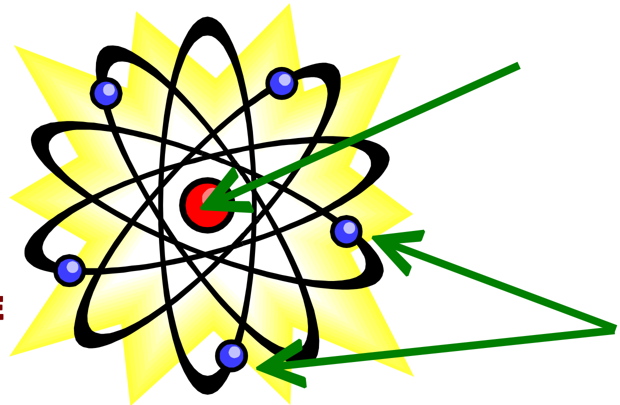
"N5 PHYSICS" NUCLEAR RADIATION - Spread 1

1) (a) Label this diagram of an atom.

NOT TO SCALE



(b) Complete this table to show the position, relative mass and electric charge of the three particles atoms are made up of.

Particle	Position in Atom	Relative Mass	Electric Charge

(c) Explain why atoms are electrically neutral.

2) (a) Explain why the nucleus (centre) of some atoms is unstable.

(b) (i) To become 'more stable', what is the first thing that the nucleus of an unstable atom emits (gives out)?

(ii) When this happens, what is formed?

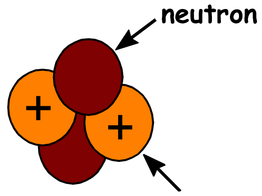
(iii) How does this newly-formed nucleus differ from the original nucleus (in terms of the number of neutrons and protons)?

(iv) What may then be emitted from the newly-formed nucleus?

(v) Explain whether this emission changes the newly-formed nucleus.

3) (a) Explain the meaning of the term 'nuclear radiation'.

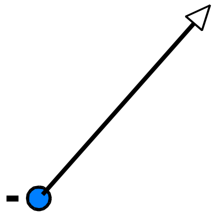
(b) (i) Which type of nuclear radiation does this diagram represent?



(ii) What is it made up of?

(iii) What is it identical to?

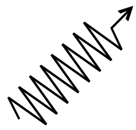
(c) (i) Which type of nuclear radiation does this diagram represent?



(ii) Describe this type of nuclear radiation.

(iii) Explain how this type of nuclear radiation is formed.

(d) (i) Which type of nuclear radiation does this diagram represent?



(ii) Describe this type of nuclear radiation.

(iii) Describe the way in which this type of nuclear radiation is emitted from an atomic nucleus.

(e) Complete this table to show the symbol, nature, relative mass, electric charge and speed in air of the three main types of nuclear radiation.

Type of Nuclear Radiation	Symbol	Nature	Relative Mass	Electric Charge	Speed in Air

"N5 PHYSICS" NUCLEAR RADIATION - Spread 2

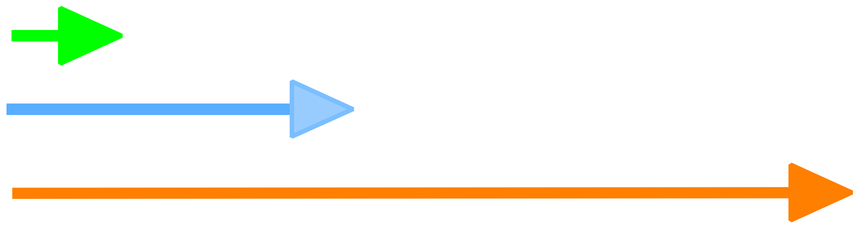
1) (a) when alpha particles, beta particles and gamma rays pass through a material, what do they collide with?

(b) During these collisions, what do the alpha particles, beta particles and gamma rays transfer to the material they are passing through?

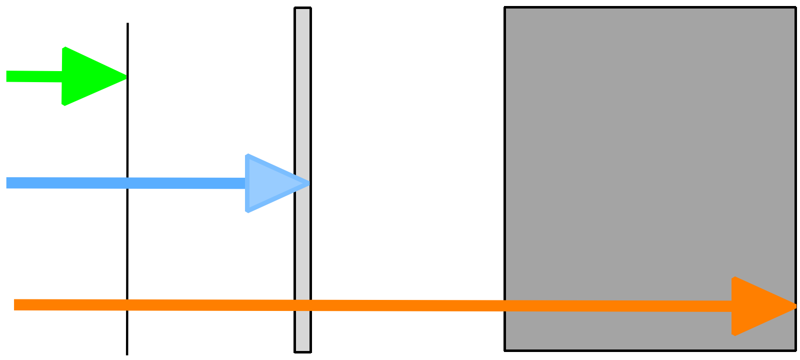
(c) Explain what is meant by the term 'absorbed' in terms of the movement of alpha particles, beta particle and gamma rays through a material.

2) Complete these two diagrams to show the relative ability of alpha particles, beta particles and gamma rays to pass through a material.

Through Air



Through Solids



3) (a) State the meaning of the term 'ionisation'.

(b) State the meaning of the term 'ionising radiation'.

(c) When an electrically-neutral atom is ionised by ionising radiation, name the type of particle formed and its type of electric charge.

(d) Complete this table to compare the relative ionising ability of alpha particles, beta particles and gamma rays.

Type of Nuclear Radiation	Ionising Ability

"N5 PHYSICS" NUCLEAR RADIATION - Spread 3

1) (a) What is a 'radioactive source'?

(b) What is emitted from the unstable nucleus of an atom when the nucleus 'disintegrates' (or 'undergoes radioactive decay')?

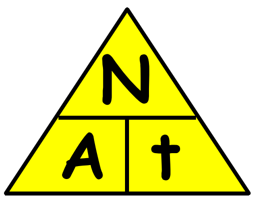
(c) Can we predict the exact time at which a particular atomic nucleus present in a radioactive material will disintegrate (decay)?

2) (a) Explain what is meant by the 'activity' of a radioactive material?

(b) In what '"unit" is 'activity' measured? - give the word and symbol.

(c) What is '1 becquerel' equal to?

(d) Label the equation triangle and complete the equations shown in the box:



A =

N =

t =

CARRY OUT THE FOLLOWING CALCULATIONS:

3) Calculate the activity of a radioactive material in which 500 atomic nuclei disintegrate (decay) in a time of 10 s.

4) Calculate the activity of a radioactive material in which 750 atomic nuclei disintegrate (decay) in a time of 25 s.

5) Calculate the activity of a radioactive material in which 8 000 atomic nuclei disintegrate (decay) in a time of 40 s.

6) A radioactive material has an activity of 36 000 Bq.

Calculate how many atomic nuclei present in the material disintegrate (decay) in 60 s.

7) The activity of a radioactive material is 96 000 Bq.

Calculate the number of atomic nuclei present in the material that will disintegrate (decay) in 80 s.

8) In 120 s, how many atomic nuclei present in a radioactive material of activity 7 200 Bq will disintegrate (decay)?

9) Calculate the time taken for 250 000 atomic nuclei present in a radioactive material of activity 40 000 Bq to disintegrate (decay).

10) A radioactive material has an activity of 4 000 Bq.

Calculate the time it will take for 35 000 atomic nuclei present in the material to disintegrate (decay).

11) In a radioactive material of activity 56 000 Bq, 14 000 atomic nuclei disintegrate (decay) in a given time.

Calculate this time.

12) In a radioactive material, 36 000 atomic nuclei disintegrate (decay) in 1.2 s.

Calculate the activity of the radioactive material.

13) Calculate how many atomic nuclei present in a radioactive material of activity 3 000 Bq will disintegrate (decay) in 15 s.

14) Calculate the time taken for 750 atomic nuclei present in a radioactive material of activity 1 000 Bq to disintegrate (decay).

15) 98 000 atomic nuclei in a radioactive material disintegrate (decay) in 2.5 s.

Calculate the activity of the radioactive material.

16) How many atomic nuclei present in a radioactive material will disintegrate (decay) in 15 s? (The material has an activity of 4 500 Bq).

17) What time will it take for 240 000 atomic nuclei present in a radioactive material of activity 12 000 Bq to disintegrate (decay)?

18) (a) Explain what is meant by the term 'background radiation'.

(b) Is the dose of 'background radiation' we receive each year in the U.K. high enough to harm us?

(c) (i) Are most sources of 'background radiation' in the U.K. natural or artificial (human-created)?

(ii) State the percentage figure for natural sources of 'background radiation' in the U.K.

(iii) State the percentage figure for artificial (human-created) sources of 'background radiation" in the U.K.

(d) Complete the table below:

Source of Background Radiation	Approximate Percentage	Natural Source? (TICK or CROSS)	Artificial Source? (TICK or CROSS)
nuclear weapon tests and leaks from nuclear power stations			
medical uses (such as cancer treatment and X-rays)			
cosmic rays from the sun and other stars			
rocks, the soil and the building materials these are made into			
our bodies and the food/drink we consume			
radon gas present in the air			

1) (a) As time passes, does the 'activity' of a radioactive material decrease, stay constant or increase?

(b) Explain why.

2) (a) Explain what is meant by the term 'half-life' - *give two definitions*.

(b) (i) Is the 'half-life' value of any specific radioactive material always constant? ..... or does the value change?

(ii) What can you say about the 'half-life' value of different radioactive materials?

