Chapter # 24
Radioactivity
Alpha, Beta & Gamma Radiation

Q-1: Which types of radiation may be emitted by radioactive nuclei?

A beta and gamma
B microwaves and infra-red
C radio waves and microwaves
D ultra-violet and X-rays

Q-2: Three types of radiation emitted by unstable nuclei are electrons, helium nuclei and electromagnetic radiation. What are these types of radiation?

	electrons	helium nuclei	electromagnetic radiation
A	alpha	beta	gamma
B	alpha	gamma	beta
C	beta	alpha	gamma
D	beta	gamma	alpha

Q-3: What are the characteristics of an alpha-particle?

	charge	ionising effect
A	negative	strong
B	negative	weak
C	positive	strong
D	positive	weak

Q-4: A nucleus contains 94 protons and 240 nucleons. It emits an alpha-particle. How many protons and how many neutrons are in the nucleus produced?

	number of protons	number of neutrons
A	90	144
B	90	236
C	92	144
D	92	236

Q-5: Which of alpha, beta and gamma radiations are waves?

A alpha only
B beta only
C gamma only
D alpha and beta

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Q-6: A nucleus of phosphorus $^{32}P_{15}$ emits a beta-particle to form a new nucleus. What is the nucleon number and what is the proton number of the new nucleus?

	nucleon number (mass number)	proton number (atomic number)
A	28	13
B	31	14
C	31	15
D	32	16

Q-7: A radioactive material decays by this process:

$$^{Y}_{Z}L \rightarrow {}^{Y}_{Z+1}M + x$$

What is particle x?

A an electro **B** a helium nucleus **C** a neutron **D** a proton

Q-8: A nucleus of uranium $^{238}U_{92}$ decays to thorium by emitting an alpha-particle. What is the resulting thorium nucleus?

A $^{234}Th_{90}$ **B** $^{236}Th_{90}$ **C** $^{238}Th_{93}$ **D** $^{239}Th_{92}$

Q-9: A nucleus of phosphorus $^{32}P_{15}$ emits a beta-particle to form a new nucleus. What is the nucleon number and what is the proton number of the new nucleus?

	nucleon number (mass number)	proton number (atomic number)
A	28	13
B	31	14
C	31	15
D	32	16

Q-10: What happens to the proton number (atomic number) of a nucleus as it emits an alpha-particle?

A It decreases by one. **B** It decreases by two.
C It decreases by four. **D** It does not change.

Q-11: Which nucleus is produced when thorium-223 $^{223}Th_{90}$ emits an alpha-particle?

A $^{219}Ra_{88}$ **B** $^{219}U_{92}$ **C** $^{227}Ra_{88}$ **D** $^{227}U_{92}$

Q-12: Which states the three types of radiation emitted by radioactive isotopes in order of their ionizing effect from highest to lowest?

A alpha-particles, beta-particles, gamma-rays
B alpha-particles, gamma-rays, beta-particles
C beta-particles, gamma-rays, alpha-particles
D gamma-rays, beta-particles, alpha-particles

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Q-13: A nucleus of $^{215}Po_{84}$ decays by emitting an alpha-particle and the resulting nucleus then decays by emitting a beta-particle. What is the nucleon number and proton number of the final nucleus?

	nucleon number	proton number
A	211	81
B	211	83
C	212	81
D	212	83

Q-14: When a radioactive atom decays by alpha-particle emission, its nucleus loses

A 1 proton only.
B 1 proton and 1 electron.
C 2 protons and 2 electrons.
D 2 protons and 2 neutrons.

Q-15: Which nucleus is produced when americium-241 $^{241}Am_{95}$ emits an alpha-particle?

A $^{237}Np_{93}$ **B** $^{237}Bk_{97}$ **C** $^{245}Np_{93}$ **D** $^{245}Bk_{97}$

Q-16: A radioactive nuclide $^{238}U_{92}$ decays into thorium by emitting an alpha-particle. The thorium then decays into protactinium by emitting a beta-particle. What is the symbol for protactinium?

A. $^{230}Pa_{90}$ **B.** $^{234}Pa_{89}$ **C.** $^{234}Pa_{90}$ **D.** $^{234}Pa_{91}$

Q-17: In one radioactive decay, radium (Ra) gives rise to radon (Rn) as shown.

$$^{226}Ra_{88} \rightarrow {}^{222}Rn_{86}$$

What particle is also produced?

A an alpha-particle
B a beta-particle
C both an alpha-particle and a beta-particle
D no particle but only gamma-rays

Q-18: Which equation represents the β-decay of lead-209?

A $^{209}_{82}Pb + {}^{0}_{-1}e \rightarrow {}^{209}_{83}Bi$

B $^{209}_{82}Pb + {}^{0}_{-1}e \rightarrow {}^{209}_{81}Tl$

C $^{209}_{82}Pb \rightarrow {}^{209}_{83}Bi + {}^{0}_{-1}e$

D $^{209}_{82}Pb \rightarrow {}^{209}_{81}Tl + {}^{0}_{-1}e$

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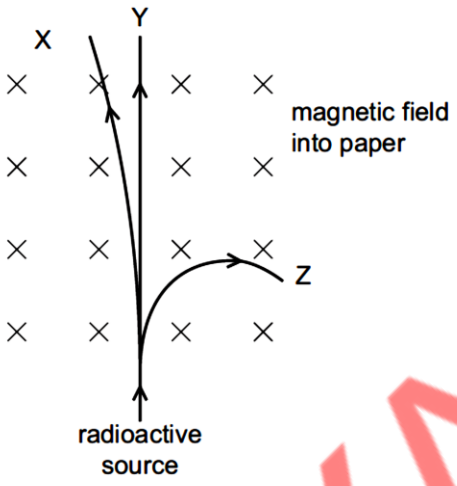
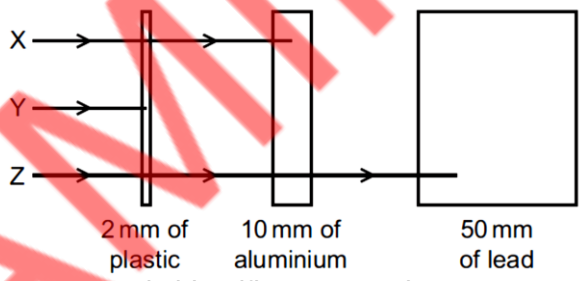
Q-19: A radioactive source emits α-particles, β-particles and γ-rays into a vacuum where there is a magnetic field. The magnetic field acts perpendicularly into the plane of the paper. The paths X, Y and Z of the three types of radiation through the magnetic field are shown.



