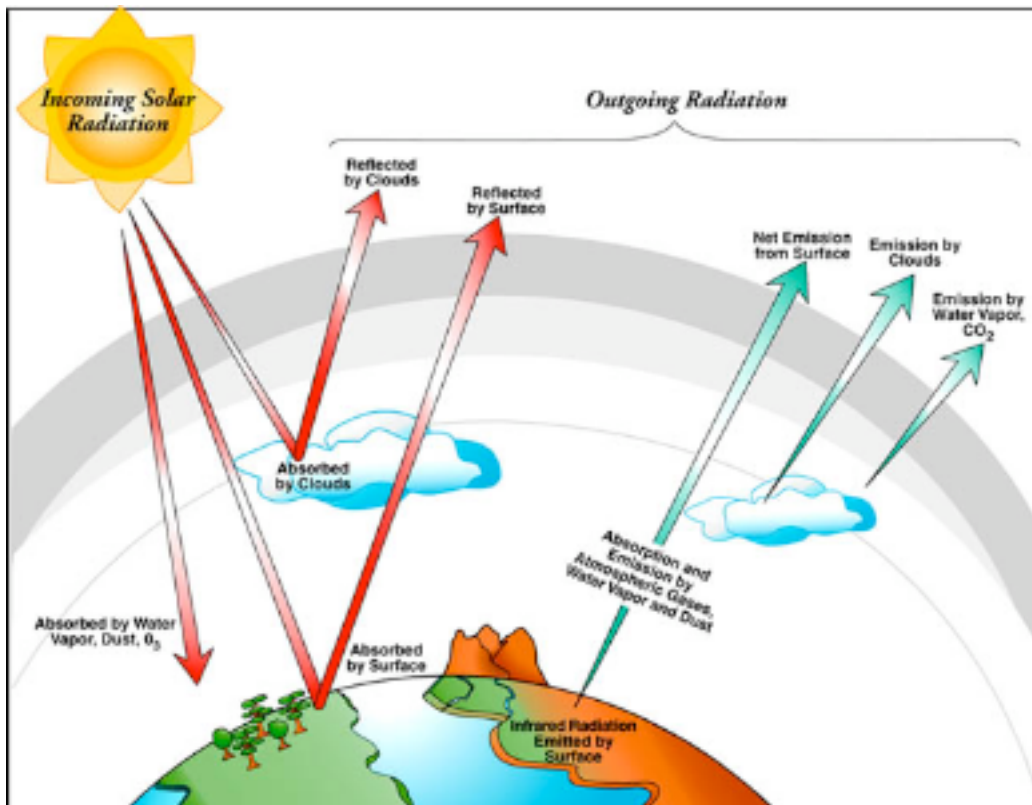


Higher  
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Past Paper questions  
2000 - 2010

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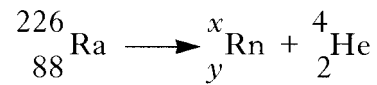
## 3.6 Radiation





**2000 Q29**

Radium (Ra) decays to radon (Rn) by the emission of an alpha particle.  
Some energy is also released by this decay.  
The decay is represented by the statement shown below.



The masses of the nuclides involved are as follows.

$$\text{Mass of } {}_{88}^{226}\text{Ra} = 3.75428 \times 10^{-25} \text{ kg}$$

$$\text{Mass of } {}_y^x\text{Rn} = 3.68771 \times 10^{-25} \text{ kg}$$

$$\text{Mass of } {}_2^4\text{He} = 6.64832 \times 10^{-27} \text{ kg}$$

(a) (i) What are the values of x and y for the nuclide



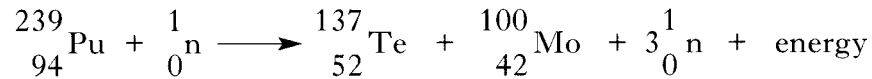
(ii) Why is energy released by this decay?

(iii) Calculate the energy released by one decay of this type.

(b) The alpha particle leaves the radium nucleus with a speed of  $1.5 \times 10^7 \text{ ms}^{-1}$ .  
The alpha particle is now accelerated through a potential difference of 25 kV.  
Calculate the final kinetic energy, in Joules, of the alpha particle.  
[Charge on an electron =  $1.6 \times 10^{-19} \text{ C}$ ]

**2001 Q29**

- (a) The following statement represents a nuclear reaction.