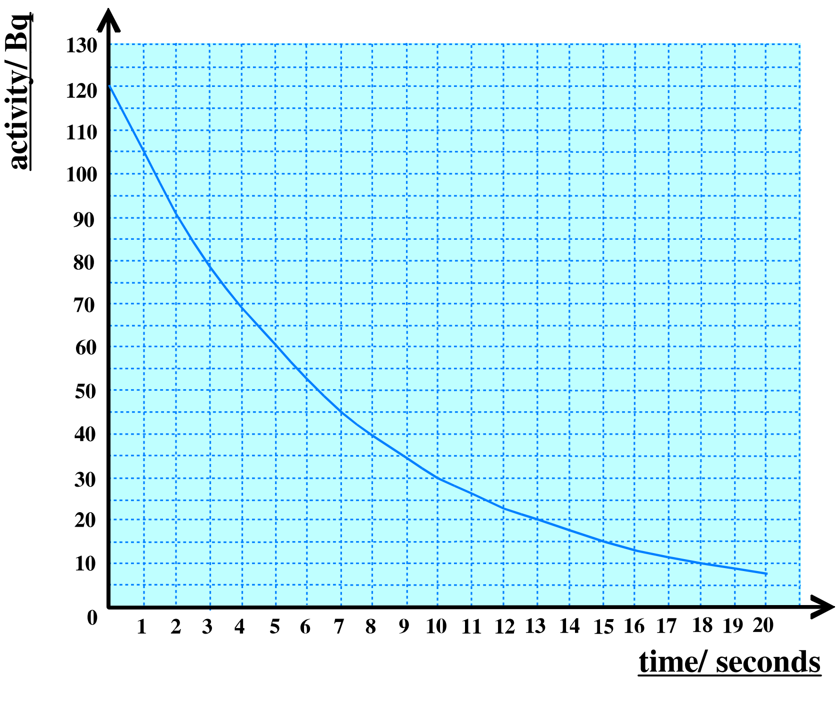
(iii) Is it possible to identify a radioactive material by its 'half-life' value?

(iv) List 5 different radioactive materials and give the 'half-life' value for each one.

3) Use the activity-time graph for each radioactive material to determine the value for its 'half-life'.

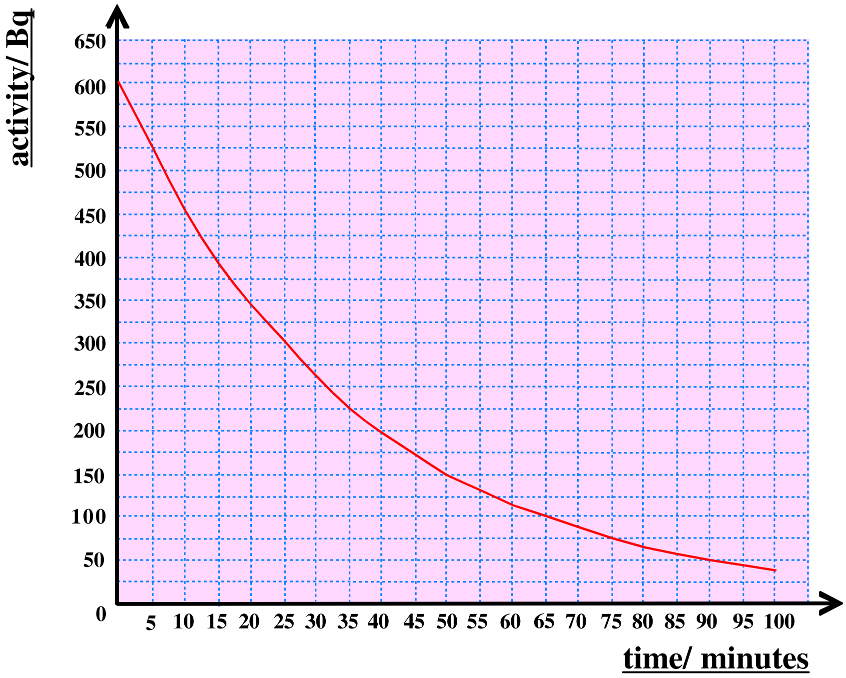
Radioactive material A

half-life =



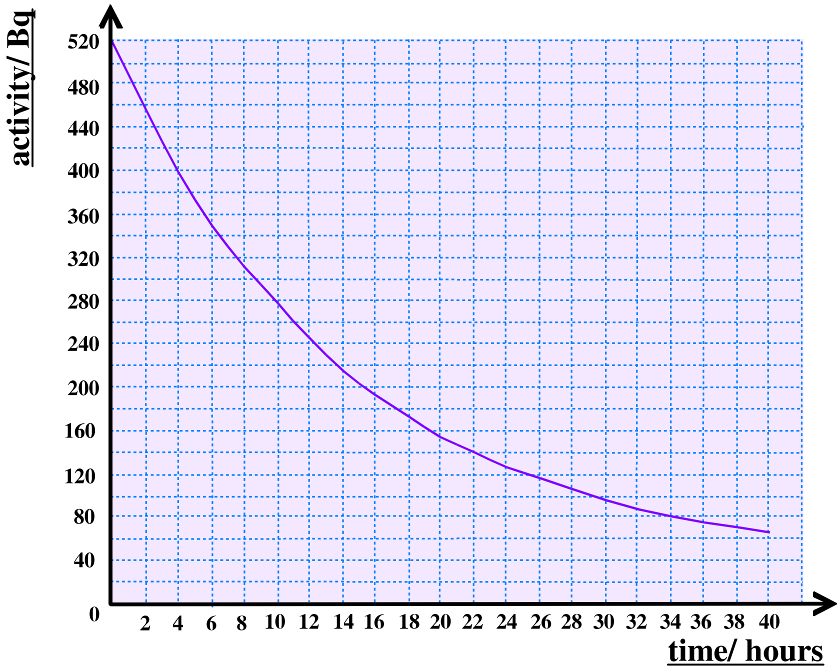
Radioactive material B

half-life =



Radioactive material C

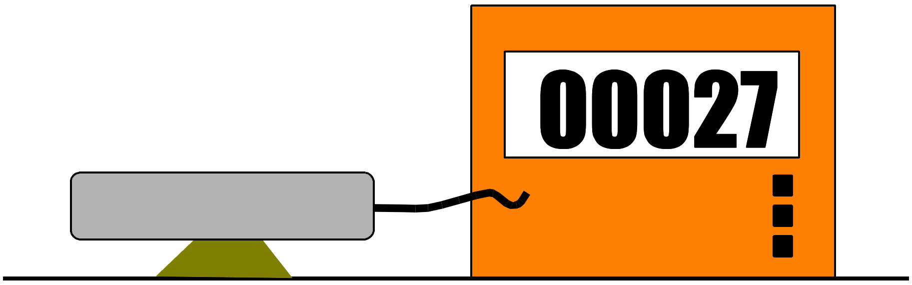
half-life =



Radioactive material D

half-life =

1) (a) Label this diagram of the apparatus we use to detect nuclear radiation:



(b) State what happens every time an alpha particle, beta particle or gamma ray enters the Geiger-Muller tube.

2) (a) With the help of a 'formula/equation', explain how we can use a Geiger-Muller tube and counter to determine a 'count rate' value.

(b) State two possible units for 'count rate'.

3) (a) (i) If a radioactive material is placed in front of a Geiger-Muller tube, is the 'count rate' value obtained (corrected for background radiation) less than, the same as or more than the 'activity' value of the radioactive material?

(ii) Explain why.

(b) (i) Is the 'count rate' value for a radioactive material (adjusted for background radiation) proportional to the 'activity' value of the radioactive material?

(ii) Can the 'count rate' value for a radioactive material (adjusted for background radiation) be used to determine a value for the 'half-life' of the material?

4) (a) When using 'count rate' values to determine the 'half-life' of a radioactive material, the 'count rate' due to background radiation has to be measured and taken into account.

Explain why?

(b) Complete the procedure below to show how you would determine the 'half-life' value of a radioactive material from 'count rate' data:

1) Determine a value for the "background count-rate"

WITH NO RADIOACTIVE MATERIAL PRESENT

1) The counter is set to ________.

2) The Geiger-Muller tube is switched on for a short set time, often ______________ (measured with a _________________).

3) The counter is ________________ after this short set time, then the _______________ ______________ is recorded.

4) The "__________________ count-rate" is calculated using this formula:

5) Steps 1 - 4 are repeated _______________ times, then an _____________ value is calculated for the "_________________

2) Determine several values for the "combined count-rate" (from the background radiation and the radioactive material) at regular time intervals over a long time period

WITH A RADIOACTIVE MATERIAL PRESENT A CONSTANT DISTANCE IN FRONT OF THE GEIGER-MULLER TUBE

At regular ________ intervals (say every ____ minutes), repeat steps 1-3 above, then calculate the "combined ___________ ___________" for each case, using this formula:

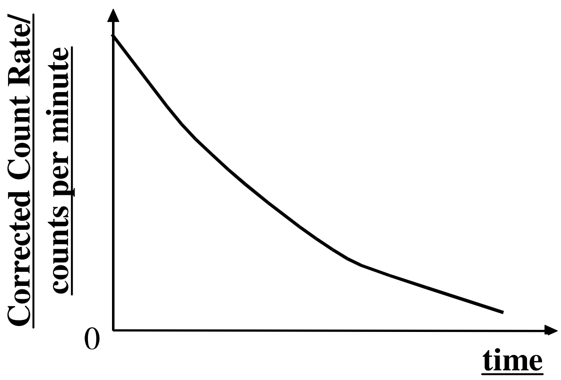
3) Calculate "corrected count-rate" values

Calculate "corrected ___________ __________" values (values due to the ____________ of the radioactive material alone without the effect of ________________ radiation):

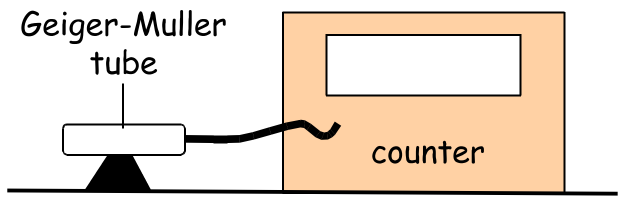
corrected count-rate = ____________ count rate - average _____________ count rate

4) Plot a "corrected count-rate against time" graph

Use this graph to determine the __________________ of the radioactive



5) An experiment was carried out to determine the 'half-life' of a radioactive material using the apparatus shown opposite by determining "corrected count rate" values for the material every 20 minutes over a period of 80 minutes.



(a) To start with, with no radioactive material present in the room, the counter was set to zero, then switched on for a time of 20 s. After this time, the counter was stopped. The counter reading was read and found to be 500 counts.