Which radiation follows path X, path Y and path Z?

	X	Y	Z
A	α-particles	β-particles	γ-rays
B	α-particles	γ-rays	β-particles
C	β-particles	α-particles	γ-rays
D	β-particles	γ-rays	α-particles

Q-20: The diagram shows the paths of three different types of radiation X, Y and Z.



Which row correctly identifies X, Y and Z?

	X	Y	Z
A	α-particles	β-particles	γ-rays
B	β-particles	α-particles	γ-rays
C	β-particles	γ-rays	α-particles
D	γ-rays	α-particles	β-particles

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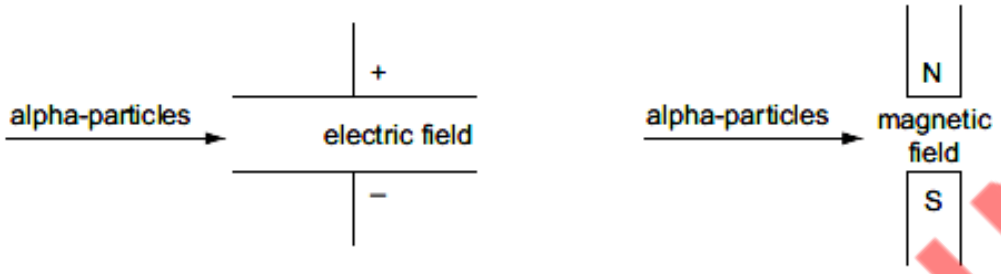
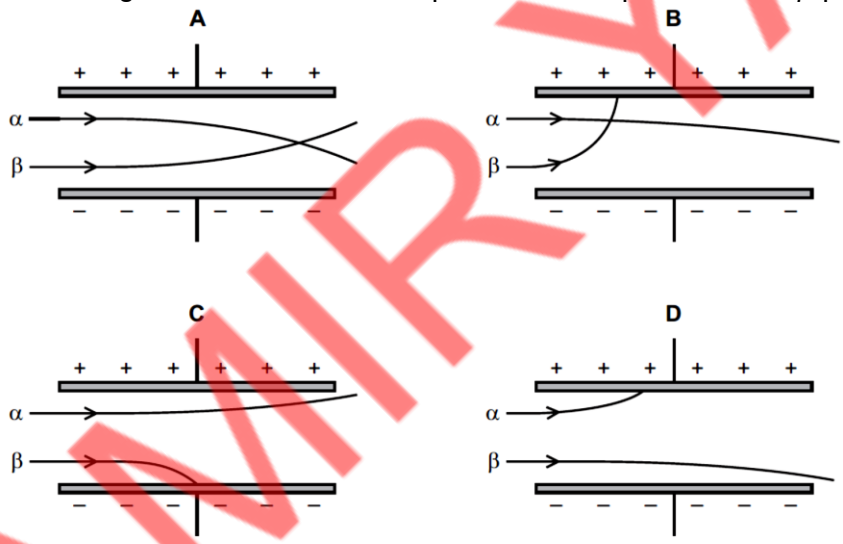
Q-21: Alpha-particles pass through an electric field or a magnetic field.



How is the path of the particles affected by these fields?

	electric field	magnetic field
A	deflected	deflected
B	deflected	undeflected
C	undeflected	deflected
D	undeflected	undeflected

Q-22: The diagrams show α-particles and β-particles passing through an electric field.
Which diagram shows the correct paths of the α-particles and β-particles?



Q-23: Which statement about γ-rays is correct?

A They are deflected by both electric and magnetic fields.
B They are deflected by magnetic fields but not by electric fields.
C They are deflected by electric fields but not by magnetic fields.
D They are not deflected either by electric fields or by magnetic fields.

Q-24: Some radioactive nuclei decay to give new nuclei which are also radioactive. Part of a series of decays is shown.

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa \rightarrow {}^{234}_{92}U \rightarrow {}^{230}_{90}Th \rightarrow {}^{226}_{88}Ra$$

How many decays involve the emission of a β-particle?

A 1 **B** 2 **C** 3 **D** 5

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Q-25: Uranium-235 is a radioactive isotope. It undergoes a chain of decays and eventually forms the stable isotope lead-207. These two isotopes are represented as shown.

$^{235}_{92}U$ $^{207}_{82}Pb$

During this chain of decay, how many protons and how many neutrons are lost from a single nucleus of uranium-235 to form a single nucleus of lead-207?

	protons	neutrons
A	10	18
B	10	28
C	18	10
D	28	10

Q-26: Why is a thick shield made of lead needed to protect people from a source of γ-rays?

A Gamma radiation is strongly ionising and so is not very penetrating.
B Gamma radiation is strongly ionising and so is very penetrating.
C Gamma radiation is weakly ionising and so is not very penetrating.
D Gamma radiation is weakly ionising and so is very penetrating.

Q-27: Which row gives the range and electrical charge of an alpha-particle?

	range in air	electrical charge
A	a few centimetres	negative
B	a few centimetres	positive
C	a few metres	negative
D	a few metres	positive

Q-28: Which row states the nature and range of beta-particles in air?

	nature	range in air
A	electromagnetic radiation	1-10 cm
B	electromagnetic radiation	10-100 cm
C	electron	1-10 cm
D	electron	10-100 cm

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Q-29: a) Table gives information about the nature and charge of three types of radioactive emission. The table is incomplete.

type of radioactive emission	nature	charge
α (alpha)	helium nucleus	
β (beta)		negative
γ (gamma)		

Complete Table

b) i) State which radioactive emission is the most ionising.

ii) State which radioactive emission is the most penetrating.