The total mass of the particles before the reaction is  $3.9842 \times 10^{-27}$  kg and the total mass of the particles after the reaction is  $3.9825 \times 10^{-27}$  kg.

- (i) State and explain whether this reaction is spontaneous or induced.
- (ii) Calculate the energy, in Joules, released by this reaction.
- (b) A radioactive source is used to irradiate a sample of tissue of mass 0.50 kg.  
The tissue absorbs  $9.6 \times 10^{-5}$  J of energy from the radiation emitted from the source.  
The radiation has a quality factor of 1.
- (i) Calculate the absorbed dose received by the tissue.
- (ii) Calculate the dose equivalent received by the tissue.
- (iii) Placing a sheet of lead between the source and the tissue would have reduced the dose received by the tissue.  
The half-value thickness of lead for this radiation is 40 mm.  
Calculate the thickness of lead which would have limited the absorbed dose to one eighth of the value calculated in part (b)(i).

**2002 Q30**

- (a) Torbernite is a mineral which contains uranium.  
The activity of 1.0 kg of pure torbernite is  $5.9 \times 10^6$  decays per second.  
A sample of material of mass 0.6 kg contains 40% torbernite.  
The remaining 60% of the material is not radioactive.  
What is the activity of the sample in becquerels?
- (b) The table below gives the quality factor for some types of radiation.

<i>Type of radiation</i>	<i>Quality factor</i>
Gamma rays	1
Fast neutrons	10
Alpha particles	20

Exposure to 150  $\mu\text{Gy}$  of alpha particles for 6 hours gives the same dose equivalent rate as exposure for 8 hours to 400  $\mu\text{Gy}$  of one of the other radiations in the table above.

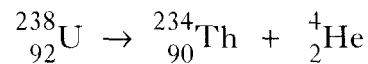
Identify this radiation.

You must Justify your answer by calculation.

**2003 Q29**

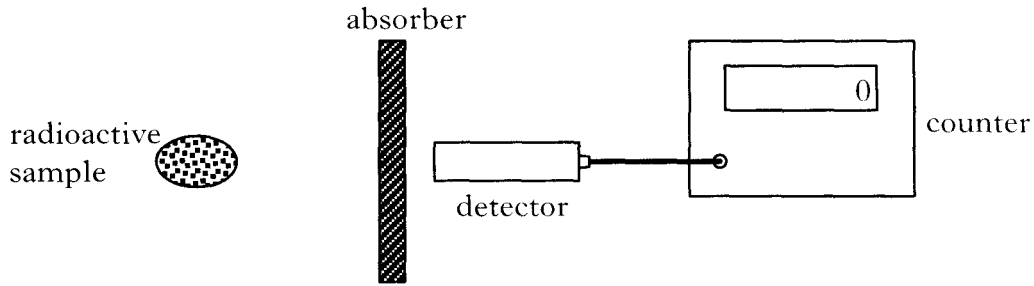
A technician is studying samples of radioactive substances.

- (a) The following statement describes a nuclear decay in one of the samples used by the technician.



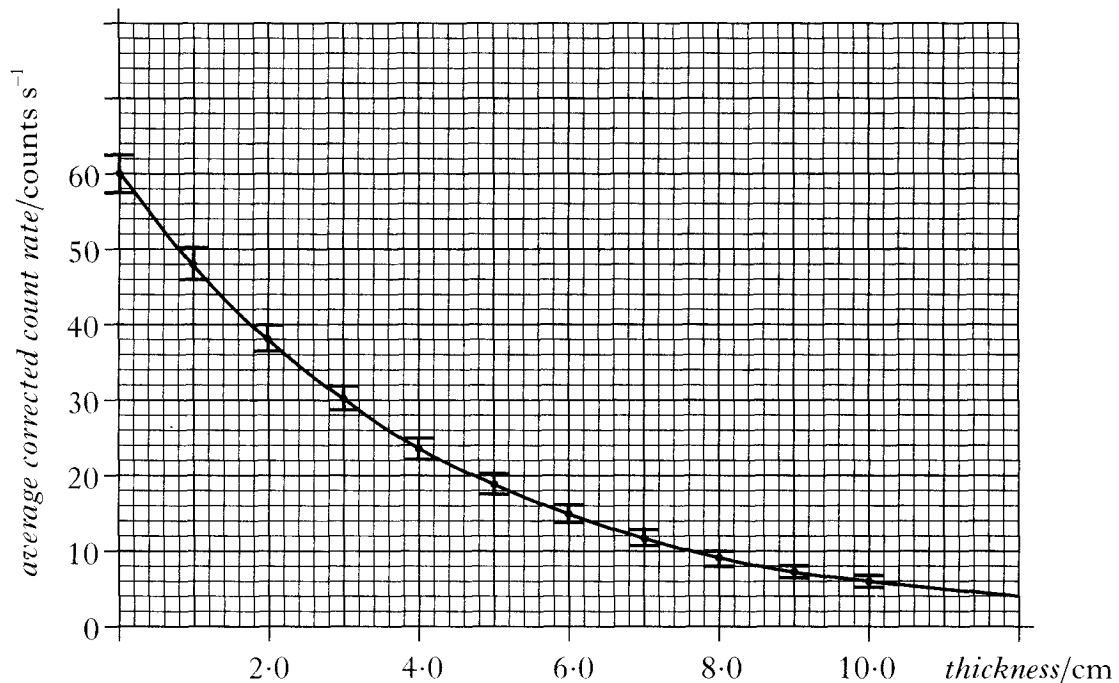
- (i) What type of particle is emitted during this decay?
- (ii) In this sample  $7.2 \times 10^5$  nuclei decay in two minutes.  
Calculate the average activity of the sample during this time.

