Higher Physics

Unit 2 : PARTICLES & WAVES

Nuclear Reactions

Rutherford's Model

1. Give reasons why the alpha particles in the Rutherford Scattering Experiment are scattered by the thin gold foil.

2. Describe the Rutherford model of the atom.

Radioactive Decay

3. Fill in the missing nuclide (X) in each of the following disintegrations:

(a) $^{226}_{88}Ra \longrightarrow {}^{X} + {}^{4}_{2}He$

(b) $^{234}_{92}U \longrightarrow {}^{X} + {}^{4}_{2}He$

(c) $^{234}_{91}Pa \longrightarrow {}^{X} + {}^{0}_{-1}e$

(d) $^{210}_{82}Pb \longrightarrow {}^{X} + {}^{0}_{-1}e$

4. Find the following missing materials or nuclides:

(a) $^{228}_{90}Th \longrightarrow {}^{228}_{91}Ra + A$

(b) $^{220}_{86}Rn \longrightarrow B + {}^{4}_{2}He$

(c) $^{211}_{82}Pb \longrightarrow {}^{211}_{83}Bi + C$

(d) $D \longrightarrow {}^{219}_{86}Rn + {}^{4}_{2}He$

5. What nuclide is produced when Uranium – 238, containing 92 protons, decays by emitting an alpha particle and two beta particles ?

6. What nuclide is produced when Thorium – 232, containing 90 protons, decays by emitting two alpha particles and a beta particle ?

7. Part of a radioactive decay series is shown below:

$$^{235}_{92}U \longrightarrow {}^{231}_{90}Th \longrightarrow {}^{231}_{91}Pa \longrightarrow {}^{227}_{89}Ac$$

(a) Identify the particles emitted at each stage.

(b) Such a series does not always give a complete picture of the radiations emitted by each nucleus. Give an explanation.

$E = mc^2$

8. How much energy is released when the following 'decreases' in mass occur in various fission reactions?

(a) $3{\cdot}25 \times 10^{-28}$ kg
(b) $2{\cdot}01 \times 10^{-28}$ kg
(c) $1{\cdot}62 \times 10^{-28}$ kg
(d) $2{\cdot}85 \times 10^{-28}$ kg

9. The following statement represents a nuclear reaction involving the release of energy.

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

The masses of these particles are given below.

Mass of $^{3}_{1}H$ = $5{\cdot}00890 \times 10^{-27}$ kg

Mass of $^{2}_{1}H$ = $3{\cdot}34441 \times 10^{-27}$ kg

Mass of $^{4}_{2}He$ = $6{\cdot}64632 \times 10^{-27}$ kg

Mass of $^{1}_{0}n$ = $1{\cdot}67490 \times 10^{-27}$ kg

(a) Calculate the decrease in mass that occurs when this reaction takes place.

(b) Calculate the energy released in this reaction.

(c) What is the name given to this type of nuclear reaction?

(d) Calculate the number of reactions required each second to produce a power of 25 MW.

10. The following statement represents a fusion reaction.

$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{0}_{1}\mathrm{e}^{+}$$

The masses of the particles involved in this reaction are shown in the table.

Particle	*Mass* (kg)
${}^{1}_{1}\mathrm{H}$	$1{\cdot}673 \times 10^{-27}$
${}^{4}_{2}\mathrm{He}$	$6{\cdot}646 \times 10^{-27}$
${}^{0}_{1}\mathrm{e}$	negligible

Calculate the energy released in this reaction.

11. In a certain star, one of the fusion reactions taking place is represented by the following statement.

$${}^{1}_{1}\mathrm{H} + {}^{15}_{7}\mathrm{N} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He}$$

The energy released by this reaction is 7.96662×10^{-13} J.

The table below shows the masses of three of the particles.

Particle	*Mass*/kg
${}^{1}_{1}\mathrm{H}$	$1{\cdot}68706 \times 10^{-27}$
${}^{12}_{6}\mathrm{C}$	$20{\cdot}1031 \times 10^{-27}$
${}^{4}_{2}\mathrm{He}$	$6{\cdot}69944 \times 10^{-27}$

Calculate the mass of the nitrogen particle.