Q-30: a) α (alpha)-particles, β (beta)-particles and γ (gamma)-rays have different characteristics. Complete Table by indicating the correct type of radiation for each characteristic. The first one is done for you.

characteristic	type of radiation		
	α-particles (alpha-particles)	β-particles (beta-particles)	γ-rays (gamma-rays)
largest mass	✓		
most ionising			
most penetrating			
negatively charged			
greatest speed			

b) A sample of radioactive material contains 80 mg of sodium-24.The half-life of sodium-24 is 15 hours. Calculate the mass of sodium-24 remaining in the sample after 45 hours.

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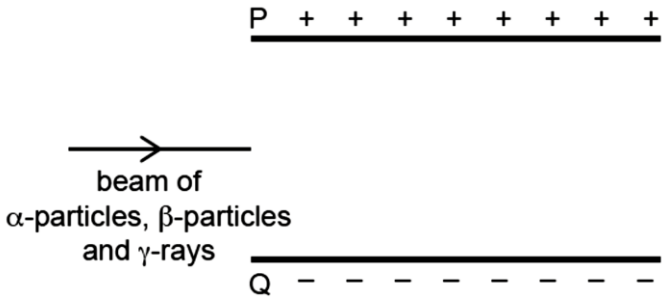
Q-31: a) Fig. 1 shows a beam of α-particles, β-particles and γ-rays directed between two Metal plates P and Q.



The metal plates are parallel and there is a large potential difference (p.d.) between them. Plate P is positive and plate Q is negative.
On Fig., draw the paths of each of the radiations between the plates and after leaving the plates. Label the paths α, β and γ.

b) State and explain **one** practical application of γ-rays.

Q-32: The nuclide notation for the radioactive isotope boron-12 is $^{12}B_5$.

a) In the space below, draw a labelled diagram to illustrate the structure of a neutral atom of this isotope. Show all the particles in the atom.

b) As boron-12 decays, it emits a beta-particle. A new atom is produced. Determine

i) the proton number (atomic number) of the new atom,

ii) the nucleon number (mass number) of the new atom.

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Q-33: a) One radioactive isotope of iodine is $^{131}I_{53}$. As a nucleus of this isotope decays, it emits a beta-particle (symbol: β) and it becomes a nucleus of an isotope of xenon (symbol: Xe). Complete the equation in nuclide form, for this decay.

$$^{131}_{53}I \rightarrow \text{.....}^{\text{.....}}_{\text{.....}}Xe + \text{.....}^{\text{.....}}_{\text{.....}}\beta$$

b) A sample of a radioactive isotope emits both beta-particles and gamma-rays. Fig. 1 shows these two types of radiation entering a magnetic field.

The direction of the magnetic field is into the page. On Fig. 1, mark **and** label the path taken by

i) the beta-particles,

ii) the gamma-rays.

c) Emission from a radioactive source is a random process.
State two ways in which the process is random.

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Half Life

Q-34: Which statement about the half-life of a radioactive isotope is correct?

A Half-life changes as the isotope decays.
B Half-life is the time it takes for the nucleon number of the isotope to halve.
C Half-life is half the time it takes for the number of nuclei of the isotope to decrease to zero.
D Half-life is the time it takes for the number of nuclei of the isotope to decrease by half.

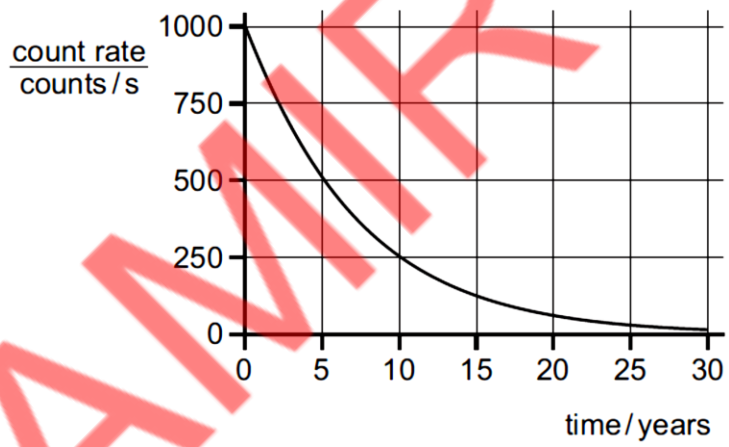
Q-35: A sample contains atoms of an isotope that has a half-life of 7.2 years.
Which quantity halves every 7.2 years?

A the mass of the sample
B the nucleon (mass) number
C the number of atoms of the isotope
D the proton (atomic) number

Q-36: A freshly made sample of radioactive material gives a count rate of 8000 counts per minute. After 20 days, it gives a count rate of 500 counts per minute. What is the half-life of the material?

A 4.0 days **B** 5.0 days **C** 20 days **D** 80 days

Q-37: The graph shows the radioactive decay curve of a substance.



What is the half-life of this substance?

A 0.5 years **B** 5 years **C** 15 years **D** 30 years

Q-38: An isotope X is radioactive and has a half-life of 4 years. A sample initially contains 8000 atoms of X. After how many years will the sample contain 1000 atoms of X?

A 4 **B** 8 **C** 12 **D** 16

Q-39: A sample contains 0.0016 g of a radioactive isotope. After 4.0 hours the mass of the radioactive isotope in the sample falls to 0.00080 g. What is the half-life of the radioactive isotope?

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A 2.0 hours **B** 4.0 hours **C** 8.0 hours **D** 16 hours

Q-40: The table shows details of two samples of radioactive nuclides X and Y.

nuclide	number of radioactive atoms at time = 0	half-life
X	16 000	1 day
Y	2 000	2 days

After how many days will the number of atoms of nuclide X be equal to the number of atoms of nuclide Y?

A 2 days **B** 4 days **C** 6 days **D** 8 days

Q-41: A radioactive isotope has a half-life of 3 years. A sample gives a count rate of 100 counts / min on a detector. Which calculation is used to predict the count rate after 12 years?