- (b) The technician now studies the absorption of the radiation emitted from a different sample using the apparatus shown below.



Different thicknesses of the absorber are placed in turn between the sample and the detector. For each thickness, the technician makes **repeated** measurements to obtain an average corrected count rate.

These results are then used to produce the following graph.



- Use the graph to calculate the half-value thickness of the absorber material for this radiation.
- The technician has plotted each value of the average corrected count rate as a point with a vertical "bar" as shown.

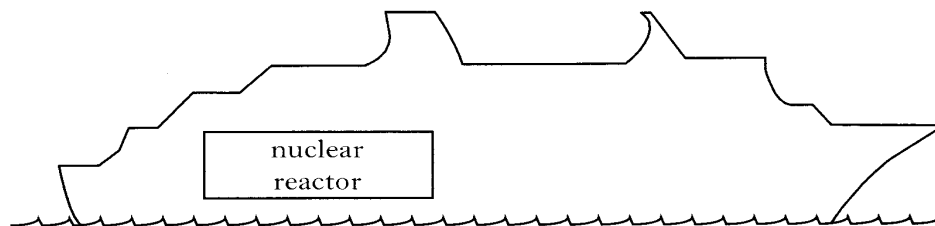


Suggest a reason for this.

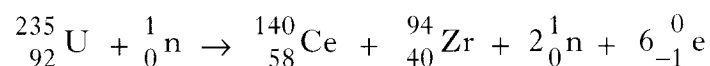
- (c) The technician receives a total dose equivalent of  $6.4 \times 10^{-5}$  Sv from these two sources. The quality factor of the radiation used in part (a) is 20. The absorbed dose received by the technician from the source used in part (b) is  $1.2 \times 10^{-5}$  Gy. The quality factor of this radiation is 1. Calculate the absorbed dose received by the technician from the source used in part (a).

**2004 Q30.**

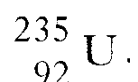
A ship is powered by a nuclear reactor.



One reaction that takes place in the core of the nuclear reactor is represented by the statement below.



- (a) The symbol for the Uranium nucleus is



What information about the nucleus is provided by the following numbers?

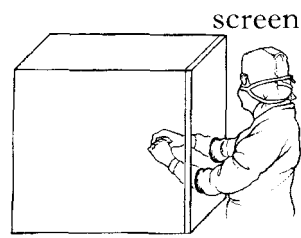
- (i) 92  
 (ii) 235
- (b) Describe how neutrons produced during the reaction can cause further nuclear reactions.  
 (c) The masses of particles involved in the reaction are shown in the table.

