A Level H2 Physics Tutorial 20: Nuclear Physics

Syllabus :

(a)) infer from the results of the Rutherford α-particle scattering experiment the existence and small size of the atomic nucleus .

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1. (i) Describe the Rutherford α-particle scattering experiment.

(ii) How do the results show the existence and small size of the atomic nucleus?

(b) distinguish between nucleon number (mass number) and proton number (atomic number)

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2. State the meanings of :

(i) nucleon number

(ii) proton number

(c) show an understanding that an element can exist in various isotopic forms each with a different number of neutrons in the nucleus $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$

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3. (i) Explain what an isotope is.

(ii) Give an of an isotope of carbon-12 and its use.

(d) use the usual notation for the representation of nuclides and represent simple nuclear reactions by nuclear equations of the form

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4. (i) $^{238}_{92}U \rightarrow ^{234}_{90}Th + $ ____

(ii) $^{2}_{1}H + ^{3}_{1}H \rightarrow$ _____ + n

(e) state and apply to problem solving the concept that nucleon number, charge and mass-energy are all conserved in nuclear processes.

(f) show an understanding of the concept of mass defect

(g) recall and apply the equivalence between energy and mass as represented by $E = mc^2$ to solve problems

(h) show an understanding of the concept of nuclear binding energy and its relation to mass defect

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5. This is a possible nuclear reaction in the Sun :

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

The mass of each nucleus :

${}^{2}_{1}H$ 2.014102u
${}^{3}_{1}H$ 3.016049u
${}^{4}_{2}He$ 4.002602u
${}^{1}_{0}n$ 1.008665u

(i) Find the total mass of the reactants, and the total mass of the products in the unit of u.

(ii) Given that 1 u is 931.494 MeV, find the energy released in MeV. Note that 1 u is 931.494 MeV.

(i) sketch the variation of binding energy per nucleon with nucleon number

(j) explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission

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6. (a) Sketch the graph of binding energy per nucleon versus nucleon number. Label the approximate points of ${}^{1}H$, ${}^{4}He$, ${}^{56}Fe$, and ${}^{235}U$.

(b) Explain, using this graph, why fission of uranium nuclei and fusion of hydrogen nuclei can produce energy.

(k) show an understanding of the spontaneous and random nature of nuclear decay

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(l) infer the random nature of radioactive decay from the fluctuations in count rate

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(m) show an understanding of the origin and significance of background radiation

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(n) show an understanding of the nature of α, β and γ radiations (knowledge of positron emission is not required)

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7. State what is :

   (a) α particle

   (b) β particle

   (c) γ particle

(o) show an understanding of how the conservation laws for energy and momentum in β decay were used to predict the existence of the neutrino (knowledge of antineutrino and antiparticles is not required)

(p) define the terms activity and decay constant and recall and solve problems using the equation A = λN

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8. The activity A of a 1 gram sample of uranium-238 is 1.23×10^4 Bq.

   (i) What is the meaning of Bq ?

   (ii) Find the number N of ^{238}U nuclei in the sample.

   (iii) Using the relation $A = \lambda N$, find the decay constant, λ.

(q) infer and sketch the exponential nature of radioactive decay and solve problems using the relationship $x = x_0 \exp(-\lambda t)$ where x could represent activity, number of undecayed particles or received count rate

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9. The decay constant of uranium-238 is 4.0×10^{-18} s^{-1}.

   (a) Find the number N_0 of atoms in 1 g of uranium-238 (^{238}U).

   (b) Find the initial activity A_0.

   (c) Write down the formula for the activity A at time t.

   (d) Find the activity after 4.5 billion years.

(r) define and use half-life as the time taken for a quantity x to reduce to half its initial value

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(s) solve problems using the relation $\lambda = \ln 2 / t_{1/2}$

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10. What is the definition of half-life of a radioactive element?

    The half life of uranium-238 is 4.5 billion years. Find the decay constant.

(t) discuss qualitatively the effects, both direct and indirect, of ionising radiation on living tissues and cells.

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11. (a) State 2 indirect effects of ionising radiation on living tissues and cells.

    (b) State 2 direct effects of ionising radiation on living tissues and cells.