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University Examinations 2022/2023

THIRD YEAR, SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN MEDICAL LABORATORIES SCIENCES

SCH 3353: NUCLEAR CHEMISTRY AND RADIOACTIVITY

DATE: APRIL 2023 **TIME:2 HOURS**

INSTRUCTIONS: *answer question one and any other two questions*
Periodic table of elements is attached

QUESTION ONE (30 MARKS)

a) The pattern of nuclear stability can be used to predict the likely mode of radioactive decay using periodic table attached and these pattern; predict the mode of radioactive decay in each of the following (6 marks)

(i) Phosphorous – 29

(ii) Carbon – 14

(iii) Uranium – 238

b) Explain why an isotope with two protons and zero neutron does not exist (2 marks)

c) What are transuranium elements? Given an example of transuranium element (2 marks)

d) Identify the daughter nucleus in each of the following decays and write balanced nuclear equation (6 marks)

(i) Beta decay of tritium

(ii) Positron decay of Yttrium – 83

(iii) Alpha decay of protactinium – 225

e) Each of the following equations represent a fission reaction. Complete and balance the equations (4 marks)

(i) $^{241}Am \rightarrow ^{134}I + ^{107}Mo + 3?$

(ii) $^{235}u + {}_{0}^{1}n \rightarrow ? + ^{138}Te + 2{}_{0}^{1}n$

f) When iranium – 235 nuclei are bombarded with neutrons, they can split apart in a variety of ways, like glass balls that shatter into pieces of different sizes. In one process, uranium – 235 forms barium – 142 and kypton – 92

$^{235}_{92}u + {}_{0}^{1}n \rightarrow {}^{142}_{56}Ba + {}^{92}_{36}Kr + 2{}_{0}^{1}n$

Calculate the energy (in Joules) released when 9.0 g of uranium - 235 undergoes this fission reaction. The masses of the particles are $^{235}_{92}u$, 235. 04 *amu*, $^{142}_{56}Ba$ = 141.92 *a.m.u*, $^{92}_{30}Kr$, = 91.92 *a.m.u*, $^{1}_{0}n$ = 1.0087 *a.m.u* (a.m.u = 1.6605 x10^{27}kg; C = 3.0 x 10^{8}m/s) (6 marks)

g) Explain each of the following terms (4 marks)

(i) Spontaneous nuclear fission

(ii) Induced nuclear fission

QUESTION TWO (20 MARKS)

a) Explain three differences between chemical reaction and nuclear reactions (6 marks)

b) Calculate the nuclear binding energy for helium – 4 given the following masses ^{4}He = 40026 a.m.u ^{1}H = 1.0078 a.m.u and $^{1}_{0}n$ = 1.0087 a.m.u (3 marks)

c) What is the meaning of "critical mass" in nuclear fission? (2 marks)

d) Explain why heavy nuclides are most likely to undergo fission whereas light nuclides are most likely to undergo fusion (4 marks)

e) Define each of the following terms (5 marks)

(i) Nucleons

(ii) Radioactive decay

(iii) Nuclear transmutation

(iv) Nuclide

(v) Nuclear decay series

QUESTION THREE (20 MARKS)

a) A sample of carbon of mass 1.00 g from wood found in an archeological site gave 7900 carbon -14 disintegrations in a period of 20 h. in the same period, 1.00g of carbon from a modern source underwent 18400 disintegrations. calculate the ages of the sample (t_2^1 of carbon = 5730 yrs) (3 marks)

b) Explain how the following two types of equipment to monitor radiation works

(i) Geiger counter (5 marks)

(ii) Scintillation counter (5 marks)

c) Rubidium – 87 has a half-life of 4.88 x 10^{10}yrs

(i) What are the rate constant and the rate of disintegration of a sample containing 2.5 mg rubidium – 87 (4 marks)

(ii) If a person applied 0.5 mg rubidium – 87 into a system under study, how much of it remains after 9 months (3 marks)

QUESTION FOUR (20 MARKS)

a) What fraction of the original activity of ^{238}U that remains after 9.0 billion years ($t\frac{1}{2} = 4.5x10^9$ yrs)? (5 marks)

b) Potassium – 40 which is presumed to exist at the formation of the earth is used for dating minerals. If one-half of the original potassium – 40 exists in a rock how old is the rock? (half-life of ^{40}K is 1.26 x10^9 yr) (5 marks)

c) Someone is exposed to a source of β radiation that results in a dose rate of 1.0 rad/day. Given that nausea begins after a dose equivalent of about 100 rem, after what period will that symptom of radiation sickness be apparent? (4 marks)

d) The cobalt – 59 has atomic mass of 58.933 a.m.u given that the mass of Hydrogen – 1 is 1.007825 a.m.u and mass of neutron is 1.0087 a.m.u

(i) Calculate the mass defect in cobalt – 59 (3 marks)

(ii) Determine the nuclear binding energy of cobalt – 59 (1 kg = 6.022x10^{26} a.m.u, IJ = 1 kgm^2/s^2) (8 marks)