Formative Practice 6.1 [Radioactive Decay]

1. Complete the radioactive decay equation. Identify *A*, *B* and *C*.

(a) $^{228}_{88}\text{Ra} \rightarrow A + {}^{0}_{-1}e$ (b) $^{209}_{84}\text{Po} \rightarrow {}^{205}_{82}\text{Pb} + B$ (c) $C \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$

2. The decay series of a radioactive source is $^{238}_{92}\text{U} \rightarrow \ldots \rightarrow {}^{206}_{82}\text{Pb}$. Determine the number of α-particles and β-particles that are emitted.

3. Table 6.4 shows the record of the activity of a radioactive sample stored in the laboratory.

Table 6.4

Date	10 January 2020	20 January 2020	30 January 2020
Activity / s^{-1}	1 520	380	95

(a) Determine the half-life of the radioactive sample.

(b) Sketch a radioactive decay curve for the sample.

Formative Practice 6.2 [Nuclear Energy]

1. What is meant by nuclear fission and nuclear fusion?

2. Describe the chain reaction that occurs in a nuclear reactor.

3. Explain how a nuclear reactor generates electrical energy.

4. A nuclear reaction is represented by the following equation: $^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{141}_{55}\text{Cs} + {}^{93}_{37}\text{Rb} + 2{}^{1}_{0}\text{n} + \text{energy}$

The mass defect is 0.19585 amu. Calculate the energy that is released by the reaction.

Summative Practice Nuclear Physics !!

1. What is meant by:

(a) radioactive decay

(b) half-life

(c) nuclear energy

2. The following shows the equation for a radioactive decay: $^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\text{X} + \text{Y}$

(a) Identify X and Y in the decay equation.

(b) How many α and β-particles will be released when $^{222}_{86}\text{Rn}$ decays to $^{210}_{82}\text{Pb}$?

3. (a) Astatine-218 has a half-life of 1.6 s. How long will it take for 99% of the nucleus in one sample of astatine-218 to disintegrate?

(b) Radium-226 has a half-life of 1 600 years. What percentage of the sample of radium-226 will be left after 8 000 years?

4. During the formation of rocks, radioisotope uranium-238 is trapped. The decay rate of uranium-238 is low and the end result of the decay series is lead-206. Table 1 shows the composition of samples of rock *A* and rock *B*.

(a) Between the samples of rock *A* and rock *B*, which one is older? Justify your answer.

Table 1

	Sample *A*	Sample *B*
Ratio of uranium-238 to lead-206	5 : 1	7 : 1

(b) The composition of the lead nucleus is unlikely to be greater than the uranium nucleus in the rocks sample. Explain your answer.

5. Carbon-14 has a half-life of 5 730 years.

(a) What is the fraction of undecayed carbon in a fossil sample at the end of 1.719×10^4 years?

(b) Based on your answer to 5(a), sketch a graph of the decay curve for carbon-14 in the fossil sample.

6. In a nuclear reaction as shown in Figure 1, the total mass of the particles that are produced is less than the initial mass of the particles. The nuclear reaction experiences a mass defect. The lost mass is converted into energy.

(a) Name the nuclear reaction and write the equation involved.

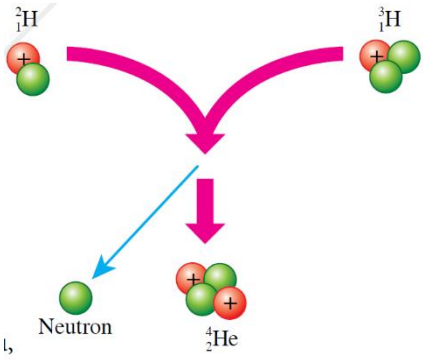


Figure 1

(b) Calculate the mass defect and the nuclear energy that is released.
[Mass $^{2}_{1}H$ = 2.01410 amu, mass $^{3}_{1}H$ = 3.01605 amu, mass $^{4}_{2}He$ = 4.00260 amu, mass $^{1}_{0}n$ = 1.00866 amu, 1 amu = 1.66×10^{-27} kg and speed of light in vacuum, $c = 3.00 \times 10^{8}$ ms^{-1}]

7. A radioactive decay series of a source of uranium-235 is

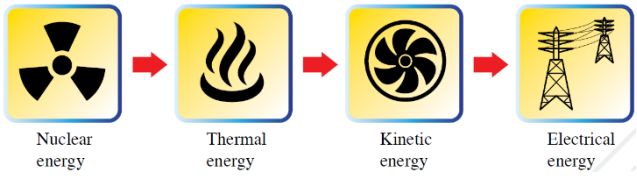
$$^{235}_{92}U \rightarrow \cdots \rightarrow {}^{207}_{82}Pb$$

(a) What is the number of α-particles and β-particles emitted?