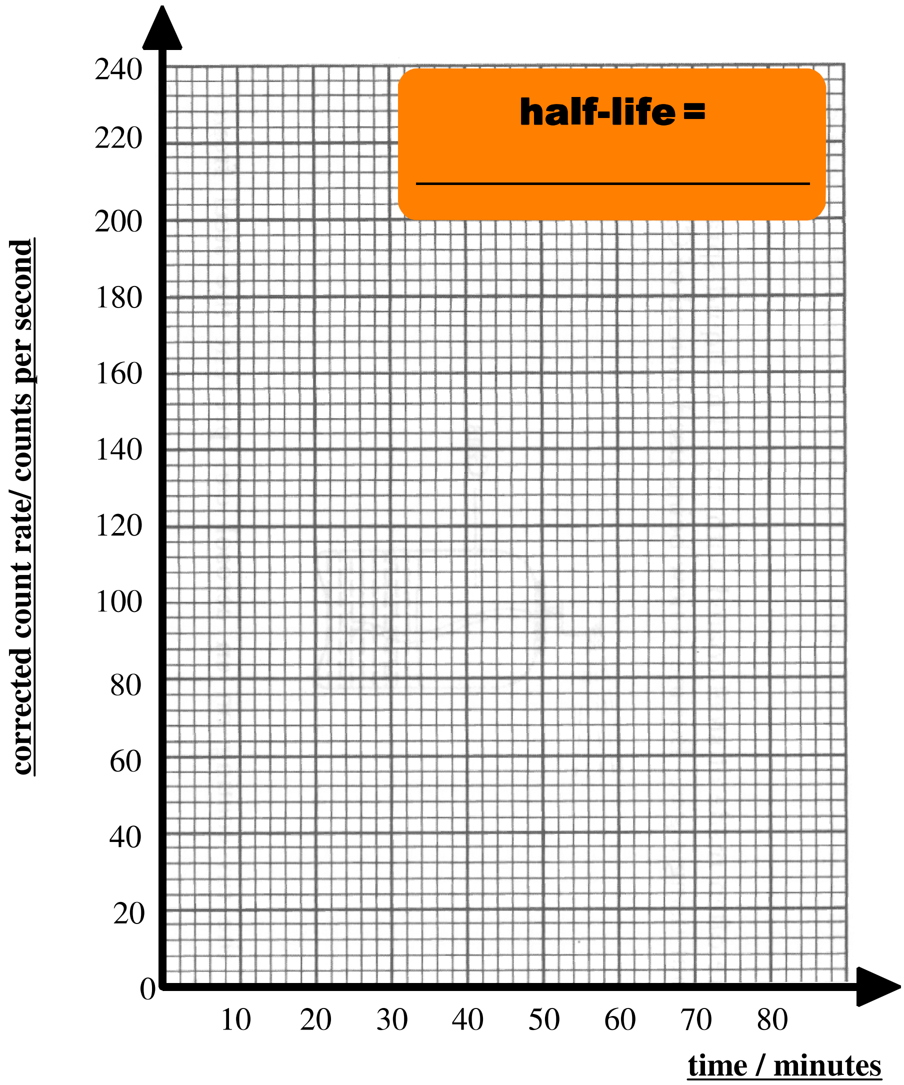
Calculate the "background count rate" due to background radiation (in 'counts per second').

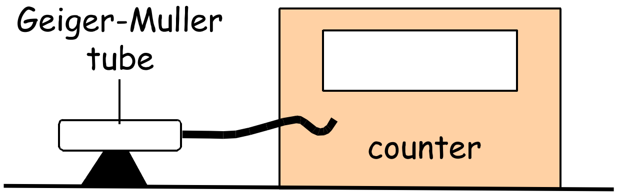
The table below shows the "combined count rate" readings determined when the radioactive material was placed a constant distance in front of the Geiger-Muller tube.

(b) (i) Complete the table to show the value for the "corrected count rate" in each case.

(ii) Complete the line graph of "corrected count rate against time" and use the graph to determine the value for the 'half-life' of the radioactive material.

time/ minutes	0 (start)	20	40	60	80
combined count rate/ counts per second	265	175	115	85	65
corrected count rate/ counts per second					





6) In a physics laboratory, a Geiger-Muller tube connected to a counter was used to determine the 'half-life' of a radioactive material.

(a) Before bringing the radioactive material into the laboratory with the Geiger-Muller tube and counter, the reading on the counter was set to zero, then the counter was switched on for 30 s. After this time, the counter was switched off. The reading it displayed was 480 counts.

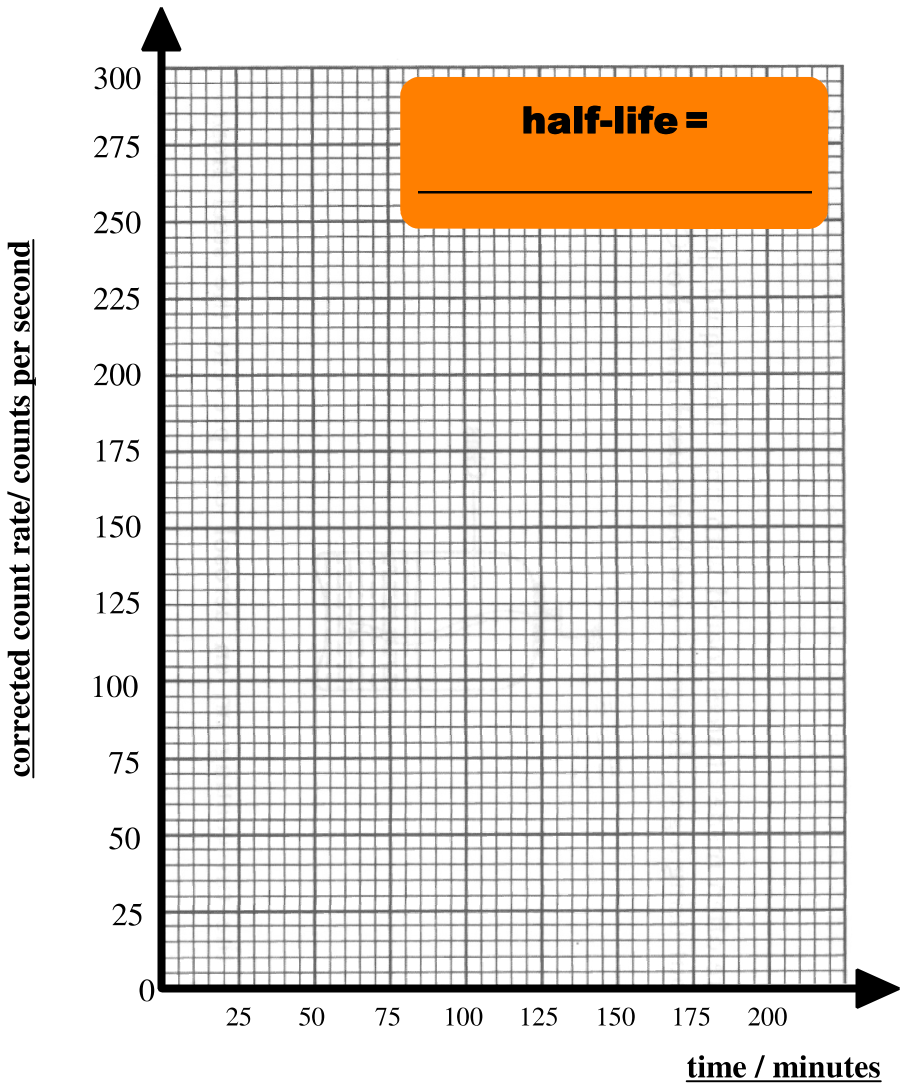
Calculate the "background count rate" due to the background radiation present in the laboratory.

The table below shows the "combined count rate" readings determined at 50 minute intervals over a period of 200 minutes once the radioactive material was positioned a constant distance in front of the Geiger-Muller tube.

(b) (i) Complete the table to show the value for the "corrected count rate" in each case.

(ii) Complete the line graph of "corrected count rate against time" and use the graph to determine the value for the 'half-life' of the radioactive material.

time/ minutes	0 (start)	50	100	150	200
combined count rate/ counts per second	316	201	141	91	61
corrected count rate/ counts per second					



1) Determine the 'half-life' of a radioactive material if its activity falls from 64 Bq to 16 Bq in a time of 16 s.

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2) Determine the 'half-life' of a radioactive material if its activity falls from 300 Bq to 75 Bq in a time of 30 hours.

---

3) Determine the 'half-life' of a radioactive material if its activity falls to 1/8 of its original value in a time of 120 minutes.

---

4) The activity of a radioactive material decreases to 1/16 of its original value in a time of 100 s.

Calculate the 'half-life' of the radioactive material.

---

5) Determine the 'half-life' of a radioactive material if its activity falls to 12.5% of its original value in a time of 45 years.

---

6) The activity of a radioactive material decreases to 6.25% of its original value in a time of 3 200 years.

Calculate the 'half-life' of the radioactive material.

7) The 'half-life' of a radioactive material is 7 minutes.
What time will it take for the activity of the material to fall from 160 Bq to 40 Bq?

---

8) The 'half-life' of a radioactive material is 5 hours.
What time will it take for the activity of the material to fall from 32 Bq to 2 Bq?

---

9) The 'half-life' of a radioactive material is 25 s.
What time will it take for the activity of the material to fall to 1/4 of its original value?

---

10) What time will it take for the activity of a radioactive material to fall to 1/32 of its original value if the material has a 'half-life' of 9.5 days?

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11) What time will it take for the activity of a radioactive material to fall to 12.5% of its original value if the material has a 'half-life' of 12.5 s?

---

12) What time will it take for the activity of a radioactive material to fall to 3.125% of its original value if the material has a 'half-life' of 99 years?

13) (a) Define the term 'ionising radiation'.

(b) When an atom is exposed to 'ionising radiation', what does the atom become?

14) (a) Through 'ionisation', what can <u>*low*</u> <u>*doses*</u> of nuclear radiation do to the DNA molecules present in the nucleus of human body cells?

(b) (i) What affect can *damaged body cell DNA* have on the behaviour of the body cells?

(ii) What term is used to describe this process?

(iii) If mutated human body cells divide uncontrollably, what may be formed?

(iv) What affect can *damaged 'reproductive DNA'* have on future generations?