A $100 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$

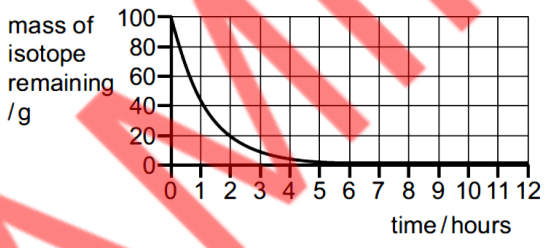
B $100 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$

C $100 \times \frac{3}{12}$

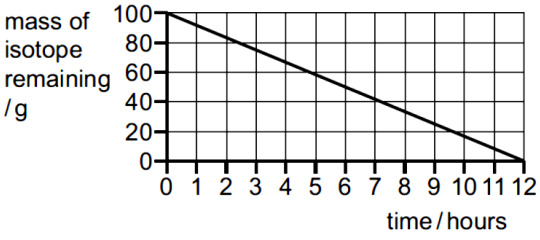
D $100 \times \frac{12}{3} \times \frac{1}{2}$

Q-42: A sample of a radioactive isotope has a mass of 100 g. The half-life of the radioactive isotope is 6.0 hours. Which graph shows the decay for this isotope?

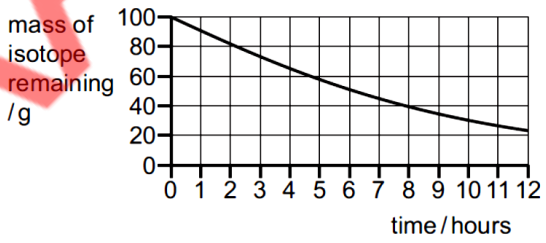
A



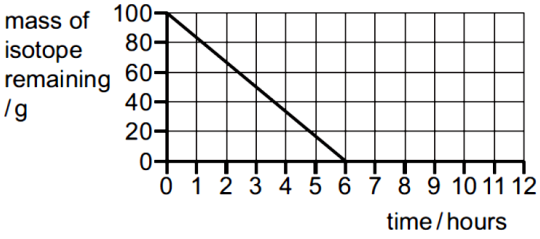
B



C



D



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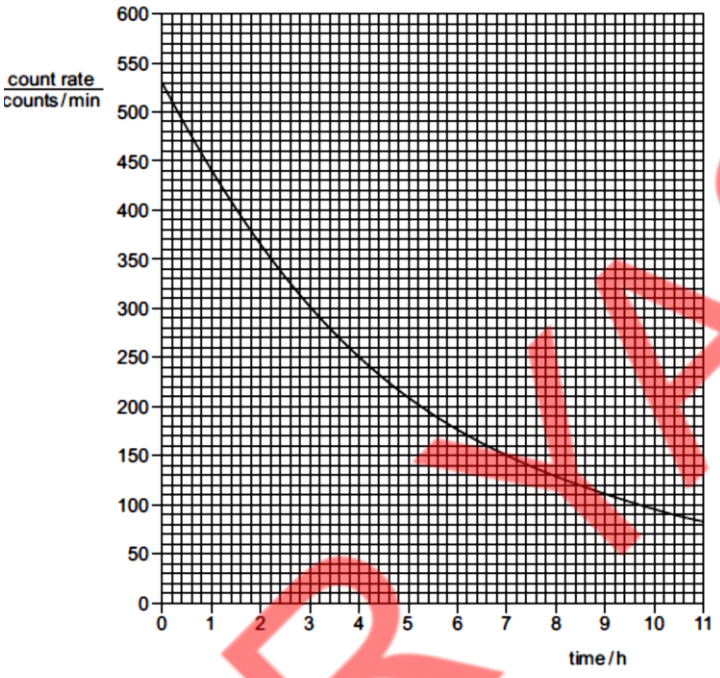
Q-43: The half-life for lead-202 is 52 500 years. A sample of lead-202 produces 800 counts / s. How long will it take for the count rate to drop to 100 counts / s?

A 105 000 years **B** 157 500 years **C** 210 000 years **D** 420 000 years

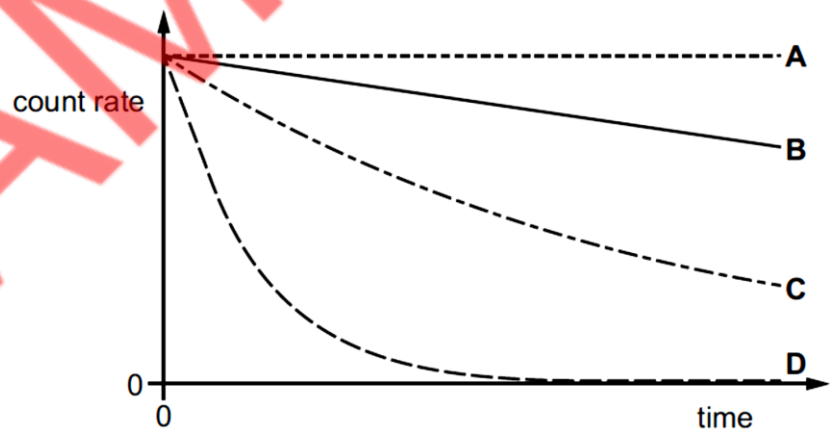
Q-44: The graph shows how the count rate measured by a radioactivity detector placed near a radioactive sample changed with time.



Given that the background count rate is 30 counts / min, what is the half-life of this sample?

A 3.4 h **B** 3.6 h **C** 4.0 h **D** 5.5 h

Q-45: The graph shows the decay curves of four different radioactive isotopes. Which isotope has the largest half-life?



Q-46: A sample of americium decays and changes into neptunium. The half-life of americium is 432 years. Which fraction of the americium will remain after 1728 years?

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A 0 **B** 1/16 **C** 1/8 **D** ¼

Q-47: a) State which radioactive emission is:

i) the most penetrating

ii) the most ionising.

b) Explain the meaning of the term *isotope*.

c) The isotope iodine-131 is used in hospitals. A sample of iodine-131 is prepared for use. The half-life of iodine-131 is 8 days. Determine the fraction of iodine-131 remaining in the sample after 16 days.