(b) Draw a graph of the nucleon number against atomic number that is possible for the decay series. (abe guna ketah graf sendiri deh)

8. Figure 2 shows the conversion of energy that occurs from nuclear energy to electrical energy in a nuclear reactor.

(a) How is nuclear energy produced in a reactor?



(b) How is heat energy converted to kinetic energy in the rotation of a turbine? Explain your answer.

(c) The kinetic energy from the turbine rotation can produce electrical energy. How does this process happen? Explain.

(d) Usually, high cooling towers are built at nuclear power stations. Explain the reason.

9. A nuclear agency plans to build a nuclear power plant in our country to meet the growing demand for energy. However, nuclear fission requires very expensive uranium or plutonium fuels. Furthermore, the issue of radioactive waste management and the threat of environmental pollution is worrying the public.

Imagine that you are a nuclear scientist assigned to construct the nuclear power station. Discuss the considerations that need to be made based on the following aspects:

- location of the nuclear power plant
- walls for the reactor core
- walls for the reactor building
- cooling agents
- energy control methods
- radioactive waste management
- safety measures

Justify each of your suggestions.

location of the nuclear power plant		
walls for the reactor core		
walls for the reactor building		
cooling agents		
energy control methods		
radioactive waste management		
safety measures		

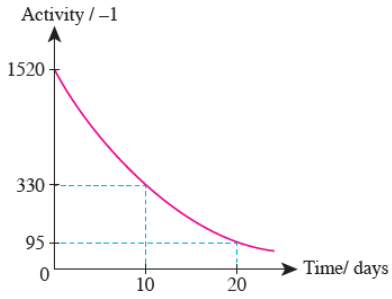
GAPO ???!?!?!???!??!

Formative Practice 6.1

1. (a) $^{228}_{89}Ac$
   (b) $^{4}_{2}He$
   (c) $^{1}_{0}n$

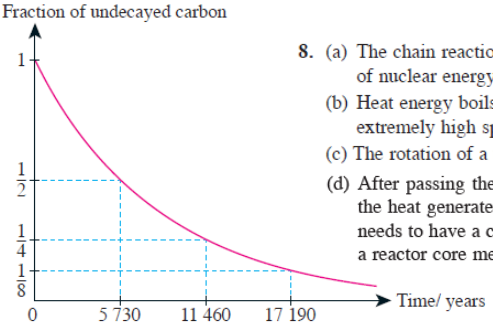
2. $238 = 4(x) + 0\ (y) + 206$
   $x = 8$
   $92 = 2(x) - 1(y) + 8$
   $y = 6$
   The number of particles that are emitted is 8 α-particles and 6 β-particles

3. (a) $\frac{1\,520}{95} = 16 = 2^4$, 4 half-lives = 20 days, half-life = 5 days
   (b)



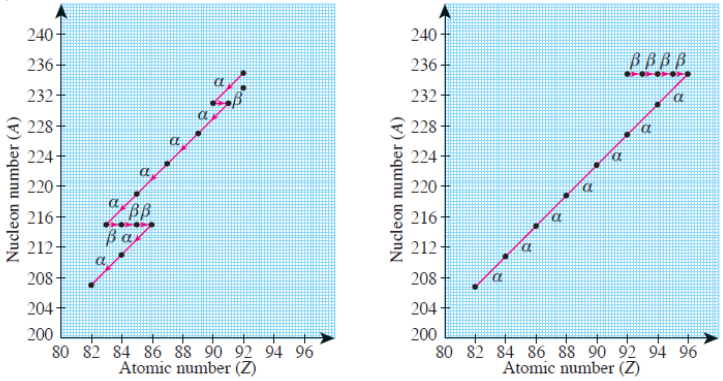
4. (a) A is the older sample. The ratio of uranium-238 to plumbum-206 is smaller.
   (b) Suppose that during the rock formation, only uranium-238 was trapped. The oldest rock formed on Earth is about 4.28 billion years. The half-life of uranium-238 is 4.5 billion years. Therefore, the decay process of uranium-238 in a rock sample has gone through less than one half-life. Hence, less than half of the uranium-238 nuclei in the sample of rock had decayed to form lead-206 nuclei. So the number of lead-206 nuclei cannot be more than the remaining uranium-238 nuclei.