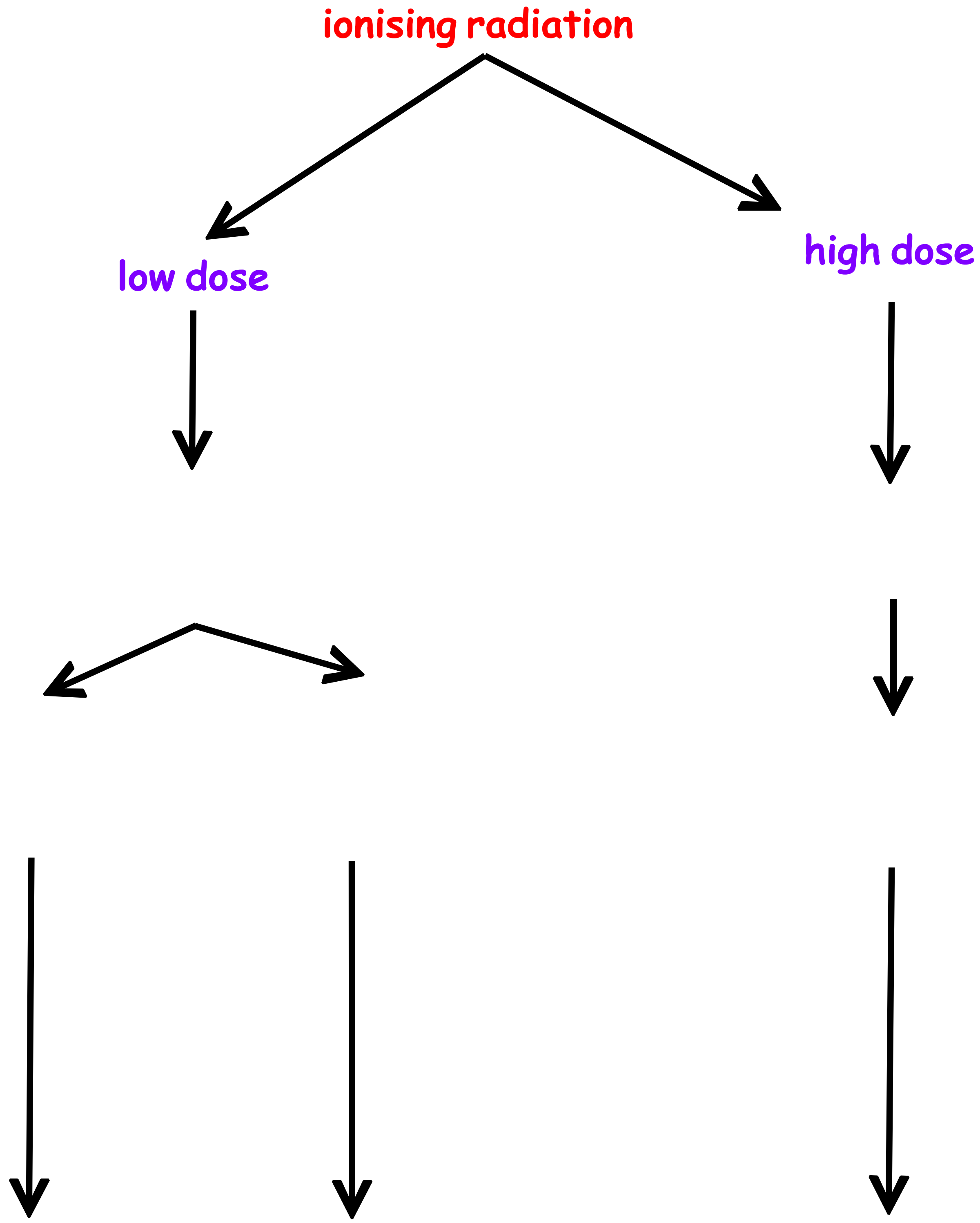
15) (a) (i) Through 'ionisation', what can <u>*high*</u> <u>*doses*</u> of nuclear radiation do to human body cells?

(ii) Explain how this occurs.

(b) (i) Explain the term 'radiation sickness'.

(ii) What usually happens to a person suffering from 'radiation sickness'?

16) Complete the diagram below to show how *low doses* and *high doses* of ionising radiation can affect human beings:



17) Explain why it is important to measure the dose of ionising radiation human beings are exposed to.

"N5 PHYSICS" NUCLEAR RADIATION - Spread 7

1) (a) What happens to the energy of 'ionising radiation' when the radiation strikes the human body?

(b) When human body tissue 'absorbs a dose of ionising radiation', what does the body tissue absorb from the radiation?

2) (a) Explain what is meant by the term 'absorbed dose'?'

(b) In what "unit" is 'absorbed dose' measured? - give the word and symbol.

(c) What is '1 gray' equal to?

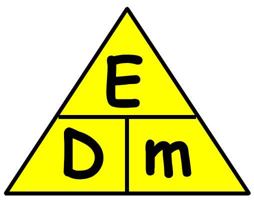
(d) Complete the following:

1 gray (Gy) is a very large quantity.

Typical absorbed dose values are measured in _______________ (μGy) or _______________ (mGy).

1 μGy = _______________ Gy = (1 x 10—) Gy   *1 mGy = _________ Gy = (1 x 10—) Gy.*

(e) Label the equation triangle and complete the equations shown in the box:



D =

E =

m =

CARRY OUT THE FOLLOWING CALCULATIONS:

3) A sample of body tissue has a mass of 0.50 kg. The tissue absorbs 8.5×10^{-4} J of energy when it is exposed to alpha radiation.

Calculate the absorbed dose received by the body tissue.

4) A 0.25 kg sample of skin tissue absorbs 1.2×10^{-6} J of energy when it is exposed to beta radiation.

Calculate the absorbed dose received by the skin tissue.

5) When exposed to gamma radiation, 0.020 kg of lip tissue absorbs 3.8×10^{-5} J of energy from the radiation.

Calculate the absorbed dose received by the lip tissue.

6) A 0.048 kg mass of heart tissue receives an absorbed dose of 1.5 mGy (1.5×10^{-3} Gy) from alpha particles.

Calculate the energy the heart tissue absorbs from the alpha particles.

7) An absorbed dose of 9.2 μGy (9.2×10^{-6} Gy) is received by a 0.25 kg mass of spleen tissue on exposure to beta particles.

Calculate the energy the spleen tissue absorbs from the beta particles.

8) A 0.015 kg sample of kidney tissue receives an absorbed dose of 4.2 mGy (4.2×10^{-3} Gy) when exposed to gamma rays.

Calculate the energy the kidney tissue absorbs from the gamma rays.

9) A mass of tongue tissue receives an absorbed dose of 3.2 mGy (3.2×10^{-3} Gy) of alpha radiation. The tissue absorbs 4.8×10^{-5} J of energy from the alpha radiation.

Calculate the mass of the tongue tissue.

10) When exposed to beta radiation, a sample of bowel tissue receives an absorbed dose of 7.5 μGy (7.5×10^{-6} Gy) on absorbing 4.8×10^{-7} J of energy from the beta radiation.

Calculate the mass of the bowel tissue sample.

11) A sample of bone absorbs 1.8×10^{-4} J of energy from gamma radiation, receiving an absorbed dose of 2.5 mGy (2.5×10^{-3} Gy) as a result.

Calculate the mass of the bone sample.

12) When gamma rays hit a 0.060 kg sample of medulla tissue, the tissue absorbs 8.4×10^{-5} J of energy from the gamma rays.

Calculate the absorbed dose received by the medulla tissue.

13) The hand of a nurse has a mass of 0.38 kg. It receives an absorbed dose of 5.0 μGy (5.0×10^{-6} Gy) when exposed to nuclear radiation.

Calculate the energy the hand absorbs from the nuclear radiation.

14) Calculate the mass of a big toe that absorbs 2.2×10^{-7} J of energy from nuclear radiation, if the absorbed dose the big toe receives from the radiation is 4.0 μGy (4.0×10^{-6} Gy).

15) If a 0.35 kg sample of brain stem tissue absorbs 9.8×10^{-7} J of energy when exposed to beta particles, what is the absorbed dose for the brain stem tissue?

16) What energy will a 0.75 kg sample of liver tissue absorb when it receives an absorbed dose of 6.8 μGy (6.8×10^{-6} Gy) on exposure to ionising radiation?

17) What mass of bladder tissue will absorb 3.2×10^{-4} J of energy from ionising radiation if the absorbed dose the tissue receives from the radiation is 8.0 mGy (8.0×10^{-3} Gy)?

18) (a) When 'ionising radiation' is absorbed by human body tissue, the tissue may be damaged. State one factor the amount of damage depends on.

(b) Explain why the amount of damage depends on this factor.

19) (a) Explain how physicists compare the amount of damage different types of 'ionising radiation' cause to the same sample of human body tissue.

(b) Complete the following sentence:

For the same sample of human body tissue exposed to 'ionising radiation', the higher the ____________ __________ of the radiation, the ___________ the __________ done to the tissue.

(c) Complete the table below to compare the 'weighting factor' assigned to different types of 'ionising radiation':

Type of Ionising Radiation	**Weighting Factor (w_r)**
	20
beta particles	
gamma rays	
X-rays	
	2.3
	10

(d) Make use of the 'weighting factor' values in the table above to complete the following sentences:

- *If a sample of human body tissue receives the same 'absorbed dose' of alpha particles and gamma rays, the ________ ________ will cause ____ times ________ damage than the ________ ________ to the tissue sample.*
- *If a sample of human body tissue receives the same 'absorbed dose' of alpha particles and fast neutrons, the ________ ________ will cause ____ times ________ damage than the ________ ________ to the tissue sample.*
- *If a sample of human body tissue receives the same 'absorbed dose' of slow neutrons and X-rays, the________ ________ will cause ____ times ________ damage than the ________ ________ to the tissue sample.*
- *If a sample of human body tissue receives the same 'absorbed dose' of beta particles and gamma rays, the ________ ________ will cause exactly the ________ amount of damage to the tissue sample as the ________ ________.*

"N5 PHYSICS" NUCLEAR RADIATION - Spread 8

1) Complete the following:

It is important to be able to compare the ____________ ______ different types of ____________ ____________ can do to the same sample of ______ ________.

We need to take into account both the ________ and the ________ of the ionising radiation striking the body tissue.

This is achieved by multiplying the ____________ ______ of ionising radiation the sample of body tissue receives by the ____________ ________ for the radiation - this gives a quantity known as ____________ ______ (__).

2) (a) Explain what is meant by the term 'equivalent dose'?

(b) In what "unit" is 'equivalent dose' measured? - give the word and symbol.

(c) (i) What is '1 sievert' equal to?

(ii) State another 'physical quantity' that has the same unit.

(d) Complete the following:

1 sievert (Sv) is a very large quantity.

