2APHY: Nuclear Physics End of Unit Assignment

Name: ____ (53 + 2 marks)

OVERALL – 2 marks for units and significant figures.

1. As part of a laboratory write-up, a student was describing the three types of radiation. The paragraph they wrote is below but parts are missing. Using the information in the paragraph fill in the missing information. (4 marks)

   There are three types of radiation; two are particles, the first of which is like a helium nucleus with two protons and two ____________ and it is called __________ radiation and has the symbol ________and the nuclide__________. The second particle is a high speed electron from the ____________ of the atom which is called ___________ radiation. It has the symbol β and the nuclide ________. *The third form of radiation is not a particle but part of the electromagnetic spectrum. This type of radiation called ___________ radiation and is high energy electromagnetic radiation with the symbol ________ and the nuclide ___________.*

2. Complete the following table. (3 marks)

Radiation symbol	**Name of radiation**	**What it is**
		High speed electron
		Helium nucleus
		Electromagnetic radiation

3. Radon has a half-life of 3.80 days. In an experiment, a student starts with a sample containing 16.0 mg of radon. What would the mass of radon be after 11.4 days? (2 marks)

4. One of the reactions that may ultimately be harnessed in nuclear fusion power generation involves the production of helium $^{4}_{2}He$ from deuterium $^{2}_{1}H$ and tritium $^{3}_{1}H$:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + \textbf{?}$$

   What else is emitted from this reaction when producing helium-4? __________________ (1 mark)

5. Complete the following equations in the space provided and name the radiation produced.

   a. $^{229}_{90}\mathbf{Th} \rightarrow ^{225}_{88}Ra +$ ________________________ (1 mark)

   b. $^{131}_{53}\mathbf{I} \rightarrow ^{131}_{54}Xe +$ ________________________ (1 mark)

   c. $^{137m}_{56}\mathbf{Ba} \rightarrow ^{137}_{56}Ba +$ ________________________ (1 mark)

6. Uranium-239 decays through a chain of nuclei, leading eventually to lead-206. The effective half-life for the whole process is about 4.50 x 10^9 years. Some of the oldest uranium-bearing rocks on Earth contain roughly equal numbers of atoms of Uranium-239 and Lead-206 .If we assume that all of the lead-206 has come from the decay of uranium-239, approximately how old are these rocks? (2 marks)

7. Complete the following. (4 marks)

Element	Nuclide	Atomic Number	Number Of Neutrons	Mass Number
Carbon-12				
	$^{13}_{7}\mathrm{N}$	7		
		7		14
Cobalt-60				

8. Two of the elements above are isotopes of each other. Which are they and why are they isotopes?

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____ (3 marks)

9. What is the value of Y in the possible fission reaction shown below?

$$^{1}_{0}n + {}^{235}_{92}\mathrm{U} \rightarrow {}^{92}_{38}\mathrm{Sr} + {}^{142}_{54}\mathrm{Xe} + \mathrm{Y}\ {}^{1}_{0}n.$$

What is the value of Y? ______________ (1 marks)

10. Using an example, explain what ionizing radiation is and its effect on the human body. (2 marks)

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11. An industrial worker accidentally inhaled a radioisotope with an activity of 255 Bq. The substance swallowed has a very long effective half-life and therefore the activity will not change significantly during the worker's lifetime. Every decay of the isotope releases 1.35×10^{-13} J of energy into the body and the radioisotope is not eliminated from the body. Determine the amount of energy absorbed in one year by the worker from this substance. (1 year = 365 days) (2 marks)

12. A worker in a nuclear accident receives 45.5 J of radioactive energy from an alpha source. His mass is 75.0 kg. (Quality factor for alpha is 15.)

a. What is his absorbed does? (1 mark)

b. What is his does equivalent? (1 mark)

c. Should he be seriously concerned? Explain (2 marks) ______________________________

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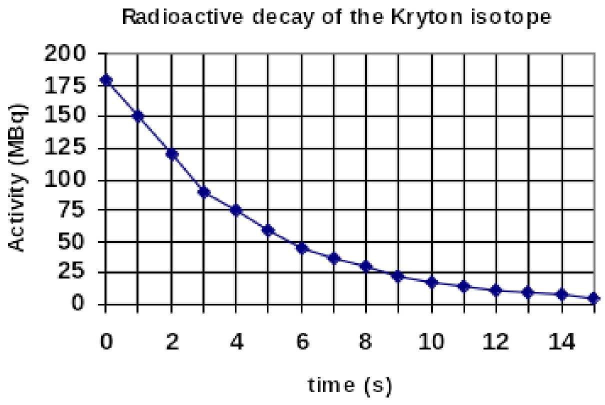
9. The radio isotope $^{60}_{24}Co$ has a half-life of approximately 5.5 years. Gamma radiation from a $^{60}_{24}Co$ source is used to treat cancer. Hospitals using such sources for therapy usually replace the source when its activity has fallen to 12.5% of its original value. After how many years must a source be replaced? (2 marks)

12. An isotope of Krypton is being studied by a university student. He records the activity of the isotope as it decays and draws the graph shown.



a. What is the half-life of the isotope?

