Unit Test :- Radioactivity, Nuclear Reactions - Quantum Physics

A Physics

Data

- $c_{light} = 3 \times 10^8$ m/s
- Planck $h = 6.6 \times 10^{-34}$ Js
- mass of electron $m_e = 9.1 \times 10^{-31}$ kg

1. This question is about using a radioisotope, Sodium-25, half life 15 hours, to find the volume of blood in a patient.
A small volume of salt solution, containing Sodium-25 has a total activity of 64 000 Bq.
It is injected into the person.

a) Calculate the decay constant of Sodium-25. (in s^{-1}) (2

b) Calculate the number of nuclei of Sodium-25 in the sample (2

c) After 30 hours a 10 cm^3 blood sample is taken and has an activity of 19 Bq. Estimate the volume of blood in the patient (3

d) Why wait 30 hours ? (1

e) What is the total activity of all the Sodium-25 in the patient's body 3 days after the injection ? (3

[11]

2. a) Why are all the energy levels negative ? (2

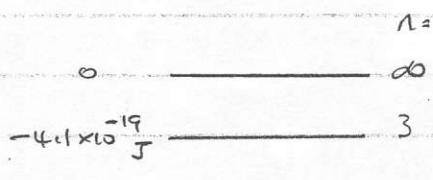
b) Why do fixed energy levels lead to line spectra ? (3

c) A light photon with wavelength 125 nm raises an electron from energy level 1 to level 2.
What is the energy of level 2 ? (4)

d) A photon with a slightly shorter wavelength hits the atom.
Describe + explain what happens (2

e) An electron drops from level 3 to level 1.
Describe, with a calculation, what happens as a result (3

[13]



Unit Test - Nuclear + Quantum Phys A Physics

3. a Explain the meaning of —

- work function (1
- threshold frequency (1

When light of wavelength 90 nm is shone on the newly discovered metal Eatonium, it emits photoelectrons with a maximum velocity of 5×10^5 m/s.

Calculate ...

b) ... the frequency of the light. (2

c) ... the maximum kinetic energy of the electrons (2

d) ... the work function of Eatonium. (2

e) When brighter light of this wavelength is shone on the metal, what happens to the number of electrons and their maximum velocity? (2

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① ... 1. 11 2. 13 3. 10.

Unit Test - Quantum Physics — Answers 2 — A Physics

1. a) $\ln 2 = T_{\frac{1}{2}}\lambda$ ① $\rightarrow \lambda = \ln 2 / T_{\frac{1}{2}} = \frac{\ln 2}{15\times60\times60} = 1.28\times10^{-5}$ ① s^{-1}

b) Activity $A = -\lambda N$ ① $\rightarrow N = A/\lambda = 64000 / 1.28\times10^{-5} = 4.99\times10^{9}$ ① nuclei

c) After 30 h total activity is $64000 \div 2 \div 2 = 16\,000$ Bq ①

So volume of blood is $16\,000 / 19$ ① $= 842 \times 10 = 8420$ ① cm^3 (3

d) for the blood to be thoroughly mixed

e) Use $A = A_0 e^{-\lambda t}$ ① $= 64000 \times e^{(-1.28\times10^{-5}\times3\times24\times60\times60)}$

$= 64\,000 \times 0.0359$ ②

$= 2297$ (or 2300) Bq (3

2. a) Because the − electron is attracted to the + nucleus ① and work must be done to remove it ①

b) Electrons dropping in level emit photons ①, with frequency depending on the energy difference ① ... if the energy levels are fixed, then the atom will emit light of certain frequencies ①

c) 125 nm $\rightarrow f = v/\lambda = 2.4\times10^{15}$ Hz ① $\rightarrow$ energy $E = hf$ ① $= 1.584\times10^{-18}$ J ①

So energy level 2 is -2.5×10^{-18} J $+ 1.58\times10^{-18}$ J $= -9.2\times10^{-19}$ J ①

d) Nothing (photon not absorbed) ① ... because its energy does not exactly match the energy gap ①

e) level 3 → 1 Energy diff $= 2.09\times10^{-18}$ J ①

$E = hf \rightarrow$ photon frequency $f = E/h = 2.09\times10^{-18} / 6.6\times10^{-34} = 3.2\times10^{15}$ Hz ①

a photon is emitted ① with frequency of 3.2×10^{15} Hz (or $\lambda = 9.5\times10^{-8}$ m)

Total /35

3. a) Φ ... minimum energy/work need to just extract an electron from the metal

f_0 ... minimum light frequency to just extract photoelectrons (2

b) $v = f\lambda \rightarrow f = v/\lambda$ ① $= 3\times10^8 / 92\times10^{-9} = 3.26\times10^{15}$ Hz ① (2

c) electron KE $= \frac{1}{2} m_e v^2$ ① $= \frac{1}{2}\times9.1\times10^{-31}\times(5\times10^5)^2 = 1.14\times10^{-19}$ J ① (2

d) $E_{photon} = hf = \Phi + \frac{1}{2}mv^2$ ① $\Rightarrow \Phi = hf -$ electron KE

So ... $\Phi = 6.6\times10^{-34}\times 3.26\times10^{15} - 1.14\times10^{-19}$ J

$= 2.15\times10^{-18}$ J $- 1.14\times10^{-19} = 2.04\times10^{-18}$ J ① (2

e) brighter light .... more photons of same energy .... so ....

more photoelectrons ① but same max velocity ① (2