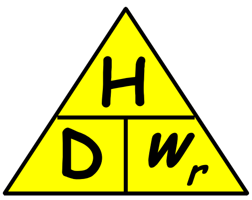
Typical equivalent dose values are measured in ____________ (µSv) or ____________ (mSv).

1 µSv = ____________ Sv = (1 x $10^{\_\_}$) Sv   1 mSv = ________ Sv = (1 x $10^{\_\_}$) Sv.

(e) Complete the following sentence:

For the same sample of human body tissue exposed to 'ionising radiation', the higher the ____________ ________ of radiation it receives, the __________ the ____________ ________ it will be subjected to.

(f) Label the equation triangle and complete the equations shown in the box:



$H =$

$D =$

$w_r =$

CARRY OUT THE FOLLOWING CALCULATIONS:

3) A sample of thyroid gland tissue receives an absorbed dose of 4.2 mGy (4.2 x 10^{-3} Gy) when exposed to beta particles.

Calculate the equivalent dose received by the tissue.

4) During a dental X-ray, a section of gum tissue receives an absorbed dose of 5.5 µGy (5.5 x 10^{-6} Gy).

Calculate the equivalent dose the gum tissue receives.

5) The hand of a nuclear radiation worker, when exposed to slow neutrons, receives an absorbed dose of 2.0 mGy (2.0 x 10^{-3} Gy).

Calculate the equivalent dose received by the hand.

6) A resident of Aberdeen receives an equivalent dose of 7.8 mSv (7.8×10^{-3} Sv) from radon gas, an emitter of alpha particles.

Calculate the absorbed dose the resident receives.

7) During a CT scan involving X-rays, a brain tumour receives an equivalent dose of 1.4 μSv (1.4×10^{-6} Sv).

Calculate the absorbed dose received by the brain tumour.

8) When exposed to slow neutrons, a sample of bone receives an absorbed dose of 6.9 μSv (6.9×10^{-6} Sv).

Calculate the absorbed dose for the bone sample.

9) When exposed to ionising radiation, a sample of skin tissue receives an equivalent dose of 120 mSv (120×10^{-3} Sv) and an absorbed dose of 6.0 mGy (6.0×10^{-3} Gy).

Calculate the weighting factor of the ionising radiation.

10) When exposed to a dose of ionising radiation, a fat tissue sample receives an equivalent dose of 9.66 μSv (9.66×10^{-6} Sv) and an absorbed dose of 4.20 μGy (4.20×10^{-6} Gy).

Calculate the weighting factor of this ionising radiation.

11) A kidney tissue sample receives an equivalent dose of 6.3 mSv (6.3×10^{-3} Sv) and an absorbed dose of 6.3 mGy (6.3×10^{-3} Gy) on exposure to ionising radiation.

Calculate the ionising radiation's weighting factor.

12) A technician's fingernail receives an absorbed dose of 0.36 μGy (0.36×10^{-6} Gy) when exposed to fast neutrons.

Calculate the equivalent dose the fingernail receives.

13) Exposure to fast neutrons results in a sample of ligament tissue receiving an absorbed dose of 15 mSv (15×10^{-3} Sv).

Calculate the absorbed dose value due to the fast neutrons for the ligament tissue sample.

14) Measurements indicate that a lymph node tissue sample receives an equivalent dose of 4.8 μSv (4.8×10^{-6} Sv) and an absorbed dose of 2.4 μGy (2.4×10^{-6} Gy) when exposed to 'proton radiation'.

Calculate the weighting factor for 'proton radiation'.

15) When exposed to alpha particles, the absorbed dose received by a hair tissue sample is 0.12 μGy (0.12×10^{-6} Gy).

Calculate the equivalent dose received by the hair tissue sample.

16) Blood cells can turn cancerous if they receive an equivalent dose of 100 mSv (100×10^{-3} Sv) when exposed to gamma rays.

Calculate the absorbed dose the blood cells must receive on exposure to gamma rays in order to turn cancerous.

17) A research scientist's thumb receives an equivalent dose of 0.90 mSv (0.90×10^{-3} Sv) and an absorbed dose of 45 μGy (45×10^{-6} Gy) due to exposure to 'heavy ions'.

Calculate the weighting factor of the 'heavy ions'.

18) A sample of tendon tissue is exposed to both alpha particles and beta particles.

The tissue sample receives an absorbed dose of 0.12 μGy (0.12×10^{-6} Gy) due to the alpha particles and an absorbed dose of 3.5 μGy (3.5×10^{-6} Gy) due to the beta particles.

Calculate the total equivalent dose received by the sample of tendon tissue.

---

19) A sample of appendix tissue is exposed to both alpha particles and slow neutrons.

The tissue sample receives an absorbed dose of 0.18 mGy (0.18×10^{-3} Gy) due to the alpha particles and an absorbed dose of 2.0 mGy (2.0×10^{-3} Gy) due to the slow neutrons.

Calculate the total equivalent dose received by the appendix tissue sample.

---

20) A sample of scalp tissue is exposed to gamma rays, slow neutrons and fast neutrons.

The tissue sample receives an absorbed dose of 1.5 μGy (1.5×10^{-6} Gy) due to the gamma rays, an absorbed dose of 3.0 μGy (3.0×10^{-6} Gy) due to the slow neutrons and an absorbed dose of 0.14 μGy (0.14×10^{-6} Gy) due to the fast neutrons.

Calculate the total equivalent dose received by the sample of scalp tissue.

---

21) A sample of colon tissue is exposed to alpha particles, X-rays and fast neutrons.

The tissue sample receives an absorbed dose of 0.16 mGy (0.16×10^{-3} Gy) due to the alpha particles, an absorbed dose of 1.9 mGy (1.9×10^{-3} Gy) due to the X-rays and an absorbed dose of 0.23 mGy (0.23×10^{-3} Gy) due to the fast neutrons.

Calculate the total equivalent dose received by the colon tissue sample.

22) When exposed to slow neutrons, a human foot of mass 0.90 kg absorbs 2.7 mJ (2.7×10^{-3} J) of energy.

For the foot, calculate:

(a) the absorbed dose

(b) the equivalent dose

---

23) A child's arm has a mass of 0.20 kg. When exposed to X-rays, the arm absorbs 1.5 μJ (1.5×10^{-6} J) of energy.

For the arm, calculate:

(a) the absorbed dose

(b) the equivalent dose

---

24) A human tongue (mass 0.15 kg) absorbs 9.0 μJ (9.0×10^{-6} J) of energy when exposed to alpha particles.

For the tongue, calculate:

(a) the absorbed dose

(b) the equivalent dose

---

25) A 9.5 kg human body torso absorbs 3.8 mJ (3.8×10^{-3} J) of energy when exposed to fast neutrons.

For the torso, calculate:

(a) the absorbed dose

(b) the equivalent dose

1) Complete the following:

For the human body, as the time of exposure to ionising radiation _______________, the level of _______________ __________ to the body _______________.

It is therefore important to take into account the _______ of _____________ to the ionising radiation.

This is achieved by dividing the _______________ __________ of ionising radiation the sample of body tissue receives by the _______ of ____________ to the radiation - this gives a quantity known as the _______________ _______ _______ (__).

2) (a) Explain what is meant by the term 'equivalent dose rate'?'

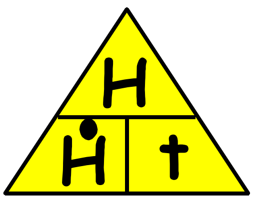
(b) List the different "units" 'equivalent dose rate' can be measured in - give the words and symbols.

(c) Complete the following:

Because 1 sievert (Sv) is a very large quantity, typical 'equivalent dose rate' values are often expressed in _______________ (μSv) per __________ / ____________ / _________ / _________ or in _______________ (mSv) per __________ / ____________ / _________ / _________ .

1 μSv = _______________ Sv = (1 x 10—) Sv   *1 mSv = _________ Sv = (1 x 10—) Sv.*

(d) Label the equation triangle and complete the equations shown in the box:



$\dot{H}$ =

H =

t =

CARRY OUT THE FOLLOWING CALCULATIONS:

3) When exposed to ionising radiation for a time of 25 s, a tooth receives an equivalent dose of 40 μSv (40 x 10^{-6} Sv).

Calculate the equivalent dose rate for the tooth.

4) A facial mole, on exposure to ionising radiation for a time of 1.5 minutes, receives an equivalent dose of 4.5 μSv (4.5 x 10^{-6} Sv).

Calculate the equivalent dose rate for the facial mole.

5) A bone fragment, exposed to ionising radiation for a time of 5.0 hours, receives an equivalent dose of 30 mSv (30 x 10^{-3} Sv).

Calculate the equivalent dose rate for the bone fragment.

6) For a sample of nasal mucus, exposed to ionising radiation for a time of 30 minutes, the equivalent dose rate is 0.24 μSv min^{-1} (0.24 x 10^{-6} Sv min^{-1}).

Calculate the equivalent dose received by the nasal mucus sample during this time.

7) Over a period of 6.5 hours, the equivalent dose rate for a blood plasma sample, on exposure to ionising radiation, is 0.12 μSv hr^{-1} (0.12 x 10^{-6} Sv hr^{-1}).

Calculate the equivalent dose received by the blood plasma sample over this period.

8) The equivalent dose rate for a urine sample exposed to ionising radiation for a time of 2.5 years is 0.80 mSv yr^{-1} (0.80 x 10^{-3} Sv yr^{-1}).

Calculate the equivalent dose received by the urine sample during this time.

9) The equivalent dose rate for a cancer tissue sample, on exposure to ionising radiation, was 3.3 mSv s^{-1} (3.3 x 10^{-3} Sv s^{-1}) when it received an equivalent dose of 9.9 mSv (9.9 x 10^{-3} Sv).

Calculate the time for which the cancer tissue sample was exposed to the ionising radiation.

10) On receiving an equivalent dose of 2.4 μSv (2.4 x 10^{-6} Sv) of ionising radiation, the equivalent dose rate for a sample of human faeces was 9.6 μSv min^{-1} (9.6 x 10^{-6} Sv min^{-1}).

Calculate the time of exposure to the ionising radiation for the human faeces sample.

11) On exposure to ionising radiation, the equivalent dose rate for a sample of human bile was 1.4 mSv hr^{-1} (1.4 x 10^{-3} Sv hr^{-1}) when it received an equivalent dose of 7.7 mSv (7.7 x 10^{-3} Sv).

Calculate the exposure time of the human bile to the ionising radiation.