<i>Particles</i>	<i>Mass/kg</i>
${}_{92}^{235}\text{U}$	$390.173 \times 10^{-27}$
${}_{58}^{140}\text{Ce}$	$232.242 \times 10^{-27}$
${}_{40}^{94}\text{Zr}$	$155.884 \times 10^{-27}$
${}_0^1\text{n}$	$1.675 \times 10^{-27}$
${}_{-1}^0\text{e}$	negligible

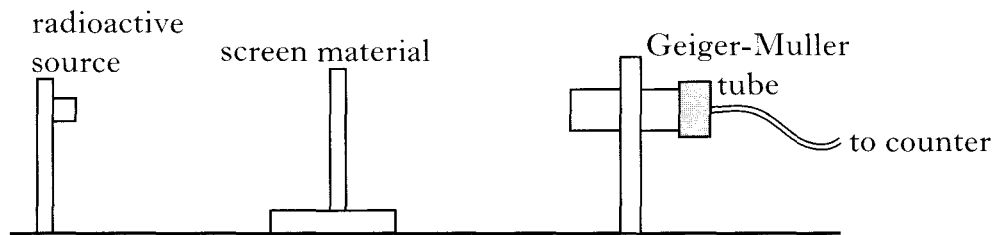
Calculate the energy released in the reaction.

2005 Q30.

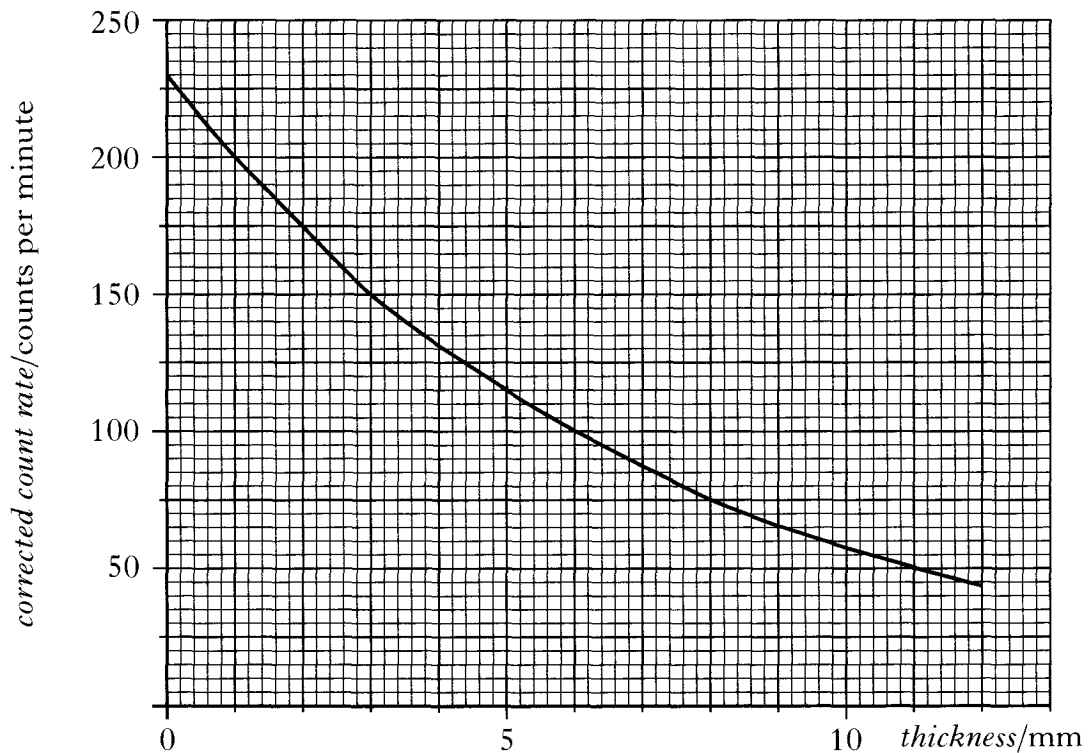
The nuclear industry must meet health and safety standards for workers.  
A worker has to handle radioactive materials behind a screen.



- (a) The screen must be sufficiently thick to reduce the radiation to an acceptable level.  
Different thicknesses of the screen material are placed between the source and the Geiger-Müller tube.



The graph shows corrected count rate plotted against thickness of material.



- (i) Determine the half-value thickness of the material.  
(ii) The dose equivalent rate in air a short distance from this source is  $20 \mu\text{Sv h}^{-1}$ .  
When a certain thickness of the material is placed in front of the source, the dose equivalent rate at the same distance falls to  $2.5 \mu\text{Sv h}^{-1}$ .  
Calculate the thickness of the material.

- (b) The recommended dose equivalent limit for exposure to the hands of a worker is 500 mSv per year. On average the worker is exposed to 2.0 mGy of gamma radiation, 400  $\mu$ Gy of thermal neutrons and 80  $\mu$ Gy of fast neutrons each hour when working in this area. The quality factors for these radiations are shown.