5. (a) $n = \frac{17\,190}{5\,730}$
   $= 3$
   $1 \xrightarrow{1} \frac{1}{2} \xrightarrow{2} \frac{1}{4} \xrightarrow{3} \frac{1}{8}$
   (b)



6. (a) Nuclear fusion
   $^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$ + energy
   (b) Mass defect, m = (4.00260 +1.00866) – (2.01410 + 3.01605)
   = 0.01889 amu
   The nuclear energy that is released
   $= 0.01889 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$
   $= 2.82 \times 10^{-12}$ J

7. (a) $235 = 4(x) + 0(y) + 207$
   $x = 7$
   $92 = 2(x) - 1(y) + 82$
   $y = 4$
   7 α-particles and 4 β-particles are emitted.
   (b)



Note: Any relevant graph is accepted

Formative Practice 6.2

1. Nuclear fission is a nuclear reaction in which a heavy nucleus splits into two or more lighter nuclei and releases a large amount of energy. Nuclear fusion is a nuclear reaction in which two small and light nuclei fuse to form a heavier nucleus while releasing a large amount of energy.
2. In a nuclear reactor, a uranium-235 nucleus is bombarded by a neutron to form the uranium-236 nucleus which is unstable. The unstable uranium-236 nucleus will split to produce lighter and more stable nuclei such as barium-141 and krypton-92 as well as three new neutrons. The three neutrons released will then bombard three other uranium-235 nuclei to form three heavy unstable uranium-236 nuclei. These unstable uranium-236 nuclei will undergo nuclear fission which in turn produce other neutrons that enable the subsequent nuclear fission. The nuclear energy produced increases with the increasing number of fissions of nuclei.
3. In a nuclear reactor, fissions occurs when uranium-235 nuclei are bombarded by neutrons to form a chain reaction. The resulting nuclear energy boils water to become steam. High pressure steam is channeled to rotate the turbine. Rotating turbines with switch on dynamos that generate electrical energy.
4. $E = mc^2$
   $E = 0.19585 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$
   $= 2.9260 \times 10^{-11}$ J
   $= 2.93 \times 10^{-11}$ J

Summative Practice

1. (a) A radioactive decay is a random and spontaneous process by which an unstable nucleus will decay by emitting radioactive radiation to become a more stable nucleus.
   (b) The half life, $T_{\frac{1}{2}}$ is the time taken for a sample of radioactive nuclei to decay to half of its initial number.
   (c) Nuclear energy is the energy produced by reactions in atomic nuclei.
2. (a) X is the helium nucleus or α-particle, Y is γ-ray.
   (b) 3 α-particles and 2 β-particles are released.
3. (a) $100\% \xrightarrow{1} 50\% \xrightarrow{2} 25\% \xrightarrow{3} 12.5\% \xrightarrow{4} 6.25\% \xrightarrow{5} 3.125\% \xrightarrow{6} 1.5625\% \xrightarrow{7} 0.78125\%$
   Total time = 7×1.6 s
   = 11.2 s
   (b) $n = \frac{8\,000}{1\,600}$
   $= 5$
   $\frac{N}{N_0} = \left(\frac{1}{2}\right)^5 = 0.03125$
   Change the fraction into percentage = $0.03125 \times 100\%$
   $= 3.125\%$
   so after $5T_{\frac{1}{2}}$, only 3.125% of the sample remains.

8. (a) The chain reaction resulting from neutron bombardment on the uranium-235 nuclei produces a large amount of nuclear energy in the reactor.
   (b) Heat energy boils the cold water. The high pressure steam produced is capable of rotating a turbine at extremely high speed.
   (c) The rotation of a turbine will enable the dynamo to generate electricity by electromagnetic induction.
   (d) After passing the turbines, the steam will be cooled by large amounts of water from lakes or ponds. Part of the heat generated through the steam cooling process is released through the cooling tower. A nuclear reactor needs to have a complete cooling system that is in good working condition. A faulty cooling system can cause a reactor core meltdown and lead to a serious radioactive leakage disaster.

9.

Suggestion	Characteristics	Justification
Location	By the sea or near abundance of natural water sources	• Abundance of water to function as cooling agents.
Walls of reactor core	Made of thick lead metal	• Prevents radioactive radiation from escaping into the environment
Walls of reactor building	Built of thick concrete	• Prevents radioactive radiation from escaping into the environment
Cooling agent	Water to act as cooling agent	• Water has a high specific heat capacity. • It can absorb large amounts of heat with a small rise in temperature.
Energy control methods	Boron control rod	• The reactor core is equipped with control rods to control the chain reaction. • The control rods will absorb excess neutrons produced from the nuclear fission.
	Graphite moderator	• The moderator slows down the neutrons to ensure a continuous nuclear fission in the reactor core.
Waste management	Disposal and storage facility site for radioactive waste material is developed	• Radioactive waste materials are buried at disposal and storage facility site at a certain depth. This facility site is situated far from residential areas depending on the type of radioactive waste.
Safety precautions	Safety precautions and work procedures in accordance to International Atomic Energy Agency (IAEA) standards	• To ensure the safety of mankind and the environment