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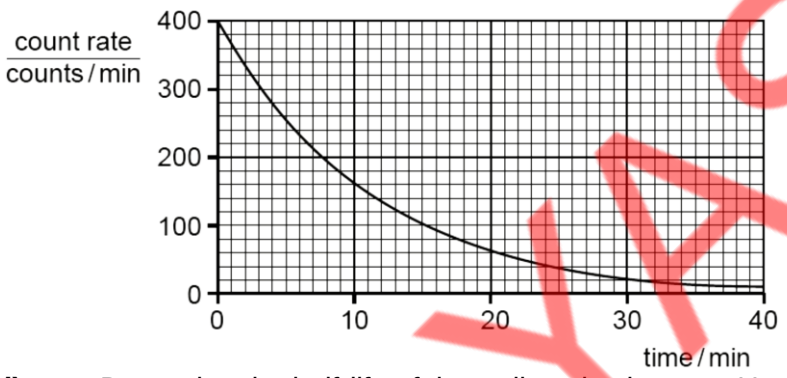
Q-48: A teacher is investigating radioactivity. The teacher measures the background radiation in the laboratory.

a) State **one** source of background radiation.

b) A teacher measures the count rate of a radioactive isotope. Fig.shows the graph of her results.



i) Determine the half-life of the radioactive isotope. Use information from Fig. Show on Fig. 1 how you obtained your value.

ii) The radioactive isotope emits γ-radiation. Describe **one** method of safely storing the radioactive isotope.

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Q-49: a) A nucleus of nitrogen-13 has the nuclide notation:

$$^{13}_{7}N.$$

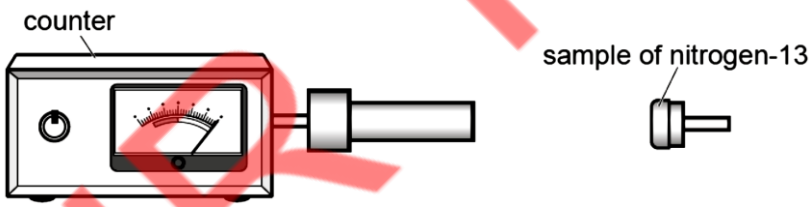
Determine:

i) the number of protons in one nucleus of nitrogen-13

ii) the number of neutrons in one nucleus of nitrogen-13

iii) the number of electrons in one neutral atom of nitrogen-13.

b) Fig. 1 shows a counter measuring the radioactivity of a sample of nitrogen-13.



The counter shows the count rate in counts per minute. Table 1 shows the count rate every 5 minutes.

time / min	count rate due to nitrogen-13 / counts / min
0	300
5	212
10	150
15	106
20	75
25	53

Calculate the half-life of nitrogen-13 using information from Table

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Fission/Fusion Reaction

Q-50: When a uranium-235 nucleus absorbs a neutron, it becomes unstable and undergoes fission. The fission process produces a barium (Ba) nucleus, a krypton (Kr) nucleus and 3 neutrons. The fission process is represented by the nuclear equation shown.

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{\cdots}_{\cdots}Kr + 3\,{}^{1}_{0}n$$

Which symbol represents the resulting krypton nucleus?

A $^{89}_{36}Kr$ **B** $^{91}_{34}Kr$ **C** $^{91}_{35}Kr$ **D** $^{91}_{36}Kr$

Q-51: Nuclear fusion is a reaction that takes place in stars. Which row describes this reaction?

	action of atomic nuclei	energy
A	an atomic nucleus splits into two or more smaller nuclei	absorbed
B	an atomic nucleus splits into two or more smaller nuclei	released
C	atomic nuclei join together to form a larger nucleus	absorbed
D	atomic nuclei join together to form a larger nucleus	released

Q-52: Which statement about the reactor in a nuclear power station is correct?

A In the reactor, the main reaction occurs when protons hit uranium nuclei.
B The process taking place in the reactor is called nuclear fusion.
C The reactor produces energy to boil water and to produce steam.
D Carbon dioxide is the major waste product from the reactor.

Q-53: Which row states where nuclear fusion occurs and what nuclear fusion is?

	nuclear fusion occurs in	nuclear fusion is
A	a power station	the joining of small nuclei
B	a power station	the splitting of large nuclei
C	a star	the joining of small nuclei
D	a star	the splitting of large nuclei

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Q-54: Uranium-235 ($^{235}U_{92}$) is a radioactive isotope of uranium that occurs naturally on Earth.

a) Describe the composition and structure of a neutral atom of uranium-235.

b) Another isotope of uranium is uranium-238. Describe how an atom of uranium-238 differs from an atom of uranium-235.

c) In the reactor in a nuclear power station, a nucleus of uranium-235 absorbs a slow-moving neutron and then undergoes nuclear fission.
Two neutrons, a nucleus of xenon-140 ($^{140}Xe_{54}$) and a nucleus of an element represented by E are produced. Complete the equation for this fission reaction.

$$n + {}^{235}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{\cdots\cdots}_{\cdots\cdots}E + 2n$$

d) Xenon-140 ($^{140}Xe_{54}$) is radioactive. It decays by β-emission to isotope Q.
Determine:

i) the proton number of Q

ii) the nucleon number of Q.

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Q-55: a) State **two** differences between nuclear fission and nuclear fusion.

b) Radioactive tracers emitting γ-rays can be used in medicine. The half-life of the source of these γ-rays is 6 hours.

i) Explain why a source of γ-rays used in this way should not have a half-life shorter or longer than about 6 hours.

ii) Technetium-99 is a source of γ-rays often used as a radioactive tracer. It is produced from molybdenum-99 which emits β-particles. The symbol for technetium is Tc and the symbol for molybdenum is Mo. Complete the nuclide equation for this decay.

$$^{99}_{42}\text{Mo} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{Tc} + {}^{\cdots\cdots}_{\cdots\cdots}\beta$$

iii) Technetium-99 is a radioactive nuclide. State another use of radioactive nuclides in medicine.

