# 30 Worksheet (A2)

Data needed to answer questions can be found in the Data, formulae and relationships sheet.

**1** **a** Write down Einstein's famous equation relating mass and energy. [1]

**b** Determine the change in energy equivalent to a change in mass:

**i** of 1.0 g [2]

**ii** equal to that of an electron ($9.1 \times 10^{-31}$ kg). [2]

**2** In nuclear physics, it is common practice to quote the mass of a nuclear particle in terms of the unified atomic mass unit, u. The unified atomic mass unit u is defined as one-twelfth of the mass of an atom of the carbon isotope $^{12}_{6}C$ .

**a** Determine the mass of each of the following particles in terms of u:

**i** an α-particle of mass $6.65 \times 10^{-27}$ kg [1]

**ii** a carbon-13 atom of mass $2.16 \times 10^{-26}$ kg. [1]

**b** Determine the mass of each of the following particles in kilograms:

**i** a proton of mass 1.01 u [1]

**ii** a uranium-235 nucleus of mass 234.99 u. [1]

**3** State **three** quantities conserved in all nuclear reactions. [3]

**4** **a** Explain why external energy is required to 'split' a nucleus. [1]

**b** Define the **binding energy** of a nucleus. [1]

**c** The binding energy of the nuclide $^{16}_{8}O$ is 128 MeV. Calculate the binding energy per nucleon. [2]

**5** **a** Define the **half-life** of a radioactive isotope. [1]

**b** The half-life of a particular isotope is 20 minutes. A sample initially contains $N_0$ nuclei of this isotope. Determine the number of nuclei of the isotope left in the sample after:

**i** 20 minutes [1]

**ii** 1.0 hour. [2]

**6** The activity of an α-source is 540 Bq. The kinetic energy of each α-particle is $8.6 \times 10^{-14}$ J. The isotope in the source has a very long half-life.

**a** Calculate the number of α-particles emitted by the source in:

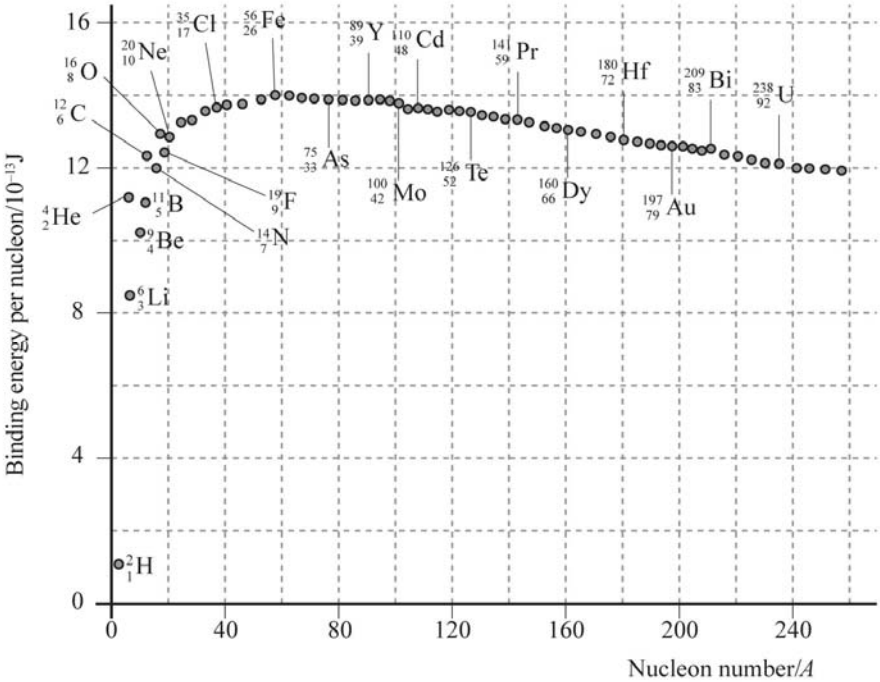
**i** 1 second [1]

**ii** 1 hour. [1]

**b** Determine the total energy released by the source in a time of 1 second. [3]

**c** State the rate at which energy is emitted from this α-source. [1]

**7** The binding energy per nucleon against nucleon number graph for some common nuclides is shown below.




**a** Identify the most stable nuclide. Explain your answer. [2]

**b** Use the graph to estimate the binding energy for the nucleus of $^{12}_{6}$C . [2]

**c** Use the graph to estimate the energy released in the following fusion reaction. [4]

$$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{4}_{2}\text{He}$$

**d** The fusion reaction shown in **c** is one of the many that occur in the interior of stars. State the conditions necessary to initiate such reactions in stars. [2]