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(1 marks)

b. Does the isotope have a high or low activity rate? ________________________
(1 mark)

Explain your answer.

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____ (2 marks)

13. When an alpha particle bombards nitrogen-14, oxygen-17 is formed. Calculate the binding energy per nucleon, firstly in MeV and then in joules, of one oxygen-17 nucleus. (5 marks)
Mass proton = 1.00728 u
Mass neutron = 1.00867 u
Mass oxygen-17 = 16.99474 u

Comprehension: **(10 marks)**

Read the passage below then answer the questions that follow passage. This passage is adapted from Microsoft Encarta Reference Library 2002.

THE BASICS OF NUCLEAR POWER

Nuclear power plants generate electricity from fission, usually of uranium-235 (U-235), the nucleus of which has 92 protons and 143 neutrons. When it absorbs an extra neutron, the nucleus becomes unstable and splits into smaller pieces and more neutrons. The products and neutrons have a smaller total mass than the U-235 and the first neutron; the mass difference has been converted into energy, mostly in the form of heat, which produces steam and in turn drives a turbine generator to produce electricity.

Natural uranium is a mixture of two isotopes, fissionable U-235 (0.7 per cent) and non-fissionable U-238. However, U-238 can absorb neutrons to form plutonium-239 (P-239), which is fissionable, and up to half the energy produced by a reactor can in fact come from fission of P-239. Some types of reactor require the amount of U-235 to be increased above the natural level, which is called enrichment. Pressurized water reactors (PWRs), the most common type of reactor, require fuel enriched to about 3 per cent U-235.

Reactor fuel is made up of fuel pellets or pins enclosed in a tubular cladding of steel, zircaloy, or aluminium. Several of these fuel rods make up each fuel assembly. The fast neutrons released in the fission reaction need to be slowed down before they will induce further fissions and give a sustained chain reaction. This is done by a moderator, usually water or graphite, which surrounds the fuel in the reactor. However, in “fast reactors” there is no moderator and the fast neutrons sustain the fission reaction.
A coolant is circulated through the reactor to remove heat from the fuel. Ordinary water (which is usually also the moderator) is most commonly used but heavy water (deuterium oxide), air, carbon dioxide, helium, liquid sodium, liquid sodium-potassium alloy, molten salts, or hydrocarbon liquids may be used in different types of reactor.

The chain reaction is controlled by using neutron absorbers such as boron, either by moving boron-containing control rods in and out of the reactor core, or by varying the boron concentration in the cooling water. These can also be used to shut down the reactor. The power level of the reactor is monitored by temperature, flow, and radiation instruments and used to determine control settings so that the chain reaction is just self-sustaining.

The main components of a nuclear reactor are: the pressure vessel (containing the core); the fuel rods, moderator, and primary cooling system (making up the core); the control system; and the containment building. This last element is required in the event of an accident, to prevent any radioactive material being released to the environment, and is usually cylindrical with a hemispherical dome on top.

During operation, and also after it is shut down, a nuclear reactor will contain a very large amount of radioactive material. The radiation emitted by this material is absorbed in thick concrete shields surrounding the reactor core and primary cooling system. An important safety feature is the emergency core cooling system, which will prevent overheating and “meltdown” of the reactor core if the primary cooling system fails. See Also Nuclear Fission.

1. The TDS rules are always used in nuclear reactors. What are the TDS rules? (2 marks)

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2. Nuclear power plants generate electricity from fission. What is fission and how does this result in a chain reaction? (3 mark)

3. Write the nuclear equation for U-238 absorbing a neutron to form Pu-239. (1 mark)

4. What is meant by “enriched” uranium? (1 mark)

5. Chain reactions are controlled by using neutron absorbers. If these were not in place, an uncontrolled chain reaction could take place if the uranium was at critical mass. What is critical mass? (2 marks)

6. Why do fast neutrons need to be slowed down in a nuclear reactor and what is used to do this? (2 marks)