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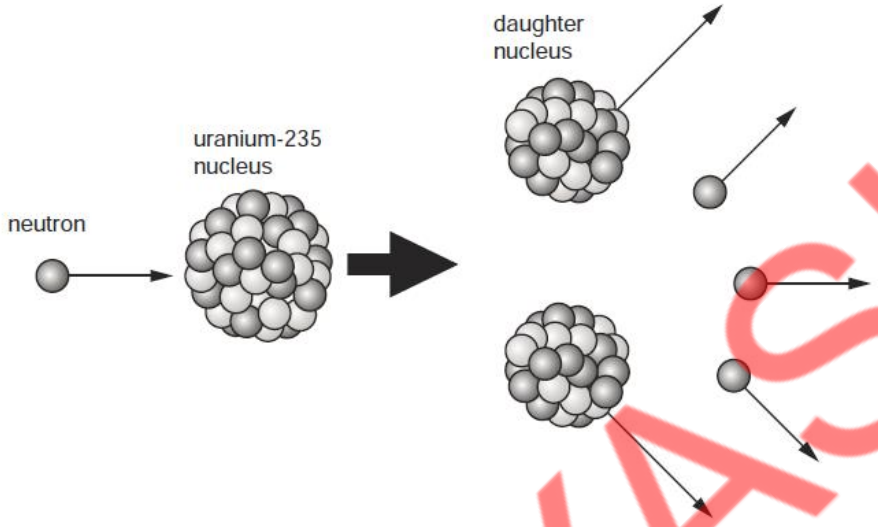
Q-56: Fig.1 illustrates the process that occurs in the core of a nuclear reactor.



a) State the name of the process illustrated in Fig.

b) Describe what happens during this process.

c) Some of the waste from a nuclear reactor is radioactive with a long half-life.
Explain what is meant by

i) radioactive,

ii) a long half-life.

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Count Rate/Background intensity

Q-57: Three sources of background radiation are listed.

1 cosmic rays
2 medical X-rays
3 radioactive emissions from radon gas from the ground

Which of these sources are naturally occurring?

A 1 and 3 only **B** 1 only **C** 2 and 3 only **D** 2 only

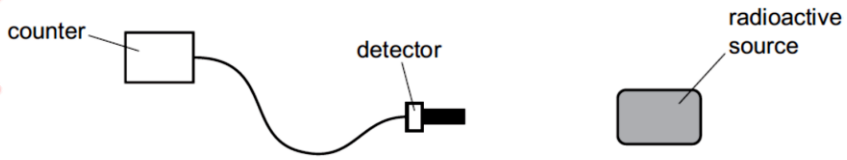
Q-58: A student is investigating the count rate of a radioactive substance.
How must he adjust his reading for the background count?

A Add the background count to his reading.
B Ignore the background count as it will not affect his reading.
C Subtract the background count from his reading.
D Take repeat readings to eliminate the background count.

Q-59: A teacher holds a radioactive source near a detector. The reading on the detector is 320 counts / min. The detector is switched on again after the source has been removed and it shows a reading of 20 counts / min. What is the counts / min solely due to the source and why is there a reading on the detector when there is no radioactive source present?

	counts / min due to the source	reason for reading with no source
A	300	zero error on detector
B	300	background radiation
C	340	zero error on detector
D	340	background radiation

Q-60: An experiment is carried out to measure the radiation from a radioactive source that has a half-life of 10 minutes. The source is placed close to a detector that is connected to a counter, as shown.



The average background count-rate is 20 counts / minute.
At the start of the experiment, the count-rate recorded by the counter is 1000 counts / minute. What is the count-rate 10 minutes later?

A 490 counts / minute
B 500 counts / minute

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C 510 counts / minute
D 530 counts / minute

Q-61: a) A detector of ionising radiation measures the background count rate in a classroom where there are no radioactive samples present. The readings, in counts/minute, taken over a period of time are shown in Table 10.1.

counts/minute	16	12	14	16	15	17

i) State **two** possible sources of this background radiation.

ii) Explain why the readings are not the same.

b) With no radioactive sample present, a scientist records a background radiation count of 40 counts / minute. He brings a radioactive sample close to the detector. The count rate increases to 200 counts / minute. After 24 days the count rate is 50 counts / minute. Calculate the half-life of the radioactive sample.

c) Draw a line between each type of ionising radiation and its property and another line between the property and its use. One has been done for you.

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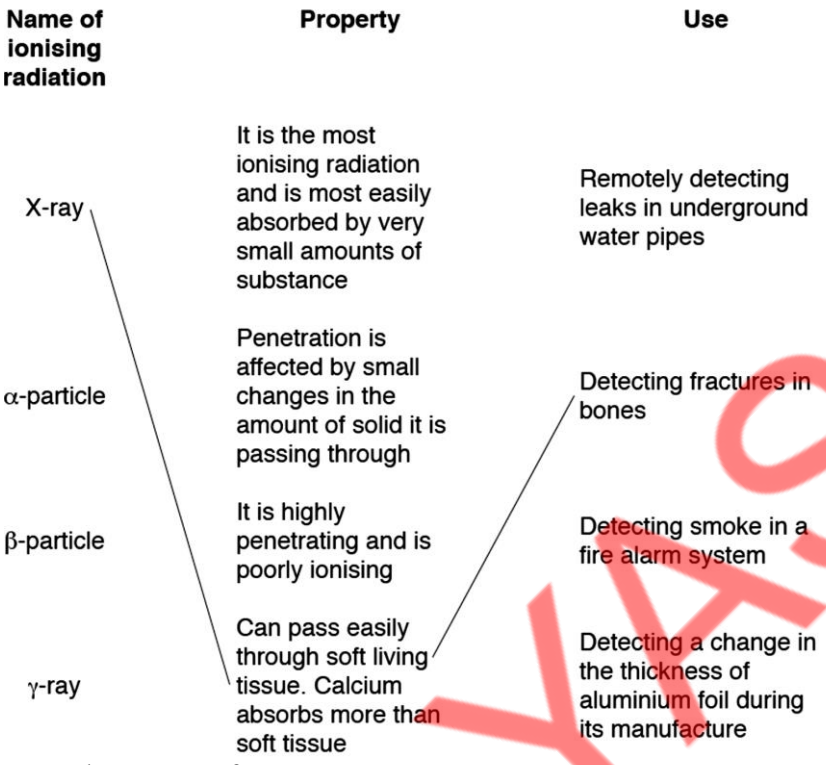

Q-62: a) State the nature of γ-rays.

b) A nucleus of technetium-99 ($^{99}Tc_{43}$) emits only a γ-ray.
State any effect of this on

i) the proton number of the nucleus,

ii) the nucleon number of the nucleus.

c) In a laboratory a radiation detector displays a count rate of 16 counts / minute due to background radiation.

i) State what is meant by *background radiation*.

