. (1 mark)

Sodium - Photocurrent may stop if frequency goes below threshold frequency

Platinum - no change

(iii) The blue light was replaced with a light of much shorter wavelength. (1 mark)

Sodium - no change

Platinum - Photocurrent may start if frequency is above threshold frequency.

(iv) A small reverse potential is applied between the anode and cathode of the photoelectric tube. (1 mark)

Sodium - Photocurrent will be reduced

Platinum - If no photocurrent already - no change

4. The light from stars can be analysed by digitising and enhancing the spectrum produced by passing the starlight through a diffraction grating. The observed continuous spectrum contains distinct black lines.

(a) Explain how these black lines are produced. (1 mark)

Continuous spectra is produced in core of star and passes through gases as it exits the star. Specific frequencies from the continuous spectra are absorbed producing energy level jumps up that are characteristic to the elements in the atmosphere of the star.

(b) Astronomers can use these lines to predict the elemental composition of the observed stars by comparison with line emission spectra produced by various elements under laboratory conditions.

Explain how this method gives accurate predictions of the elements in the observed stars. (1 mark)

Black lines are characteristic to elements, so lines can be used to identify the elements in the star.

5, At right is a diagram representing some of the energy levels in a caesium atom.

13.87 eV Ionization

2.30 eV

1,38 eV

0.00 eV

A beam of electrons with energy of 2.70 eV is incident on a gaseous sample of caesium in a sealed container.

(a) What are the possible energies that electrons in the emerging beam can have? (Scattered Electrons) (1.5 marks)

$2.7 - 1.38 = 1.32 eV$

$2.7 - 2.3 = 0.4 eV$

$2.7 - 0 = 2.70 eV$

(b) What are the possible energies of any photons emitted? (1.5 marks)

$2.30 \rightarrow 0 = 2.30 eV$

$2.30 \rightarrow 1.38 = 0.92 eV$

$1.38 \rightarrow 0 = 1.38 eV$

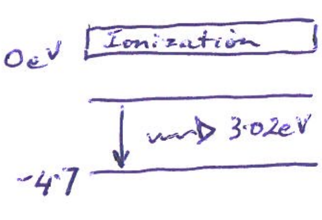
This sample of caesium was bombarded with photons forming a continuous spectrum containing all energies between 1.00 eV and 14.0 eV.

(c) What difference would be observed in this photon beam, after it emerged from the caesium sample? (1 mark)

There should be 3 black lines (3 frequencies of light missing) coresponding to the 3 jumps up from 0eV to 1.38eV, 2.30eV and 13.87eV. - 14eV

6. An electron undergoes a transition from a higher to a lower energy level of -4.7 eV and emits a photon with an ~~energy~~ frequency of 7.30 x 10^{14} Hz. In which energy level was this electron before it undertook this transition? (give its energy in eV) (2 marks)
Note that ionization is the highest level at 0.0 eV

$f = 7.30 \times 10^{14} Hz$



$E = hf = 6.63 \times 10^{-34} \times 7.30 \times 10^{14}$

$= 4.84 \times 10^{-19} J$

$E(eV) = 4.84 \times 10^{-19} \div 1.6 \times 10^{-19}$

$= 3.02 eV$

Energy Level $= -4.7eV + 3.02eV$

$= \underline{-1.68 eV}$

End of Test