Solutions to "From Quanta To Quarks" THSC Questions

(a) Bohr postulated that electrons within an atom could only occupy certain allowed orbits or stationary states and could not exist anywhere else in the atom. The energy of electrons in an atom was thus quantised and could only take on certain discrete values. (1) Further, Bohr stated that electrons within these stationary states did not radiate energy, which overcame the problem with the Rutherford Model which suggested that electrons would emit a continuous stream of energy as they spiralled down towards the nucleus, making all atoms inherently unstable. (1)

(b)(i) Mass on LHS $= 1.0078 + 7.0160 = 8.0238\,u$

Mass on RHS $= 2 \times 4.0026 = 8.0052\,u$

$\Delta m = RHS - LHS = -0.0186\,u$

$\therefore$ Mass has been lost in this reaction.

$\therefore$ Energy has been <u>released</u>. (1)

(ii) Mass defect $= 0.0186\,u$ (from (i) above) (1)

$\therefore$ Energy released $= 0.0186 \times 931.5$

$= 17.3$ MeV (1)

$= (17.3 \times 1.6 \times 10^{-13})$ J

$= 2.77 \times 10^{-12}$ J (1)

<u>OR</u> convert amu into kg and then use $E = mc^2$.

(c)(i) Bohr postulated that when an electron in an atom moves from one stationary state to another it does so by absorbing or emitting exactly the energy difference between the stationary states. $\Delta E = E_f - E_i = h\nu$. Thus, when an electron drops from a higher energy level of hydrogen to a lower energy level, it emits electromagnetic energy of a discrete value ΔE, with a discrete frequency ν corresponding to a particular colour if in the visible part of the EM spectrum. So, electron transitions between particular energy levels, correspond to particular, individual spectral lines in the hydrogen emission spectrum. Since only certain discrete electron energy values are allowed, only certain discrete spectral lines exist in the hydrogen spectrum.

(1) = partial explanation (2) = full explanation

(ii) $$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\therefore \frac{1}{\lambda} = 1.097 \times 10^7 \times \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$ (1)

$$= 1.52 \times 10^6 \text{ m}^{-1}$$

$$\therefore \lambda = \underline{6.56 \times 10^{-7} \text{ m}} \text{ or } \underline{656 \text{ nm}}$$ (1)

(d) Phosphorus-32 is used in agriculture for tracking a plant's uptake of fertilizer from roots to leaves by addition of this radioactive tracer to the soil water. As it has a half-life of 14.3 days and emits β-particles its passage through the plant can be traced and the tagged fertilizer's rate of uptake mapped. β-particles have sufficient penetration power to emerge from root systems + from inside plant tissues. They can be detected by Geiger-Muller tubes. Only small, safe quantities need to be used.

(For 3 marks – must correctly name (+ spell) an isotope used in agriculture, accurately describe how it is applied, how it works (does its job) + how it is detected if appropriate (eg as in the case of tracers).)

(e) The Manhattan Project, the project set up to plan and build an atomic bomb was of great significance to society in both positive and negative ways. From the positive perspective, the project led to a rapid end to World War II. Perhaps the greatest positive outcome of the project was the very large increase in knowledge about the nucleus and nuclear fission. This knowledge has been used in many peaceful, productive ways: nuclear fission reactors for the controlled release of nuclear energy have been built – these provide society with an alternative power source to fossil fuels and with radioactive isotopes that can be used in medicine, industry, agriculture and other areas. From the negative perspective, the Project led directly to massive destruction on a scale never seen before and the loss of hundreds of thousands of human lives when atomic bombs were dropped on Hiroshima and Nagasaki in August 1945. The radioactive fallout from these blasts killed thousands of Japanese people and led to genetic disease and disorders for many generations afterwards. Another negative impact of the Manhattan Project ~~is~~ is that it led to further research and development of nuclear weapons — nuclear missiles, hydrogen (fusion) bombs, neutron bombs — and ultimately to a proliferation of nuclear weapons in several countries around the world. This has placed the world in real danger of self-destruction. It is also true to say that the Cold War and arms race that resulted probably cost the world the chance to rid ourselves of disease and hunger. If we add to the above the very real problem of disposing of or storing nuclear waste materials from nuclear reactors, it is very clear that the Manhattan Project has probably had a much greater negative impact on society than can be compensated for by its positive spin-offs.

(For 4 Marks — mention some of the above — should do both +ve + -ve impacts. My answer is a typical "8-Mark" ~~question~~ answer.)

(f) Experiments during the 1920's + 1930's on beta-decay seemed to indicate that the law of conservation of energy was being violated. The total energy lost by the nucleus during β-decay was not equal to the total energy of the emitted β-particle. Further to this, the β-particles emitted were distributed over a wide range of energies from very low to a particular maximum value. In an effort to account for this energy distribution, Wolfgang Pauli suggested in 1930 the existence of a neutral particle (named the neutrino by Enrico Fermi) that was ejected from a nucleus along with the β-particle. This neutrino had no mass, no charge but did possess spin, energy and momentum. Pauli proposed that it was this neutrino particle that carried away the "missing" energy in β-decay. He also showed that the neutrino made sense of the energy distribution of β-particles in β-decay, since β-particles would obviously be emitted with a range of energies depending on how much energy was carried away by the neutrino.

(For 4 Marks you should really have all of the above. I was generous when marking this one.)

(g) The term "nucleons" refers to the protons and neutrons located inside the nucleus. Clearly, both particles possess mass and will therefore attract each other with a gravitational force in accordance with Newton's Law of Universal Gravitation. Let us consider two protons separated by a distance "d". The gravitational force between the protons is:

$$F_G = \frac{G m_1 m_2}{d^2}. \quad \text{So, } F_G \propto \frac{6.67\times10^{-11}\times(1.673\times10^{-27})^2}{d^2}$$

$$\therefore F_G \propto 1.87\times10^{-64}/d^2$$ (1)

Now since protons are positively charged, there will also be an electrostatic force of repulsion between the two protons separated by distance "d" in the nucleus. The size of this force is:

$$F_E = k.\frac{q_1 q_2}{d^2}. \quad \text{So, } F_E \propto \frac{9\times10^9\times(1.602\times10^{-19})^2}{d^2}$$ (1)

$$\therefore F_E \propto 2.34\times10^{-28}/d^2$$

(1) (1)

Clearly, the gravitational force between nucleons is 36 orders of magnitude smaller than the electrostatic force between the protons.

⊛ A general appeal ⇒ learn to SPELL the physics names + terms that pertain to this topic.