7.1 Discrete Energy & Radioactivity

Question Paper

Course	DP IB Physics
Section	7. Atomic, Nuclear & Particle Physics
Topic	7.1 Discrete Energy & Radioactivity
Difficulty	Medium

Time allowed: 80

Score: /62

Percentage: /100

Question 1a

In a HeNe laser, electrons collide with helium atoms. The ground state of a helium is labelled as 1s and the next energy level is labelled 2s.

When an electrons de-excite from 2s to 1s in helium, photons are emitted with a wavelength of 58.4 nm.

(a)
Calculate the energy difference of this transition, giving your answer in eV.

[3 marks]

Question 1b

An electron collides with a helium in its ground state, causing an electron to transition from 1s to 2s. The electron initially has 45.0 eV of kinetic energy.

(b)
Calculate the electron's kinetic energy after the collision.

[2 marks]

Question 1c

(c)
Explain why it is not possible for the same electron from (b) to collide with the ground state helium atom and be left with 40.0 eV of kinetic energy.

[3 marks]

Question 1d

Helium and neon coincidentally have very similar energy gaps for certain transitions, allowing one atom to cause an excitation in the other.

The excited helium atom from part (b) then collides with a ground state neon atom. The neon atom becomes excited and subsequently emits two photons in order to return to its ground state.

(d)

(i)
If the helium is left back in its ground state after the collision, determine the amount of energy transferred to the neon atom.

(ii)
If one photon has an energy of 1.96 eV, calculate the wavelength of the other.

[5 marks]

Question 2a

The decay series of an isotope of thorium, $^{232}_{90}Th$, produces an isotope of radium, $^{224}_{88}Ra$. This process involves four separate decays.

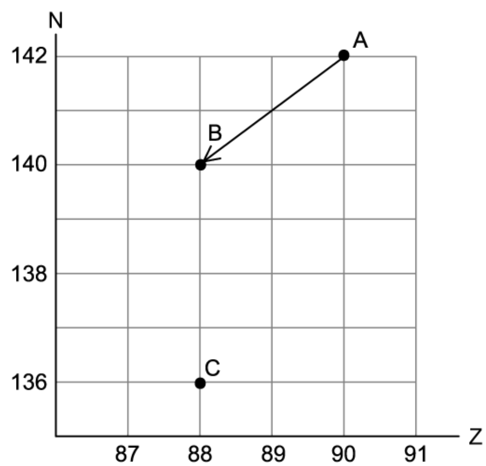
The first decay involves the emission of an alpha particle.

(a)
Write the decay equation for this process, including the symbol of the daughter product.

[3 marks]

Question 2b

The first decay can be represented on an N-Z diagram as an arrow from point A to point B.



Three more decays occur before $^{224}_{88}Ra$ is produced, denoted by "C" on the N-Z diagram.

(b)
Outline the possible sequence of decays which lead from point B to C.

[3 marks]

Question 2c

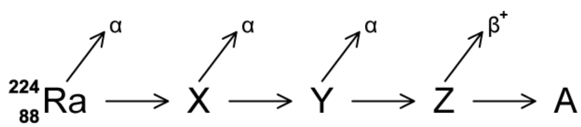
Nuclei can be unstable for a number of reasons.

(c)
In terms of forces within the nucleus, explain why large nuclei emit alpha radiation.

[4 marks]

Question 2d

$^{224}_{88}Ra$ then decays four more times, shown below.



The first three decays result in the emission of an alpha particle each time. The fourth and final decay results in the emission of a beta-particle.

(d)
Calculate the nucleon number and atomic number of nuclide A.

[3 marks]

Question 3a

A radioactive source is used to measure the thickness of paper. A Geiger counter is used to measure the count rate on the opposite side of the paper to the radioactive source. The radioactive source used must be chosen carefully.

(a)

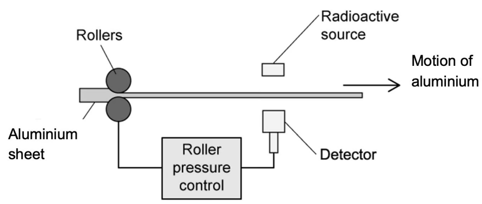
(i)
State and explain the type of radioactive source that should be used for this process.

(ii)
A new type of paper is placed between the Geiger counter and the radioactive source. Explain how the equipment can be used to show if the new paper is thicker or thinner than the previous type.

[4 marks]

Question 3b

The arrangement below is used to maintain a constant 0.10 m thickness of aluminium sheets. Alpha, beta or gamma sources are available to be used.