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ii) A sample of a radioactive isotope is placed near to the radiation detector and a count rate of 112 counts / minute is recorded. After 18 hours, the count rate recorded is 28 counts / minute. Determine the half-life of this isotope.

d) Radioactive isotopes are stored in thick lead containers.
State **two** precautions to be taken when radioactive isotopes are **used**.

Carbon Dating

Q-63: Tritium is a radioactive isotope of hydrogen with a half-life of 12 years. If a sample starts with 40 million atoms of tritium, how many atoms of tritium will be left after 12 years?

A 40 million **B** 20 million **C** 10 million **D** 5 million

Q-64: Radioactive carbon-14 decays to nitrogen-14 by the emission of a particle.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + \text{particle}$$

Which particle has been emitted in this process?
A a β-particle **B** an α-particle **C** a neutron **D** a proton

Q-65: This notation represents the nucleus of a neutral atom of carbon-14.

$$^{14}_{6}C$$

a) State the number of:
1. protons in the nucleus of an atom of carbon-14

2. electrons orbiting the nucleus of an atom of carbon-14

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3. neutrons in the nucleus of an atom of carbon-14.

b) Carbon-14 is an isotope of carbon. Carbon-12 is another isotope of carbon. Compare the nucleus of carbon-14 with the nucleus of carbon-12. State the similarities and differences.

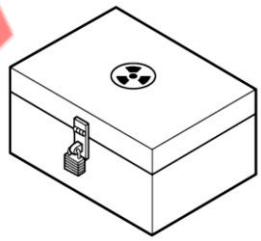
c) Scientists use carbon-14 to estimate the age of wood that is very old.
A very old sample of wood contains 1.0 × 108 carbon-14 atoms.
When the sample was new, it contained 8.0 × 108 carbon-14 atoms.
The half-life of carbon-14 is 5 700 years. Estimate the age of the sample of wood.

Safety Precautions

Q-66: Radioactive materials must be handled in a safe way.
What is **not** a safety procedure?

A Monitor exposure time to radioactive materials.
B Store radioactive materials in cardboard boxes.
C Use tongs to pick up the radioactive source.
D Wear protective clothing.

Q-67: The diagram shows a lead-lined box used for storing radioactive sources.



Why is the inside of the box lined with lead?

A It helps the sources to stay radioactive for longer.
B It makes the box heavier.
C It makes the radioactive sources more stable.
D It reduces the amount of radiation that can escape from the box.

Q-68: In 1986 the Chernobyl nuclear power station in Ukraine suffered a meltdown.

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This caused background radiation in many countries, thousands of kilometres from Chernobyl, to increase. What was transported in the atmosphere to these countries to cause this rise in background radiation?

A α-particles
B β-particles
C γ-rays
D radioactive isotopes

Q-69: What is the safest way to dispose of a large quantity of highly radioactive waste?

A burning it on a fire
B burying it in dry rock deep underground
C pouring it down the drain
D pumping it into a river

Q-70: A scientist needs to reduce the risks when working with radioactive sources.

a) Explain why radioactive sources can be dangerous.

b) Describe how to reduce the risks when working with radioactive sources.

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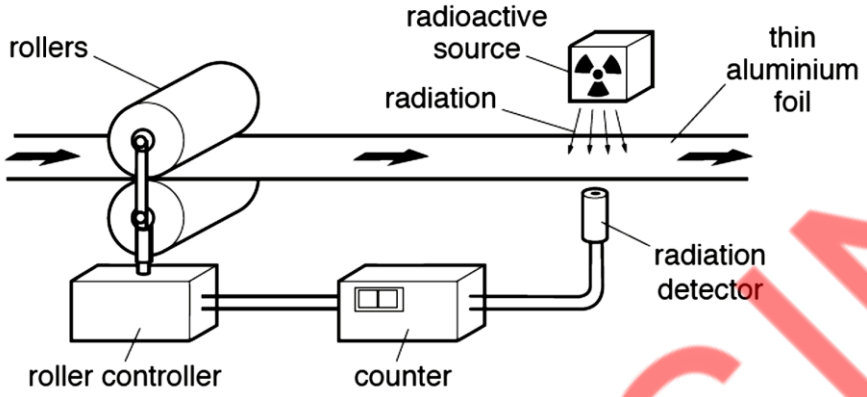
Q-71: Radioactive decay may include the emission of:
α-radiation
β-radiation
γ-radiation

a) **i)** From the list, state the type of radiation which has the **greatest** ionizing effect.

ii) From the list, state the type of radiation which has the **lowest** penetrating ability.

b) In a factory, rollers press aluminium metal to make thin foil sheets. An automatic system for controlling the thickness of the foil uses a radioactive source. The automatic system changes the gap between the top and bottom roller. Fig. 12.1 shows the equipment.



i) Use your ideas about the properties of radiation to suggest and explain the type of radiation used.

ii) The aluminium foil passing the radiation detector is too thin. Describe how this fault affects the reading on the counter.

iii) Suggest how the fault in **(b)(ii)** is corrected. State what happens to the rollers.

iv) The source used is strontium-90. A nucleus of strontium-90 can be described as $^{90}Sr_{38}$. State the number of protons in a nucleus of strontium-90.

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Answer

Q-1: A **Q-2: C** **Q-3: C** **Q-4: C** **Q-5: C** **Q-6: D** **Q-7: A**

Q-8: A **Q-9: D** **Q-10: B** **Q-11: A** **Q-12: A** **Q-13: B** **Q-14: D**

Q-15: A **Q-16: D** **Q-17: A** **Q-18: C** **Q-19: B** **Q-20: A** **Q-21: A**

Q-22: B **Q-23: D** **Q-24: B** **Q-25: A** **Q-26: D** **Q-27: B** **Q-28:D**

Q-29: a)

type of radioactive emission	nature	charge
alpha (α)	helium nucleus	positive/+

type of radioactive emission	nature	charge
beta (β)	electron	negative

type of radioactive emission	nature	charge
gamma (γ)	(electromagnetic/em) wave	no charge/neutral

b) i) alpha / α

ii) gamma / γ

c) i) selects a count rate value and another count rate that is half this value
e.g. 800 AND 400, OR 560 AND 280
4 (min)

ii) 70 (counts / s)