12. The following statement represents a nuclear reaction.

$$ {}^{A}_{Z}\mathrm{X} + {}^{2}_{1}\mathrm{H} \longrightarrow 2\,{}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \text{energy} $$

The masses of some of the particles involved in this reaction are shown in the table.

Particle	*Mass*/kg
${}^{2}_{1}\mathrm{H}$	$3{\cdot}342 \times 10^{-27}$
${}^{4}_{2}\mathrm{He}$	$6{\cdot}642 \times 10^{-27}$
${}^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$

(a) Use a periodic table to identify the element X.

(b) The energy released in this reaction is 2.97×10^{-12} J.

Calculate the mass of nucleus X.

13. The Sun is the source of most of the energy on Earth. The energy is produced by nuclear reactions which take place in the interior of the Sun.

One such reaction can be described by the following statement.

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

The masses of the particles involved in this reaction are shown in the table.

Particle	*Mass*/kg
${}^{3}_{1}\mathrm{H}$	$5{\cdot}005 \times 10^{-27}$
${}^{2}_{1}\mathrm{H}$	$3{\cdot}342 \times 10^{-27}$
${}^{4}_{2}\mathrm{He}$	$6{\cdot}642 \times 10^{-27}$
${}^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$

(a) Name this type of nuclear reaction.

(b) Calculate the energy released in this reaction.

14. The following statement represents a nuclear reaction.

$$^{240}_{94}\text{Pu} \longrightarrow {}^{236}_{92}\text{U} + {}^{4}_{2}\text{He}$$

The table shows the masses of the particles involved in this reaction.

Particle	*Mass*/kg
$^{240}_{94}\text{Pu}$	$398{\cdot}626 \times 10^{-27}$
$^{236}_{92}\text{U}$	$391{\cdot}970 \times 10^{-27}$
$^{4}_{2}\text{He}$	$6{\cdot}645 \times 10^{-27}$

Calculate the energy released in this reaction.

15. A nuclear fission reaction is represented by the following statement.

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{137}_{r}\text{Cs} + {}^{s}_{37}\boldsymbol{T} + 4\,{}^{1}_{0}\text{n}$$

(a) Is this a spontaneous or induced reaction? You must justify your answer.

(b) Determine the numbers represented by the letters ***r*** and ***s*** in the above reaction.

(c) Use a periodic table to identify the element represented by ***T***.

(d) The masses of the nuclei and particles in the reaction are given below.

	Mass/kg
$^{235}_{92}\text{U}$	$390{\cdot}219 \times 10^{-27}$
$^{137}_{r}\text{Cs}$	$227{\cdot}292 \times 10^{-27}$
$^{s}_{37}\boldsymbol{T}$	$157{\cdot}562 \times 10^{-27}$
$^{1}_{0}\text{n}$	$1{\cdot}675 \times 10^{-27}$

Calculate the energy released in the reaction.

16. Some power stations use nuclear fission reactions to provide energy for generating electricity. The following statement represents a fission reaction.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{139}_{57}\mathrm{La} + {}^{r}_{42}\mathrm{Mo} + 2\,{}^{1}_{0}\mathrm{n} + s\,{}^{0}_{-1}\mathrm{e}$$

(a) Determine the numbers represented by the letters ***r*** and ***s*** in the above statement.

(b) Explain why a nuclear fission reaction releases energy.

(c) The masses of the particles involved in this reaction are shown in the table.

Particle	*Mass*/kg
$^{235}_{92}\mathrm{U}$	$390{\cdot}173 \times 10^{-27}$
$^{139}_{57}\mathrm{La}$	$230{\cdot}584 \times 10^{-27}$
$^{r}_{42}\mathrm{Mo}$	$157{\cdot}544 \times 10^{-27}$
$^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$
$^{0}_{-1}\mathrm{e}$	negligible

Calculate the energy released in the reaction.