11 PHYSICS ATAR
ASSIGNMENT 7: NUCLEAR PHYSICS

NAME: SOLUTIONS **DUE DATE:** ______________ **TOTAL:** $\frac{\quad}{52}$

1. Complete the following table.

ELEMENT	NUMBER OF PROTONS	NUMBER OF NEUTRONS	NUMBER OF ELECTRONS
$^{87}_{37}Rb$	37	50	37
$^{148}_{62}Sm$	62	86	62
$^{187}_{75}Re$	75	112	75

(3)

2. Explain the following characteristics and behaviours of the different radiations.

(a) α particles are stopped by tissue paper but β particles are not.

α particles: slow, large He nucleus is much bigger and easier to stop.

β particles: small, fast-moving electrons easily penetrate.

(1)

(b) β particles are electrons that originate from the nucleus.

$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \bar{\nu}_e$

A neutron becomes a proton and releases a β particle and an antineutrino.

(1)

(c) γ rays have no charge or mass.

$^{0}_{0}\gamma$ is pure light energy and is not a particle.

(1)

(d) α particles have a much larger quality factor than either β particles or γ rays.

α particles are much larger and easily removes electrons from atoms.

(1)

(e) α particles are dangerous if in contact with the skin but are far more dangerous if inhaled.

α particles are very big and easily stopped by the skin, but they can easily penetrate the very thin lung lining and enter the blood.

(1)

3. (a) Background radiation constantly exists around us. Describe ***two sources*** of this radiation.

(i)
- Cosmic rays from the sun.
- Nuclear weapon testing fallout.
- Ground and buildings.
- Air travel.
- Food and drink.
- Nuclear power plants.

(ii)
- Natural radioactivity in the air.
- Medical sources.
- Burning coal.

[Any 2 - 2 marks]

(2)

(b) Some communities of people live at high altitudes in various countries. Are they exposed to more or less background radiation? Explain your answer.

- More radiation. (1)
- With less protection from the atmosphere, people are more exposed to the radiations from the sun. (1)

(2)

4. Complete the following nuclear equations.

(a) $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + \underline{^{1}_{0}n}$ (1)

(b) $^{9}_{4}Be + \underline{^{4}_{2}He} \rightarrow ^{12}_{6}C + ^{1}_{0}n$ (1)

(c) $^{27}_{13}Al + ^{4}_{2}He \rightarrow \underline{^{31}_{15}P} + ^{0}_{0}\gamma$ (1)

(3)

5. When Lithium-7 is bombarded with protons, two α particles are produced. The disintegration is represented by the following equation.

$$^{7}_{3}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + ^{4}_{2}He$$

Calculate the E_k possessed by the α particles.

(Masses: $^{7}_{3}$Li - 7.01818 u   proton - 1.00813 u $^{4}_{2}$He - 4.00389 u)

Mass of reactants = 7.01818 u + 1.00813 u = 8.02631 u (1)

Mass of products = 2 × 4.00389 u = 8.00778 u (1)

∴ Mass difference = 0.01853 u

= (0.01853)(931.4)

= 17.26 MeV

= 2.761×10^{-12} J

∴ E_k = 2.76×10^{-12} J (total) or 1.38×10^{-12} J (each)

(4)

6. During a controlled experiment, a researcher measured the radioactivity levels of a sample as 4.25×10^3 counts/minute. The half-life had previously been determined as 4.70 minutes.

(a) What radiation level would be measured after 21.0 minutes?

half-lives: $n = \frac{21.0}{4.70} = 4.468$ (1)

$N = N_0 \frac{1}{2^n}$

$= (4.25 \times 10^3)\left(\frac{1}{2^{4.468}}\right)$ (1)

= 192 counts/min (1)

(3)

(b) If the sample had an initial mass of 38.0 g and decayed by emitting α particles, about how much mass would be left after 23 minutes? Explain your answer.
(**No calculations are necessary**.)

