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University Examinations 2023/2024

THIRD YEAR SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR
OF SCIENCE IN CHEMISTRY

SCH 3353: NUCLEAR CHEMISTRY AND RADIATION CHEMISTRY

DATE: APRIL 2024

TIME: 2 HOURS

INSTRUCTIONS: Answer question *one* and any other *two* questions

QUESTION ONE (30 MARKS)

- a) Describe the following terms: (3 marks)
- Radiochemistry
 - Internal conversion
 - electron capture
- b) Write the equations for the following nuclear reactions:
- The alpha decay of ${}_{94}^{242}\text{Pu}$ (2 mark)
 - Magnesium-25 undergoes positron emission (2 mark)
 - Americium-243 undergoes beta emission (2 mark)
- c) Compare and contrast nuclear reactions with chemical reactions (6 marks)
- d) Define nuclear mass defect and nuclear binding energy (2 marks)
- e) Calculate the nuclear binding energy of helium-4 given the following masses: ${}^4_2\text{He} = 4.0028$ a.m.u; ${}^1_1\text{P} = 1.0078$ a.m.u and, ${}^1_0\text{n} = 1.0087$ a.m.u (given that 1 a.m.u = 1.6605×10^{-27} kg and $1\text{J} = 1\text{kg m}^2\text{s}^{-2}$) (4 marks)
- f) With reasons, predict the mode of decay of each of the following nuclides (4 marks)

- i) carbon-14,
- ii) xenon-118.

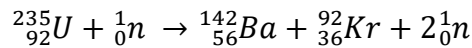
A wooden object from an archeological site is subjected to radiocarbon dating. The activity of the sample that is due to ^{14}C is measured to be 11.6 disintegrations per second. The activity of a carbon sample of equal mass from fresh wood is 15.2 disintegrations per second. The half-life of ^{14}C is 5715 yr. What is the age of the archeological sample? (5 marks)

QUESTION TWO (20 MARKS)

- a) $^{17}_8\text{O}$ is an isotope of oxygen that can be made through nucleosynthesis by bombarding nitrogen-14 with an alpha particle.
 - i) Explain what is meant by nucleosynthesis (2 marks)
 - ii) Assuming one proton and $^{17}_8\text{O}$ are the only products of the reaction, write a balanced nuclear equation to represent the reaction. (2 marks)
 - iii) Giving relevant example, differentiate between isotope and isotone (4 marks)
 - iv) With reason, Predict the mode of reaction of $^{17}_8\text{O}$ (2 marks)
- b) Radioactive decay proceeds according to a principal called the half-life.
 - i) Define half-life (2 marks)
 - ii) What is the meaning radioactive decay (2 marks)
 - iii) the radioactive element bismuth (Bi-210) can undergo alpha decay to form the element thallium (Tl-206) with a reaction half-life equal to five days. If we begin an experiment starting with 100 g of bismuth in a sealed lead container, what amount of Bismuth remains after 15 days? (3 marks)
 - iv) A rock contains 0.257 mg of lead-206 for every milligram of uranium-238. The half-life for the decay of uranium-238 to lead-206 is 4.5×10^9 yr. How old is the rock? (3 marks)

QUESTION THREE (20 MARKS)

- a) Define the term nuclear fission (1 mark)
- b) When uranium -235 nuclei is bombarded with neutrons, they can split a part in a variety of ways. In one process, uranium-235 forms barium-142 and krypton-92



Calculate the energy in joules released when 2.0g of uranium -235 undergoes this fission reaction. The masses of the particles are: ${}_{92}^{235}\text{U} = 235.04$ a.m.u; ${}_{56}^{142}\text{Ba} = 141.92$; a.m.u; ${}_{36}^{92}\text{Kr} = 91.92$; and, ${}_0^1\text{n} = 1.0087$ a.m.u (given that 1 a.m.u = 1.6605×10^{-27} kg and 1J = 1kg m²s⁻²) (7 marks)

- c) Differentiate between spontaneous nuclear fission and induced nuclear fission (2 marks)
- d) (i) What is ionizing radiation? (1 mark)
- (ii) Explain three ways in which ionizing radiations can be detected (6 marks)
- (iii) Explain how alpha particles can cause severe biological damage, even though their penetrating power is relatively low. (3 marks)

QUESTION FOUR (20 MARKS)

- a) Describe any four modern applications of radioisotopes (8 marks)
- b) State the relative penetrating power and shielding required for each of the radiations below (6 marks)
- (i) Alpha
- (ii) Beta
- (iii) gamma
- c) Complete the following equations by using periodic table attached to identify the nuclides W, X and Y (6 marks)

- i) ${}_{20}^{41}\text{Ca} \rightarrow W + {}_{-1}^0\text{e}$
- ii) ${}_{53}^{131}\text{I} \rightarrow X + {}_{-1}^0\text{e} + {}_0^1\text{n}$
- iii) ${}_{92}^{238}\text{U} + {}_0^1\text{n} \rightarrow Y + {}_{82}^{207}\text{Pb} + {}_0^0\gamma$