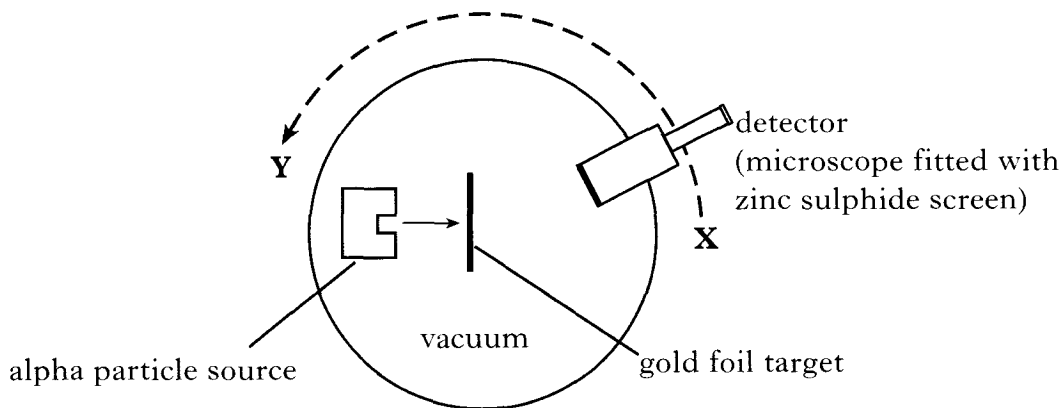
<i>Radiation</i>	<i>Quality factor</i>
gamma	1
thermal neutrons	3
fast neutrons	10

The recommended dose equivalent limit must not be exceeded.

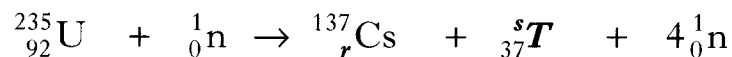
Calculate the maximum number of working hours in one year permitted in this area.

2006 Q29.

- (a) About one hundred years ago Rutherford designed an experiment to investigate the structure of the atom. He used a radioactive source to fire alpha particles at a thin gold foil target. His two assistants, Geiger and Marsden, spent many hours taking readings from the detector as it was moved to different positions between **X** and **Y**.



- (i) How did the number of alpha particles detected at **X** compare with the number detected at **Y**?  
 (ii) State **one** conclusion Rutherford deduced from the results.
- (b) A nuclear fission reaction is represented by the following statement.



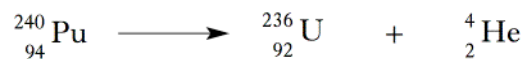
- (i) Is this a spontaneous or an induced reaction? You must justify your answer.  
 (ii) Determine the numbers represented by the letters **r** and **s** in the above reaction.  
 (iii) Use the data booklet to identify the element represented by **T**.  
 (iv) The masses of the nuclei and particles in the reaction are given below.

	<i>Mass/kg</i>
${}_{92}^{235}\text{U}$	$390.219 \times 10^{-27}$
${}_r^{137}\text{Cs}$	$227.292 \times 10^{-27}$
${}_{37}^s\text{T}$	$157.562 \times 10^{-27}$
${}_0^1\text{n}$	$1.675 \times 10^{-27}$

Calculate the energy released in the reaction.

**2007 Q31.**

(a) The following statement represents a nuclear reaction.

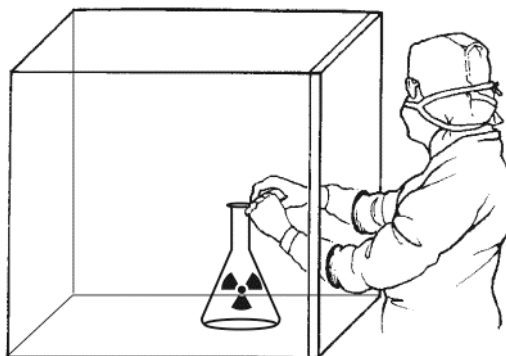


The table shows the masses of the particles involved in this reaction.

<i>Particle</i>	<i>Mass/kg</i>
${}_{94}^{240}\text{Pu}$	$398.626 \times 10^{-27}$
${}_{92}^{236}\text{U}$	$391.970 \times 10^{-27}$
${}_2^4\text{He}$	$6.645 \times 10^{-27}$

Calculate the energy released in this reaction.

(b) A technician is working with a radioactive source as shown.



