Pages 66–68 Exam practice questions

1 Answer D

2 Answer A

3 Answer C

4 Answer B

5 Answer C

6 Answer B

7 Answer A

8 Answer D

9 Answer B

10 Answer A

11 a) A photoelectron is an electron released during the photoelectric effect / when it absorbs energy from a photon

b) Energy from each photon is used to release the photoelectron, and any surplus is the electron's KE. Electrons released from the surface have the most KE as they need to smallest amount of energy to be released. An electron can only absorb one photon.

c) Energy of photon = work function + max KE of photoelectron

$= 4.7 \times 1.6 \times 10^{-19} + 2.4 \times 10^{-20}$

$= 7.76 \times 10^{-19}$ J

wavelength = $hc/E = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 7.76 \times 10^{-19} = 2.56 \times 10^{-7}$m

12 a) Electron diffraction.

b) The new theory must be able to explain experimental data, e.g. electron diffraction patterns; experimental data must be reproducible, e.g. by scientists in other laboratories using different crystals; evidence and theory must be presented to peers and peer reviewed, e.g. in the literature and at conferences.

13 a) Threshold frequency is the minimum frequency required to release photoelectrons from a material.

b) Different materials have different work functions. Since hf = work function when photoelectrons are just released, then the threshold frequency = work function/h.

This means that the threshold frequency of light increases if a material's work function increases.

c) The work function is the minimum energy needed to release an electron from the surface of a metal. It is measured in J or eV.

14 a) Wave–particle duality is when particle-like and wave-like behaviour is exhibited by particles or waves.

b) The de Broglie wavelength = h/mv

$= 6.63 \times 10^{-34} / (3.2 \times 10^{4} \times 9.11 \times 10^{-31})$

$= 2.3 \times 10^{-8}$ m

c) The proton's mass (and momentum) is greater than the mass and momentum of an electron by a factor of 1836, so the proton's wavelength is smaller by the same factor = 1.24×10^{-11} m

15 a) $E = hf = 9.28 \times 10^{-19}$ J

b) Number of photons per second = total energy per second/energy per photon

$= 3.0 \times 10^{7} / 9.28 \times 10^{-19}$

$= 3.23 \times 10^{11}$

16 Main features – electrons released with range of KE when light above a threshold frequency shines on a material; above the threshold, increasing intensity increases number of photoelectrons released; increasing frequency increases the maximum KE of electrons released.

Explanation: light travels as a stream of photons which are absorbed by electrons; the energy, and therefore frequency, of photons must be greater than the energy needed to release each electron; increasing intensity increases the number of photons and therefore the number of electrons emitted.

17 a) The work function is the minimum energy needed to release an electron from the surface of a metal.

b) Energy of photon = $\frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{280 \times 10^{-9}} = 7.10 \times 10^{-19}$ J

The work function = $3.6 \times 1.6 \times 10^{-19}$ J = 5.76×10^{-19}

The energy of the photon is greater than the work function, so a photoelectron will be emitted.

c) Minimum energy required = $(3.6 + 2) \times 1.6 \times 10^{-19} = 8.96 \times 10^{-19}$ J

$\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{8.96 \times 10^{-19}} = 2.22 \times 10^{-7}$ m = 222 nm.

Pages 68–69 Stretch and challenge questions

18 a) The electrons have an associated wavelength that is similar in size to the lattice spacing.

b) i) 600 V; Kinetic energy = $eV = 1.6 \times 10^{-19} \times 5000 = 8 \times 10^{-16}$ J;

ii) Velocity, $v = \sqrt{2E/m} = 4.19 \times 10^{7}$ ms^{-1}

iii) De Broglie wavelength, $\lambda = h/mv = 6.63 \times 10^{-34} / (9.1 \times 10^{-31} \times 2.96 \times 10^{7})$

$= 1.7 \times 10^{-11}$ m

c) i) If the potential difference halves

ii) the electron's KE halves

iii) its momentum decreases by a factor of 4 (KE is proportional to velocity^2)

iv) its de Broglie wavelength increases by a factor of 4 (proportional to 1/momentum).

d) The diameter of the rings increases because the electrons are travelling slower, have a longer wavelength and are diffracted more.

e) The electrons are moving charged particles travelling through the magnetic field and feel a force that deflects them.

19 a) Each image has regions of dark and bright patches (fringes); (the colour and scale cannot be directly compared).

b) These fringe patterns are only seen when waves diffract and interfere, which are wave properties. These pictures provide evidence that protons, electrons and single photons can behave as a wave.

c) The de Broglie wavelength is about 10 000 times smaller for protons than electrons (calculated in TYQ), and these are much smaller than the wavelength of visible light so the spacing of the slits would be different for diffraction to occur.