12) Due to constant exposure to ionising background radiation for exactly 1 year, a girl receives an equivalent dose of 2.2 mSv (2.2 x 10^{-3} Sv).

Calculate the equivalent dose rate for the girl.

13) The equivalent dose rate for a sample of cervix tissue, exposed to ionising radiation for a time of 15 minutes, is 1.2 μSv min^{-1} (1.2 x 10^{-6} Sv min^{-1}).

Calculate the equivalent dose the cervix tissue sample received during this time.

14) When a sample of oesophagus tissue received an equivalent dose of 7.2 μSv (7.2 x 10^{-6} Sv) of ionising radiation, the equivalent dose rate for the tissue sample was 1.6 μSv hr^{-1} (1.6 x 10^{-6} Sv hr^{-1}).

Calculate the exposure time of the oesophagus tissue sample to the ionising radiation.

15) A sample of synovial fluid, when exposed to ionising radiation for a time of 18 s, receives an equivalent dose of 81 μSv (81 x 10^{-6} Sv).

Calculate the equivalent dose rate for the synovial fluid sample.

16) Over a period of 5.5 hours, the equivalent dose rate for a testicular tissue sample was 0.20 mSv hr^{-1} (0.20 x 10^{-3} Sv hr^{-1}). when exposed to gamma rays.

Calculate the equivalent dose the testicular tissue sample received during this period.

17) The equivalent dose rate for a gastric gland exposed to ionising radiation was 2.7 mSv yr^{-1} (2.7 x 10^{-3} Sv yr^{-1}). During the exposure time, the gastric gland received an equivalent dose of 8.1 mSv (8.1 x 10^{-3} Sv).

Calculate the time for which the gastric gland was exposed to the ionising radiation.

18) A salivary gland is exposed to both 'proton radiation' and 'heavy ions' for a time of 2.5 s.

The salivary gland receives an absorbed dose of 2.5 μGy (2.5×10^{-6} Gy) due to the 'proton radiation' and an absorbed dose of 0.15 μGy (0.15×10^{-6} Gy) due to the 'heavy ions'.

For 'proton radiation', $w_r = 2$. For 'heavy ions', $w_r = 20$.

(a) Calculate the total equivalent dose received by the salivary gland.

(b) Calculate the equivalent dose rate for the salivary gland.

---

19) A sample of diaphragm tissue is exposed to both alpha particles and slow neutrons for a time of 8.0 minutes.

The diaphragm tissue sample receives an absorbed dose of 0.21 mGy (0.21×10^{-3} Gy) due to the alpha particles and an absorbed dose of 2.0 mGy (2.0×10^{-3} Gy) due to the slow neutrons.

(a) Calculate the total equivalent dose received by the diaphragm tissue sample.

(b) Calculate the equivalent dose rate for the diaphragm tissue sample.

20) A sample of larynx tissue is exposed to beta particles, slow neutrons and fast neutrons for a time of 5.0 hours.

The larynx tissue sample receives an absorbed dose of 1.4 μGy (1.4×10^{-6} Gy) due to the beta particles, an absorbed dose of 3.0 μGy (3.0×10^{-6} Gy) due to the slow neutrons and an absorbed dose of 1.2 μGy (1.20×10^{-6} Gy) due to the fast neutrons

(a) Calculate the total equivalent dose received by the larynx tissue sample.

(b) Calculate the equivalent dose rate for the larynx tissue sample.

---

21) A cartilage disc is exposed to alpha particles, gamma rays and fast neutrons for a time of 1.5 years.

The cartilage disc receives an absorbed dose of 0.10 mGy (0.10×10^{-3} Gy) due to the alpha particles, an absorbed dose of 2.5 mGy (2.5×10^{-3} Gy) due to the gamma rays and an absorbed dose of 0.21 mGy (0.21×10^{-3} Gy) due to the fast neutrons

(a) Calculate the total equivalent dose received by the cartilage disc.

(b) Calculate the equivalent dose rate for the cartilage disc.

1) (a) Complete this table to compare the equivalent dose of background radiation we typically receive each year in the U.K. from different sources.

Tick or cross the appropriate boxes to show whether each source is natural or artificial.

Source of Background Radiation	Approximate Equivalent Dose Received Each Year (mSv)	Natural Source? (TICK or CROSS)	Artificial Source? (TICK or CROSS)
nuclear weapon tests and leaks from nuclear power stations	0.02		
medical uses (such as cancer treatment and X-rays)	0.26		
cosmic rays from the sun and other stars			
rocks, the soil and the building materials these are made into			
our bodies and the food/drink we consume			
radon gas present in the air			

(b) (i) Add up the approximate equivalent dose values shown in the table to give a value for the approximate total annual equivalent dose that a resident of the U.K. receives from background radiation.

(ii) State the average annual equivalent dose rate in the U.K. due to background radiation.

(iii) Explain why the value you stated in (ii) is an 'average' value.

2) State the value of the 'annual effective equivalent dose safety limit' in the U.K. set for exposure to ionising radiation:

(a) by members of the public

= __________

(in addition to background radiation)

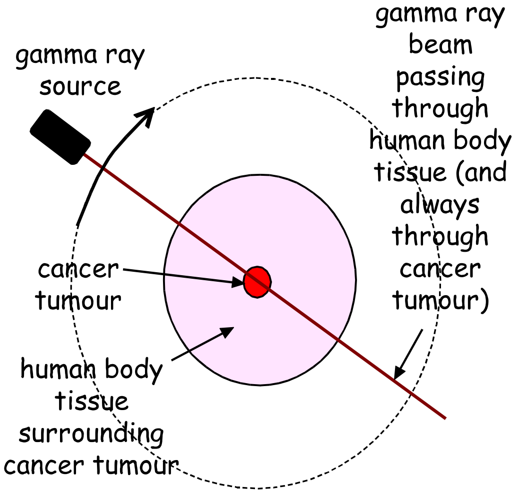
(b) by radiation workers

= __________

(in addition to background radiation).

1) (a) What is 'radiotherapy' used for?

(b) This diagram shows how gamma rays are used to kill/damage cancer cells inside the human body.



(i) Suggest why gamma rays are used instead of alpha particles or beta particles.

(ii) Describe the path of the gamma ray source around the human body.

(iii) What does the gamma ray beam always pass through?

(iv) During each rotation of the gamma ray source around the human body, how many times does the gamma ray beam pass through each section of the surrounding human body tissue?

(v) Compare the dose of gamma radiation received by the cancer tumour and the surrounding human body tissue.

(vi) Suggest why it is important for a patient receiving treatment by this method to 'remain still' during the treatment process.

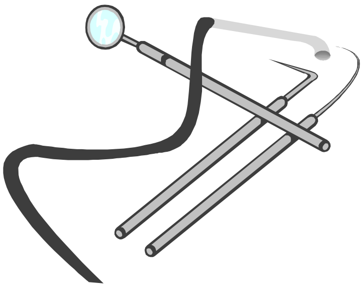
2) (a) What is a 'tracer'?

(b) (i) Why do doctors inject a 'tracer' into a patient's bloodstream?

(ii) What is used to detect the gamma radiation emitted by the 'tracer'?

(iii) What can this process detect?

3) (a) Explain what is meant by the term 'sterilise'.



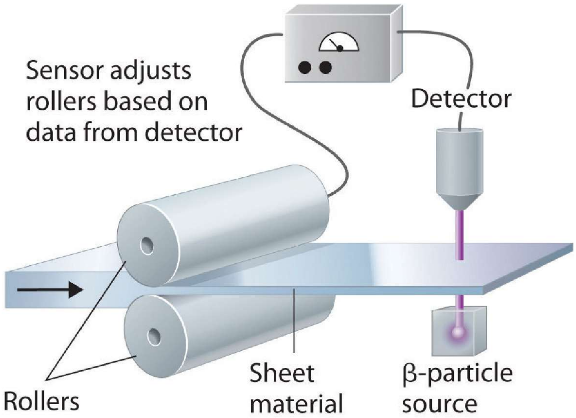
(b) Explain how surgical instruments are 'sterilised'.

4) This diagram shows how beta radiation is used to monitor the thickness of a sheet material such as paper as the paper is being produced.

(a) Explain how the reading on the beta particle detector will be affected if the paper thickness:

(i) increases

(ii) decreases.



(b) Explain how this system allows the correct thickness of paper to be maintained.

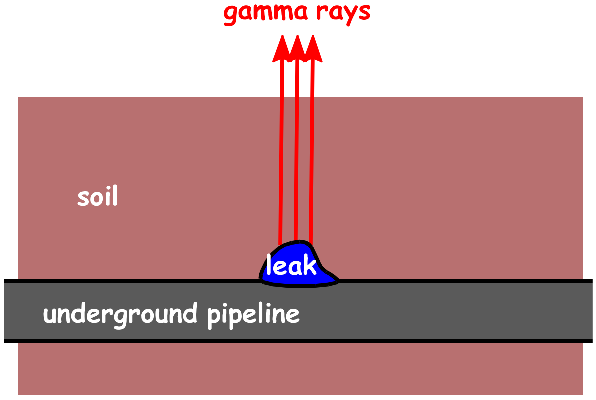
(c) (i) Suggest why alpha particles would not be suitable for this process.

(ii) Suggest why gamma rays would not be suitable for this process.

5) (a) In order to detect the position of a leak in an underground pipeline, what can be added to the liquid flowing through the pipeline?

(b) Describe the path of any gamma radiation emitted from the leak in the pipeline.

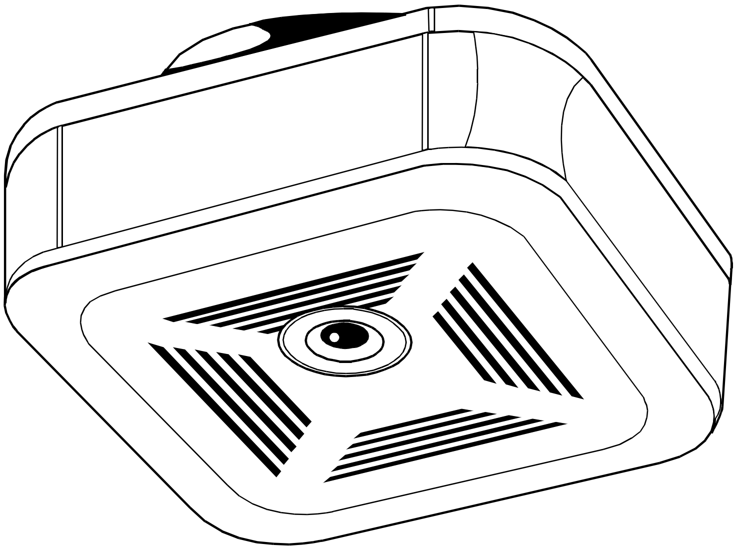
(c) State what will happen to the reading on the counter of a Geiger-Muller tube when the tube is on the soil surface, positioned directly over the leak.