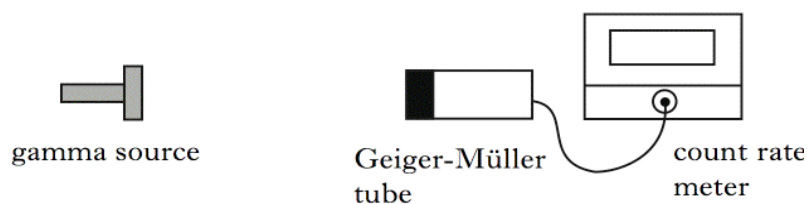
The technician's hands receive an absorbed dose at a rate of  $4.0 \mu\text{Gyh}^{-1}$  for 2 hours. The radiation from the source has a radiation weighting factor of 3. Calculate the equivalent dose received by the technician's hands.

2008 Q30.

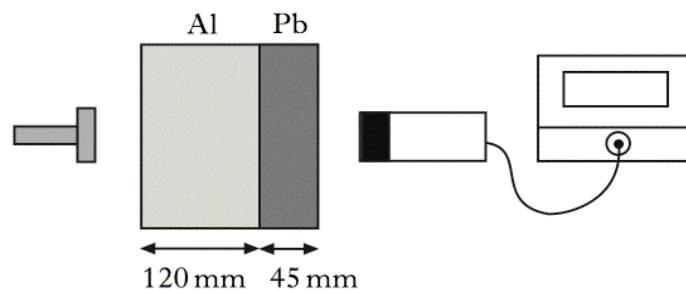
- (a) A technician is carrying out an experiment on the absorption of gamma radiation. The radioactive source used has a long half-life and emits only gamma radiation. The activity of the source is 12 kBq.
- (i) State what is meant by an *activity of 12 kBq*.
- (ii) The table shows the half-value thicknesses of aluminium and lead for gamma radiation.

<i>Material</i>	<i>Half-value thickness/mm</i>
aluminium (Al)	60
lead (Pb)	15

The technician sets up the following apparatus.



The count rate, when corrected for background radiation, is 800 counts per second. Samples of aluminium and lead are now placed between the source and detector as shown.



Determine the new corrected count rate.

- (b) X-ray scanners are used as part of airport security. A beam of X-rays scans the luggage as it passes through the scanner.

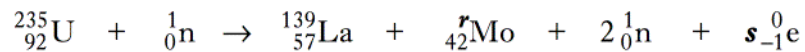


A baggage handler sometimes puts a hand inside the scanner to clear blockages. The hand receives an average absorbed dose of  $0.030 \mu\text{Gy}$  each time this occurs. The radiation weighting factor for X-rays is 1.

- (i) State the average equivalent dose received by the hand on each occasion.
- (ii) The occupational exposure limit for a hand is  $60 \mu\text{Sv}$  per hour. Calculate how many times the baggage handler would have to put a hand into the scanner in one hour to reach this limit.