Mass ≈ 38.0 g (1)

Although the sample has transmuted, there will still be a significant amount of a new element. (1)

(2)

7. Calculate the binding energy per nucleon in MeV for ${}^{32}_{16}S$ atoms, given the mass of an atom is 32.00122 u.

Mass of 16 protons = 16 × 1·00728u = 16·11648 u

" " 16 neutrons = 16 × 1·00867u = 16·13872 u

" " 16 electrons = 16 × 0·000549u = 0·008784 u

Total = 32·263984 u (2)

Mass of the atom = 32·00122 u

∴ Mass defect = 32·263984 u − 32·00122 u

= 0·262764 u (1)

= 244·7 MeV. (1)

Binding energy = $\frac{244 \cdot 7}{32}$

= 7·65 MeV / nucleon (1)

(5)

8. A 70.0 kg worker in the food-irradiation industry is exposed to a total of 14.7 J of energy due to slow neutron radiation. Calculate:

(a) the absorbed dose of the worker.

Absorbed dose = $\frac{E}{m}$

= $\frac{14 \cdot 7}{70 \cdot 0}$

= 0·210 Gy

(2)

(b) the dose equivalent in Sieverts.

Dose equivalent = Absorbed dose × Quality factor

= (0·210)(3) (1)

= 0·630 Sv. (1)

(2)

9. Nuclear fission is used to produce about 17 % of the world's electrical energy. With increasing concern for global warming and the impact of increasing CO_2 levels from burning fossil fuels, greater attention is being paid to using nuclear power as a "clean alternative".

(a) Explain the role of the following in a fission reactor, giving an example of a suitable material for each role.

(i) moderator • Slows down neutrons so that "capture" occurs. (1)
e.g. graphite, "heavy" water, CO_2. (1)

(ii) control rod • Absorbs neutrons to control the rate of fission. (1)
e.g. cadmium, boron steel. (1)

(iii) coolant • Removes heat from the core and transfers it outside to generate electricity. (1)
e.g. liquid Na, H_2O, CO_2. (1)

(6)

(b) (i) What is a ***breeder reactor***?

• Produces plutonium from depleted uranium (U-238). (1)
• U-238 surrounds a core of plutonium. (1)

(2)

(ii) Why does this type of reactor not require a moderator?

• Plutonium requires a high-speed neutron to undergo fission so no moderator is required.

OR • Uranium-238 has the ability to capture fast neutrons to start the process.

(1)

(c) Describe ***two disadvantages*** that nuclear power stations have over conventional power stations.

(i) • Disposal of nuclear wastes - they have very long half-lives.
• Accidents within the facility have the potential to seriously affect a wide area of the environment.

(ii) • Much more expensive to set up initially.
• Must be sited in very isolated areas away from major populations.

[Any 2 - 2marks] (2)

10. (a) What is meant by the term ***critical mass***?

- The mass of fissile material required to have an uncontrolled chain reaction. (1)
- Most of the neutrons remain inside the material. (1)

(2)

(b) Explain how this term relates to the development of atomic weapons during the 1940's and 1950's?

- Two sub-critical masses were separated within the weapons. (1)
- An explosive charge rams them together, forming a critical mass that explodes. (1)

(2)

11. Nuclear fusion is a process for producing energy that is seen in stars, producing successively heavier elements as the process continues. Scientists have had limited success on Earth in developing the fusion process.

(a) Describe ***one significant advantage*** that fusion power would have over fission-based processes.

- Huge amounts of energy are produced with little or no residual radioactive wastes. (1)

(1)

(b) As heavier nuclei are produced within a star, what must be true about the successive binding energies of the elements as the fusion process continues?

- The binding energy increases with increasing atomic mass. (1)

(1)

(c) Which nuclide represents the "end product" of such reactions?

$^{56}_{26}Fe$ (1)

(1)

(d) Why is it necessary to have temperatures of a least 1.0 x 10^6 °C to initiate a fusion reaction?

- To overcome the repulsion between the protons as the new nuclei are formed. (1)

(1)