6) (a) What is a 'weld' in a metal pipeline?

(b) Explain how gamma radiation is used to detect cracks or gaps in the welds of a metal pipeline. (You should describe the reading on a gamma ray detector positioned at a crack or gap in the weld).

7 (a) Describe the 'ionising radiation' source contained in a smoke alarm.



(b) (i) What do the alpha particles emitted from this 'ionising radiation' source do to the nearby air molecules inside the smoke alarm?

(ii) What does this release?

(iii) What do these electrons create? ..... and where?

(iv) Explain, in detail, what happens when smoke enters a smoke alarm, from the moment the smoke enters the alarm until the moment the alarm's buzzer is switched on.

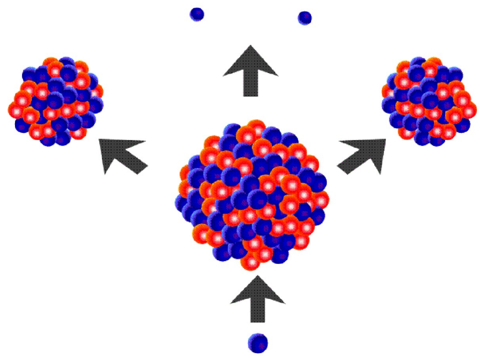
1) (a) Complete the following:

During nuclear ____________ , a ________ ___________ hits the __________ (centre) of a ______________ atom, causing that ___________ to break up into two smaller parts called _____________ ____________ . Every time this happens, the ___________ energy of the ____________ ____________ is converted to _________ energy.

Two or three more ________ ___________ are also released from the split __________ .

(b) This diagram represents the process of 'nuclear fission'.

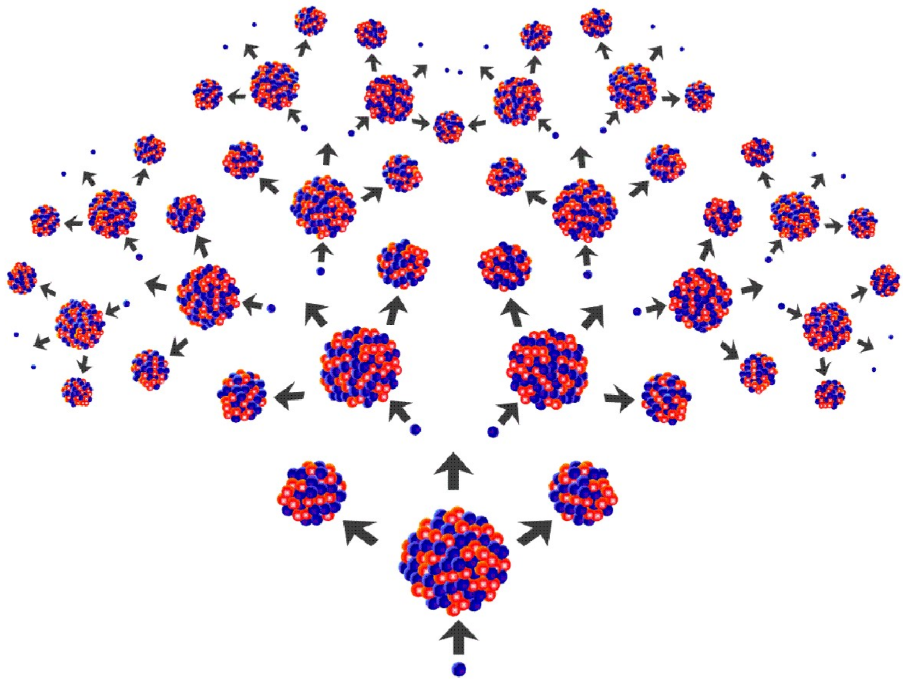
Label the diagram.



(c) Complete the following:

Following the nuclear ____________ process represented in the above diagram, the ________ ___________ that are released (once __________ down sufficiently to become ________ ___________) hit the __________ (centre) of other ___________ atoms, causing these ___________ to break up into two _____________ ____________ and release more ________ ____________ that, once __________ down to become ________ _________ , cause the process to ____________ each time - this is known as a _________ ____________ . ___________ ______________ generate a great deal of _________ energy.

(d) Name the process represented by the diagram opposite.



(e) Explain why the neutrons taking part in 'nuclear fission' are classified as 'nuclear radiation'.

2) (a) Complete the following:

A large part of the ________________ energy (electricity) used in the U.K. is generated as a result of ___________ ___________ reactions in the ___________ ___________ ___________ of a ___________ power station.

The purpose of the ___________ ___________ __________ is to produce a constant source of _______ energy. This _______ energy is used to boil _________ in order to produce ______ pressure ________ .

The ______ pressure ________ is used to turn __________ _________ connected to __________ that convert the ___________ energy of the __________ to ____________ energy (electricity).

(b) the diagram below represents the 'nuclear fission reactor' in a typical nuclear power station. Fill in the missing words to explain the function of each part.

These _______ or ________ rods are lowered into the __________ __________ to absorb unwanted ____________ - this stops the _______ __________ getting '_____ of ____________'.

_________ (under ______ pressure) that has been heated as it passes through the ______ of the _________ _________ transfers its _______ energy to ___________ _________ in a __________ , turning that ________ to __________. This _________ is used to turn a ____________ that generates ______________ energy (______________).

Prevents the escape of _________ ___________ from the __________ ___________ and protects it from ___________ ___________.

A hollow ______ filled with _________ of __________ or ___________ for the ___________ ___________ process.

Slows down the '______ ___________' produced by the _________ ___________ reactions - these ___________ thus become '______ ___________.' This ____________ the chance of further ___________ ___________ reactions taking place.

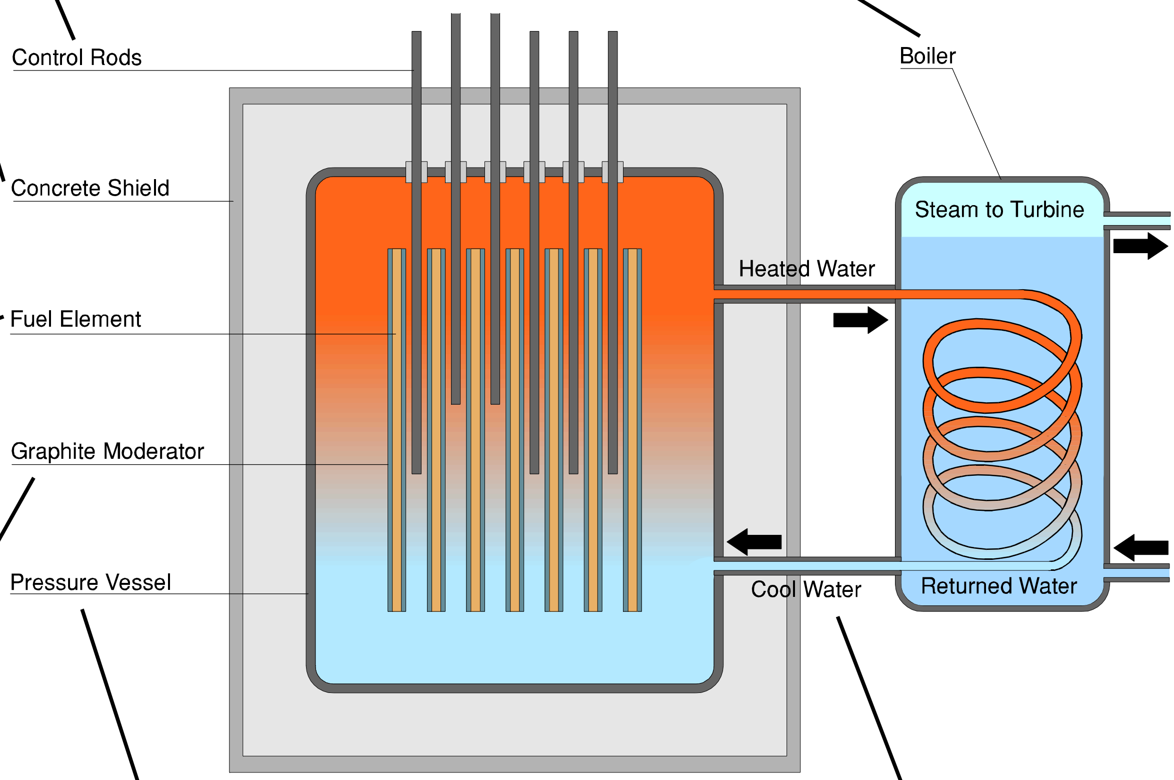


diagram copyright Global Software Publishing Ltd.

Contains the '____________ parts' of the __________ __________. It withstands the high ____________ and _______________ inside the ___________ ___________ , ensuring the _____________ ___________ does not ___________ ___________ / _________.
It also prevents the escape of ___________ and __________ __________ from the ____________ ___________.

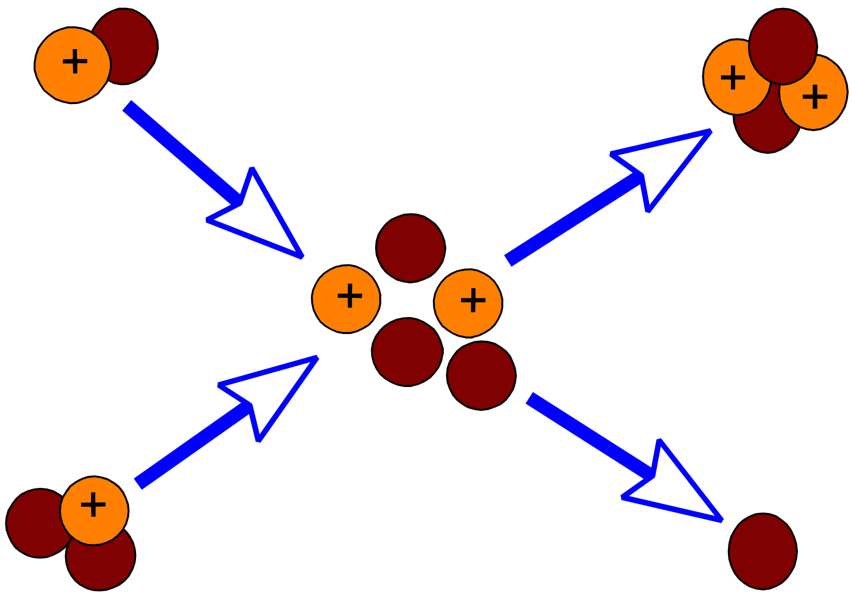
_________ ___________ (under _______ pressure) acts as a '_____________' to remove ________ energy from the ________ of the _________ _________.