**2009 Q30.**

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

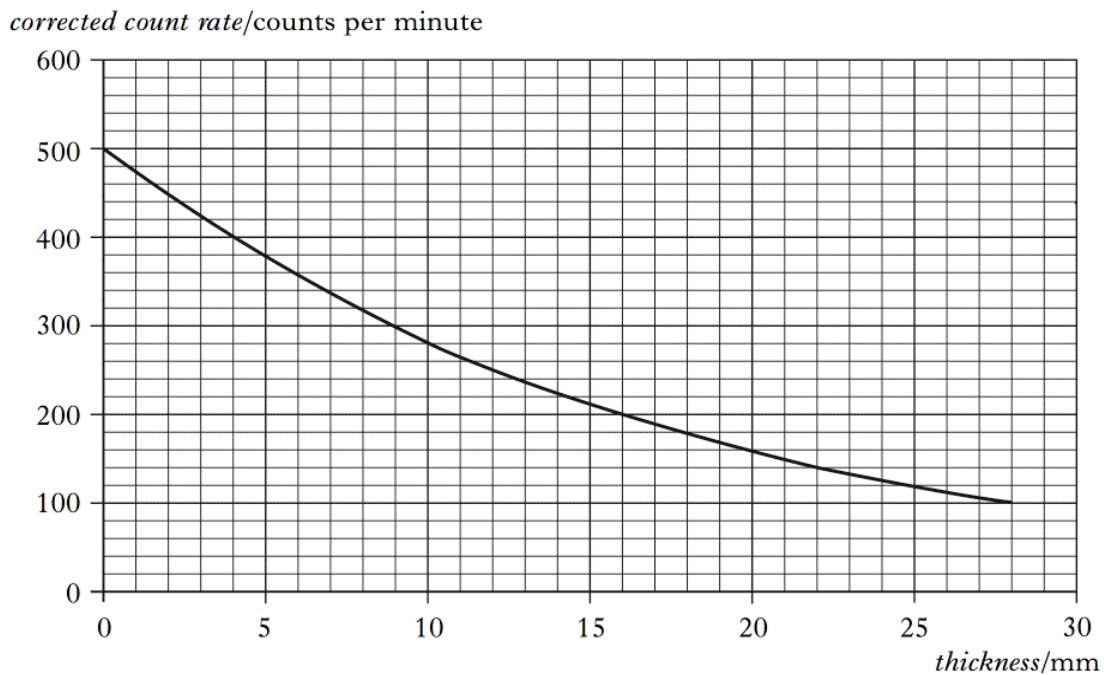


- (i) Determine the numbers represented by the letters r and s in the above statement.  
 (ii) Explain why a nuclear fission reaction releases energy.  
 (iii) The masses of the particles involved in the reaction are shown in the table.

<i>Particle</i>	<i>Mass/kg</i>
${}_{92}^{235}\text{U}$	$390.173 \times 10^{-27}$
${}_{57}^{139}\text{La}$	$230.584 \times 10^{-27}$
${}_{42}^r\text{Mo}$	$157.544 \times 10^{-27}$
${}_0^1\text{n}$	$1.675 \times 10^{-27}$
${}_{-1}^0\text{e}$	negligible

Calculate the energy released in this reaction.

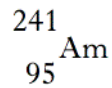
- (b) One method of reducing the radiation received by a person is by using lead shielding. In an investigation of the absorption of gamma radiation by lead, the following graph of corrected count rate against thickness of lead is obtained.



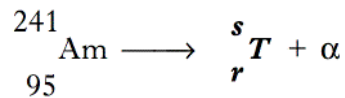
- (i) Determine the half-value thickness of lead for this radiation.  
 (ii) With no shielding, the equivalent dose rate a short distance from this source is  $200 \mu\text{Sv h}^{-1}$ . When the source is stored in a lead container, the equivalent dose rate at the same distance falls to  $50 \mu\text{Sv h}^{-1}$ . Calculate the thickness of the lead container.

**2010 Q30.**

A smoke alarm contains a very small sample of the radioactive isotope Americium-241, represented by the symbol

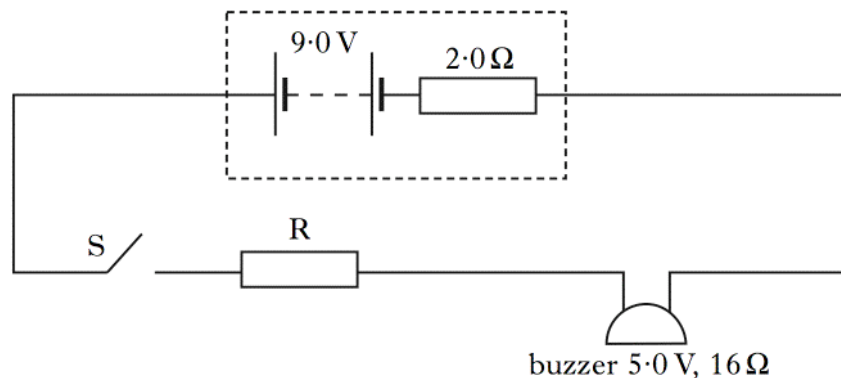


- (a) How many neutrons are there in a nucleus of this isotope?
- (b) This isotope decays by emitting alpha particles as shown in the following statement.



- (i) Determine the numbers represented by the letters  $r$  and  $s$ .
- (ii) Use the data booklet to identify the element  $T$ .
- (c) The activity of the radioactive sample is 30 kBq. How many decays take place in one minute?
- (d) The alarm circuit in the smoke detector contains a battery of e.m.f. 9.0 V and internal resistance 2.0  $\Omega$ .

This circuit is shown.



When smoke is detected, switch S closes and the buzzer operates.

The buzzer has a resistance of 16  $\Omega$  and an operating voltage of 5.0 V.

Calculate the value of resistor R required in this circuit.