Q-30: a)

property	type of radiation		
	α-particles	β-particles	γ-rays
largest mass	✓		
most ionising	✓		
most penetrating			✓
negatively charged		✓	
greatest speed			✓

b) idea of 3 half-lives OR 45 ÷ 15
80 ÷ 8 OR 80 × ½ × ½ × ½
10 (mg)

Q-31: a) α deflected in smooth curve away from plate P / towards plate Q
α continues in straight line beyond plates OR multiple paths for β and no more than a single α path
β deflected in smooth curve towards plate P / away from plate Q
β deflected more than α
γ passes straight through without deviation and continues in straight line beyond plates

b) suitable application e.g. sterilisation of equipment, medical diagnosis / treatment, thickness control, detecting leaks / cracks, food preservation

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explanation e.g. destroys bacteria, destroys cancer cells, lower amount of radiation detected if thickness too large, radiation detected at site of leak, destroys microbes in food

Q-32: a) neutrons and protons together and alone in the middle
5 protons
7 neutrons (if protons and neutrons unlabelled 1/2)
5 electrons and electrons surrounding nucleus

b) i) 6
ii) 12

Q-33:

(a) $^{131}_{54}Xe$ OR ^{131}Xe and $^{0}\beta$

$^{0}_{-1}\beta$ $_{54}Xe$ and $_{-1}\beta$

b) i) downward curve
ii) horizontal line

c) any two of:
direction/space (of emission)
time/frequency (of emission) or period/interval between emissions or different

Q-34: D Q-35: C Q-36: B Q-37: B Q-38: C Q-39: B Q-40: C

Q-41: A Q-42: C Q-43: B Q-44: A Q-45: A Q-46: B

Q-47: a) i) gamma OR
ii) alpha OR

b) same atomic number / Z / number of protons
different nucleon number / A / number of neutrons

c) idea of 2 half-lives
1 / 4

Q-48: a) rocks, buildings, (natural) radon, air, cosmic rays, sun, food, drink

b) i) evidence of using graph
TWO pairs of coordinates seen
7.5 (min)

ii) Use a lead(-lined) box / container

Q-49: a) i) 7
ii) 6
iii) 7

b) using a pair of values e.g. 300 and 150 OR 212 and 106 etc.
(difference in time is) 10 (min)

Q-50: A Q-51: D Q-52: C Q-53: C

Q-54: a) (very small) nucleus and surrounded by electrons (in orbit / shells)

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92 protons or 92 electrons or number of protons = number of electrons
protons and neutrons in nucleus
143 neutrons

b) (uranium-238 has) three more neutrons (in nucleus)

c) ^{94}(E) $_{(38)}$

d) i) 55
ii) 140

Q-55: a) nuclear fission – nucleus / atom splits (into two)
AND
nuclear fusion – two nuclei / atoms join together
One from
{nuclear fission –large(r) mass (number) OR heavy nuclei / atoms involved OR neutrons involved / emitted}
AND
nuclear fusion – small(er) mass (number) OR light nuclei / atoms involved OR no neutrons
fission in a nuclear reactor AND fusion in Sun / stars
fission produces very radioactive / long lasting waste
fission makes lighter new elements AND fusion makes heavier new elements
fission at normal p / T AND fusion at high p / T
fusion produces more energy (than fission)

b) i) longer half-life – radioactive substance active in body for a long time
shorter half-life – might be insufficient time for investigation OR it takes time / hours for the tracer to spread round the body

ii) proton numbers balance for equation
expected answer : 42Mo → 43Tc + –1
all nucleon numbers correct B1
correct proton and nucleon number for β-particle

iii) any suitable use, e.g. sterilisation of equipment, treatment of cancer, gamma for diagnosis, radiotherapy
NOT any link to X-rays

Q-56: a) fission cao

b) neutron hits/goes inside (U) nucleus
atom/nucleus/particle/uranium/nuclide splits/forms daughter nuclei and emits neutrons/energy

c) i) emits particles // emits ionising/nuclear radiation //spontaneous or random emission (of radiation) // atom/nucleus decays

ii) long time to decay // radioactive for a long time // decays slowly
long time for any quantity to halve halving of:

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count, count rate, emissions, (number of) nuclei, (number of) atoms, activity

Q-57: A **Q-58: C** **Q-59: B** **Q-60: C**

Q-61: a) i) any two from
- soil / rocks / buildings / the Earth
- cosmic rays / space
- the Sun
- medical sources
- food or drink
- air / radon

ii) random (variation of background radiation / radioactivity)

b) 160 and 10 (counts / min)
(160 / 10=) 16
4 half-lives
(24 / 4 =) 6 days

c) 2 correct lines
4 correct lines
6 correct lines

Q-62: a) electromagnetic (waves / rays / radiation)

b) high frequency / energy or short wavelength

i) no change or (stays at) 43

ii) no change or (stays at) 99

c) i) (radiation) always present / due to environment / in absence of radioactive sample / natural (radiation)

ii) 112 – 16 or 96 or 112 / 28 or ¼ or 18 / 2
28 – 16 or 12 or 1 / 8 or 18 / 3 or 9.0 (hours)
6.0 hours

d) any two of:
(distance): tongs / manipulator / centre of cardboard box
(absorption): lead gloves / suit / lead glass screen / googles / glasses
(time): limit exposure time / keep in box until needed / film badge

Q-63: B **Q-64: B**

Q-65: a) 1. 6
2. 6
3. 8

b) Any three from:
(nucleus has) same number protons or same atomic / proton number
same charge
different mass
different nucleon number

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different number of neutrons

c) idea of 3 half-lives Or 8.0 → 4.0 → 2.0 → 1.0
5700 x 3
17 100 (years)

Q-66: B Q-67: D Q-68: D Q-69: B

Q-70: a) i) (They) emit ionising radiation
(which) damage DNA/cells/cause tumours/cancers

ii) Any 2 from:
reduce exposure time
keep source at distance
use of suitable shielding
monitor exposure to radiation

Q-71: a) i) α or alpha

ii) α or alpha

b) i) beta or
beta emission would be affected by the thickness of the metal

ii) (counter) reading higher 1

iii) rollers move apart/provide less force/pressure

iv) 38

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