**8** Use the data given below to determine the binding energy and the binding energy per nucleon of the nuclide $^{235}_{92}$U . [7]

mass of proton = 1.007 u

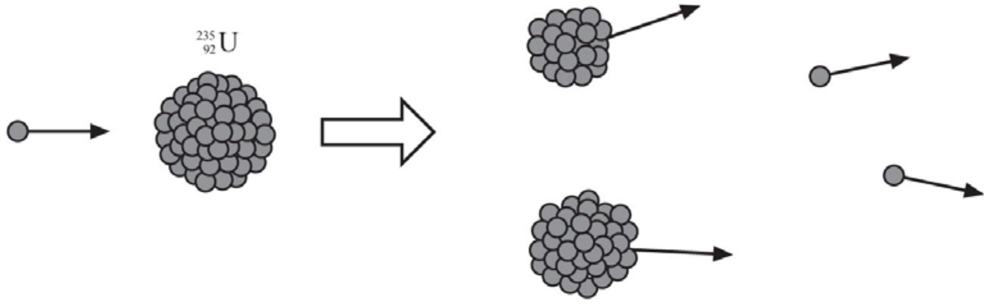
mass of neutron = 1.009 u    mass of uranium-235 nucleus = 234.992 u

**9 a** Describe the process of induced nuclear fission. [1]

**b** The diagram shows the fission of uranium-235 in accordance with the nuclear equation:

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{38}Sr + ^{139}_{54}Xe + 2^{1}_{0}n$




**i** Copy the diagram, adding labels to identify the neutrons, the strontium nuclide and the xenon nuclide. [1]

**ii** Explain why energy is released in the reaction above. [2]

**iii** Use the following data to determine the energy released in a single fission reaction involving $^{235}_{92}U$ and $^{1}_{0}n$. [5]

mass of $^{235}_{92}U = 3.902 \times 10^{-25}$ kg  mass of $^{95}_{38}Sr = 1.575 \times 10^{-25}$ kg

mass of $^{1}_{0}n = 1.675 \times 10^{-27}$ kg  mass of $^{139}_{54}Xe = 2.306 \times 10^{-25}$ kg

**10** One of the neutron-induced fission reactions of uranium-235 may be represented by the following nuclear equations.

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U$

$^{236}_{92}U \rightarrow ^{146}_{57}La + ^{87}_{35}Br + 3\,^{1}_{0}n$

The binding energies per nucleon for these nuclides are:

$^{236}_{92}U$, 7.59 MeV; $^{146}_{57}La$, 8.41 MeV; $^{87}_{35}Br$, 8.59 MeV.

Calculate the energy released in MeV when the $^{236}_{92}U$ nucleus undergoes fission. [3]

**11** The half-life of the radon isotope $^{220}_{86}Rn$ is 56 s.

**a** Determine the decay constant in $s^{-1}$. [3]

**b** Calculate the activity of a sample containing $6.0 \times 10^{10}$ nuclei of $^{220}_{86}Rn$. [3]

**12** The activity of a radioactive source containing $8.0 \times 10^{14}$ undecayed nuclei is $5.0 \times 10^{9}$ Bq.

**a** Determine the decay constant in $s^{-1}$. [3]

**b** Calculate the half-life of the nucleus. [3]

**c** How many undecayed nuclei will be left after 40 hours? [3]

**13 a** Define the **decay constant** of a nucleus. [1]

**b** The thorium isotope $^{227}_{90}Th$ has a half-life of 18 days.

A particular radioactive source contains $4.0 \times 10^{12}$ nuclei of the isotope $^{227}_{90}Th$.

**i** Determine the decay constant for the thorium isotope $^{227}_{90}Th$ in $s^{-1}$. [3]

**ii** What is the initial activity of the source? [3]

**iii** Calculate the activity of the source after 36 days. [2]

**14** A sample of rock is known to contain 1.0 μg of the radioactive radium isotope $^{226}_{88}Ra$.

The half-life of this particular isotope is 1600 years. The molar mass of radium-226 is 226 g.

**a** Determine the number of nuclei of the isotope $^{226}_{88}Ra$ in the rock sample. [2]

**b** Calculate the activity from decay of the radium-226 in the sample. [3]

**15** In a process referred to as 'annihilation', a particle interacts with its antiparticle and the entire mass of the combined particles is transformed into energy in the form of photons. The following equation represents the interaction of a proton (p) and its antiparticle, the antiproton ( $\overline{\mathrm{p}}$ ).

$${}^{1}_{1}\mathrm{p} + {}^{1}_{-1}\overline{\mathrm{p}} \rightarrow \gamma + \gamma$$

The antiproton has the same mass as a proton – the only difference is that it has a negative charge. Determine the wavelength $\lambda$ of each of the two identical photons emitted in the reaction above. (Mass of a proton = $1.7 \times 10^{-27}$ kg.) [5]

**16** Does fusion or fission produce more energy per kilogram of fuel? Answer this question by considering the fusion reaction in **7 c** and the fission reaction in **9 b**.
(The molar masses of hydrogen-2 and uranium-235 are 2 g and 235 g, respectively.) [7]

**17** Some astronomers believe that our solar system was formed $5.0 \times 10^{9}$ years ago. Assuming that all uranium-238 nuclei were formed before this time, what fraction of the original uranium-238 nuclei remain in the solar system today? The isotope of uranium ${}^{238}_{92}\mathrm{U}$ has a half-life of $4.5 \times 10^{9}$ y. [4]

Total: $\frac{\phantom{000}}{100}$ Score: %