1) (a) Complete the following:

In a nuclear ____________ reaction, _____ small ____________ - charged __________ __________ collide together at _______ _______ _______ . They __________ __________ to form ____ larger __________ __________ . A single ___________ is usually released as well.

When ___________ _________ is carried out by physicists/engineers on earth, ____________ and _____________ nuclei are commonly used for collision - these are types of ___________ . In this case, the larger atomic nucleus formed is __________ .

(b) This diagram represents the process of 'nuclear fusion' between deuterium and tritium nuclei. Label the diagram.



(c) Complete the following:

Nuclear ___________ reactions can only take place at very high ______________ and ______________ - typically above ____ ____________ °C (1 x 10 — °C). These _____________ conditions are needed to overcome the _________ ____________ ________ acting between the two small _____________ - charged colliding __________ as they ___________ one another.

At such high temperatures, matter exists in a ___________ state known as _________ - a _____ energy ____________ of small __________ particles, larger ___________ - charged __________ __________ and the ____________ these ___________ - charged __________ __________ have lost.

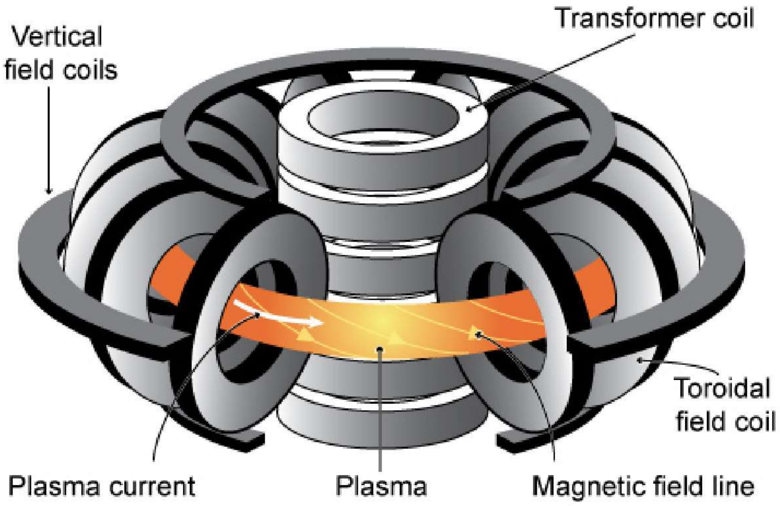
(d) Explain why 'nuclear fusion' reactions can only take place at very high pressures and very high temperatures.

(e) Describe the physical state of matter known as 'plasma'.

2) (a) State a major problem with the 'nuclear fusion' process carried out by physicists/engineers on earth.

(b) Explain how this problem is overcome.

3) This diagram shows a device that can be used to 'confine' plasma, i.e., keep the plasma away from its container walls:



(a) What is this device known as?

(b) Describe the shape of the device and state what is inside it.

(c) This device uses 'enormously-strong magnetic fields'.

(i) Describe how these are created.

(ii) Describe two affects these 'enormously-strong magnetic fields' have on the plasma inside the device.

4) (a) Describe how heat energy is obtained from a 'nuclear fusion' process - HINT: the neutrons released by the process.

(b) Explain why the potential of 'nuclear fusion' as a low-cost and plentiful supply of energy in the future is enormous.

Answers to Questions Involving Calculations

Spread 3

3) 50 Bq
4) 30 Bq
5) 200 Bq
6) 2.16×10^6 nuclei
(2 160 000 nuclei)
7) 7.68×10^6 nuclei
(7 680 000 nuclei)
8) 8.64×10^5 nuclei
(864 000 nuclei)
9) 6.25 s
10) 8.75 s
11) 0.25 s
12) 30 000 Bq
13) 45 000 nuclei
14) 0.75 s
15) 39 200 Bq
16) 67 500 nuclei
17) 20 s

Spread 4

3) A = 5 seconds
B = 25 minutes
C = 11 hours
D = 18 days

Spread 5

5) (a) 25 counts per second
(b) (i) 240
150
90
60
40
(ii) 30 minutes

6) (a) 16 counts per second
(b) (i) 300
185
125
75
45
(ii) 75 minutes

Spread 6

1) 8 seconds
2) 15 hours
3) 40 minutes
4) 25 seconds
5) 15 years
6) 800 years
7) 14 minutes
8) 20 hours
9) 50 seconds
10) 47.5 days
11) 37.5 seconds
12) 495 years

Spread 7

3) 0.0017 Gy
4) 4.8×10^{-6} Gy (4.8 µGy)
(0.000 004 8 Gy)
5) 0.0019 Gy
6) 7.2×10^{-5} J
(0.000 072 J)
7) 2.3×10^{-6} J (2.3 µJ)
(0.000 002 3 J)
8) 6.3×10^{-5} J
(0.000 063 J)
9) 0.015 kg
10) 0.064 kg
11) 0.072 kg
12) 1.4×10^{-3} Gy
(0.001 4 Gy)
13) 1.9×10^{-6} J (1.9 µJ)
(0.000 001 9 J)
14) 0.055 kg
15) 2.8×10^{-6} Gy (2.8 µGy)
(0.000 002 8 Gy)
16) 5.1×10^{-6} J (5.1 µJ)
(0.000 005 1 J)
17) 0.040 kg

Spread 8

3) 4.2×10^{-3} Sv (4.2 mSv)
(0.004 2 Sv)
4) 5.5×10^{-6} Sv (5.5 µSv)
(0.000 005 5 Sv)
5) 4.6×10^{-3} Sv (4.6 mSv)
(0.004 6 Sv)
6) 3.65×10^{-4} Gy
(0.000 365 Gy)
7) 1.4×10^{-6} Gy (1.4 µGy)
(0.000 001 4 Gy)
8) 3×10^{-6} Gy (3 µGy)
(0.000 003 Gy)
9) 20
10) 2.3
11) 1
12) 3.6×10^{-6} Sv (3.6 µSv)
(0.000 003 6 Sv)
13) 1.5×10^{-3} Gy (1.5 mGy)
(0.001 5 Gy)
14) 2
15) 2.4×10^{-6} Sv (2.4 µSv)
(0.000 002 4 Sv)
16) 0.1 Gy
17) 20

18) 5.9×10^{-6} Sv (5.9 μSv)
(0.000 005 9 Sv)
19) 8.2×10^{-3} Sv (8.2 mSv)
(0.008 2 Sv)
20) 9.8×10^{-6} Sv (9.8 μSv)
(0.000 009 8 Sv)
21) 7.4×10^{-3} Sv (7.4 mSv)
(0.007 4 Sv)
22) (a) 3.0×10^{-3} Gy
(3.0 mGy)
(0.003 Gy)
(b) 6.9×10^{-3} Sv
(6.9 mSv)
(0.006 9 Sv)
23) (a) 7.5×10^{-6} Gy
(7.5 μGy)
(0.000 007 5 Gy)
24) (a) 6.0×10^{-5} Gy
(0.000 06 Gy)
(b) 1.2×10^{-2} Sv
(12 mSv)
(0.012 Sv)
25) (a) 4.0×10^{-4} Gy
(0.000 4 Gy)
(b) 4.0×10^{-3} Sv
(4.0 mSv)
(0.004 Sv)

Spread 9

3) 1.6×10^{-6} Sv second^{-1}
(1.6 μSv second^{-1})
(0.000 001 6 Sv second^{-1})
4) 3.0×10^{-6} Sv minute^{-1}
(3.0 μSv minute^{-1})
(0.000 003 Sv minute^{-1})
5) 6.0×10^{-3} Sv hour^{-1}
(6.0 mSv hour^{-1})
(0.006 0 Sv hour^{-1})
6) 7.2×10^{-6} Sv
(7.2 μSv)
(0.000 007 2 Sv)
7) 7.8×10^{-7} Sv
(0.000 000 7 8 Sv)
8) 2.0×10^{-3} Sv
(2.0 mSv)
(0.002 0 Sv)
9) 3 seconds
10) 0.25 minutes
11) 5.5 hours
12) 2.2×10^{-3} Sv year^{-1}
(2.2 mSv year^{-1})
(0.002 2 Sv year^{-1})
13) 1.8×10^{-5} Sv
(0.000018 Sv)
14) 4.5 hours
15) 4.5×10^{-6} Sv second^{-1}
(4.5 μSv second^{-1})
(0.000 004 5 Sv second^{-1})
16) 1.1×10^{-3} Sv
(1.1 mSv)
(0.001 1 Sv)
17) 3.0 years
18) (a) 8.0×10^{-6} Sv
(8.0 μSv)
(0.000 008 0 Sv)
(b) 3.2×10^{-6} Sv second^{-1}
(3.2 μSv second^{-1})
(0.000 003 2 Sv second^{-1})
19) (a) 8.8×10^{-3} Sv
(8.8 mSv)
(0.008 8 Sv)
(b) 1.1×10^{-3} Sv minute^{-1}
(1.1 mSv minute^{-1})
(0.0011 Sv second^{-1})
20) (a) 2.03×10^{-5} Sv
(0.000 0203 Sv)
(b) 4.06×10^{-6} Sv hour^{-1}
(4.06 μSv hour^{-1})
(0.000 004 06 Sv hour^{-1})
21) (a) 6.6×10^{-3} Sv
(6.6 mSv)
(0.006 6 Sv)
(b) 4.4×10^{-3} Sv year^{-1}
(4.4 mSv year^{-1})
(0.004 4 Sv year^{-1})