(b)
Outline the most suitable radioactive source for this arrangement and explain why the other sources may not be appropriate.

[2 marks]

Question 3c

The source used in part (b) has a half-life of 14 days and it has an initial count rate of 240 counts per minute when first used in the apparatus.

(c)
Giving your answer in weeks, calculate the length of time it takes for the Geiger counter to detect a count rate of 0.25 s^{-1}.

[3 marks]

Question 3d

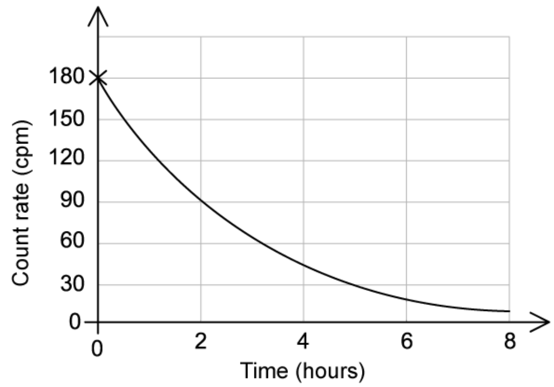
Once the source has reached an activity of 0.25 s^{-1}, it is replaced as the count rate of the source is comparable with that of background radiation.

(d)
State two natural sources of background radiation and two man-made sources of background radiation.

[4 marks]

Question 4a

A sample's count rate in counts per minute (cpm) is measured using a ray detector. This data is plotted on a graph.



(a)

(i)
Use the graph to determine the half-life of this sample.

[2]

(ii)
Explain why the distance between the detector and the source is a control variable.

[2]

[1 mark]

Question 4b

The scientist wonders how the experiment in part (a) would have changed if the sample was twice the size.

(b)
Assuming the experiment from part (a) was repeated with a sample the exact same age but twice the mass, calculate the length of time it would have taken to reach a count rate of 22.5 cpm.

[3 marks]

Question 4c

(c)

In reality the detector will measure a count rate of more than 5 cpm long after the length of time in part (b) has passed.

(i)

Outline the reason for this larger-than-expected count rate.

[2]

(ii)

Describe the measurements the scientist could take to accurately account for this additional count rate in the final data.

[2]

[4 marks]

Question 4d

The scientist can measure the count rate of the source but is unable to directly measure the activity of the source using their detector. Activity is the total number of particles emitted from the sample per unit time.

(d)

Explain why this is not possible.

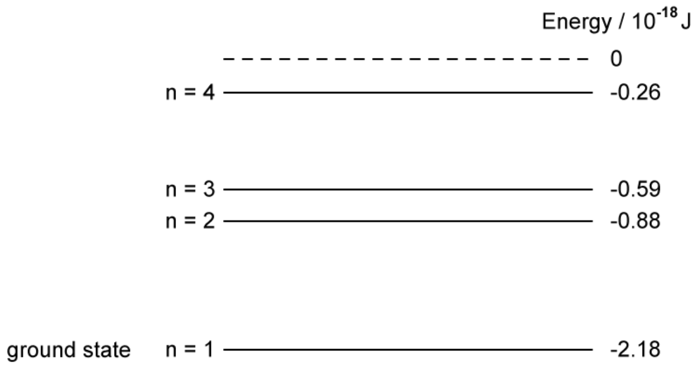
[2 marks]

Question 5a

Fluorescent tubes operate by exciting the electrons of mercury atoms.

(a)

The energy levels of a mercury atom are shown below (not to scale):



An electron is excited to n = 4. On the diagram, draw all the possible de-excitation routes from n = 4 to the ground state.

[4 marks]

Question 5b

(b)

State and explain which energy transition will emit the photon with the lowest frequency.

[2 marks]

Question 5c

An unstable isotope of mercury, Hg-203, is tested for its radioactive emissions in a laboratory that has a background rate of 0.3 s^{-1}.

A source is placed a fixed distance from a Geiger-Muller tube. Various materials are placed in between the detector and the source while the count rate is recorded. The results are shown below.

Material	Count rate / s^{-1}
None	68
0.5 mm thick paper	69
2.0 mm thick paper	65
5 cm thick aluminium foil	15

(c)
State and explain what types of radiation are being emitted by the Hg-203 source.

[4 marks]

Question 5d

(d)
A student notices that the count rate recorded actually increases when 0.5 mm thick paper was placed between the Geiger-Muller tube and the source.

(i)
Suggest one cause of this increase.

(ii)
Describe what the experimenter could do to check if this data point was anomalous.

[3 marks]