12.2 Nuclear Physics

Mark Schemes

Course	DP IB Physics
Section	12. Quantum & Nuclear Physics (HL only)
Topic	12.2 Nuclear Physics
Difficulty	Easy

To be used by all students preparing for DP IB Physics HL
Students of other boards may also find this useful

1

The incorrect answer is **B** because:

- The nuclear radius, R is defined by the equation
  - $R = R_0 A^{\frac{1}{3}}$
  - Where R_0 is the constant of proportionality and A is the nucleon (mass) number
- Therefore, the radius of the nucleus depends on the nucleon number, A of the atom not the atomic number, Z.

Sometimes in a question which asks you to find the incorrect answer it can be helpful to see which answers are clearly correct and eliminate those first. This is good exam technique, especially if you're running out of time.

2

The correct answer is **B** because:

- The first minimum is identified as the angle at which the first dip in intensity of scattered electrons occurs
  - This is at 42° on the graph
- Therefore the correct answer is **B**

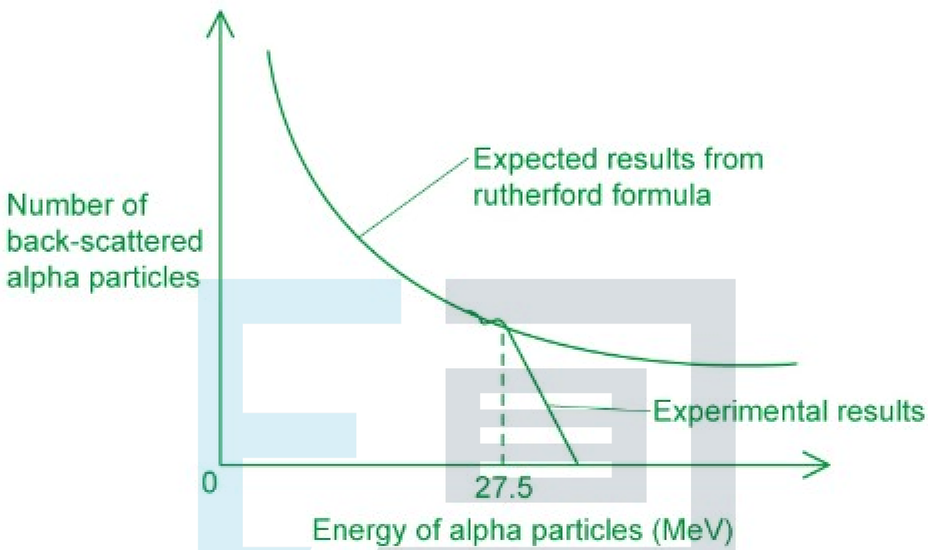
It is important to be able to identify maxima and minima on graphs involving diffraction. In structured questions you will also be expected to perform calculations involving readings from the graphs, therefore you should ensure you are comfortable interpreting them.

The graph has increasing and decreasing intensity due to the diffraction pattern when electrons scatter being concentric bright (high intensity) and dark (low intensity) rings.

3

The correct answer is **D** because:

- Rutherford's alpha scattering experiment originally assumed that the alpha particles were only interacting through electrostatic repulsion
- However, if the energy of the alpha particles exceeds around 27.5 MeV, then the number of back-scattered alpha particles observed decreases rapidly



- This implies another force is acting as well as the electrostatic force
  - This is the strong nuclear force
- Therefore, the correct answer is **D**

Being able to explain deviations from experimental results is an important skill - science often makes progress by discovering something isn't as expected!

4

The correct answer is **A** because:

- Nuclear radius, R, is calculated using the equation
  - $R = R_0 A^{\frac{1}{3}}$
  - Where R_0 is a constant of proportionality, 1.20 fm, and A is the nucleon number
- $A^{\frac{1}{3}}$ is the same as $\sqrt[3]{A}$

- For cobalt-27 this is equal to
  - $\sqrt[3]{27} = 3$
- Therefore *R* is
  - $R = 1.2 \times 3 = 3.6$ fm

Although you cannot use a calculator in the exam for the MCQs, you can be asked to do simple calculations that are possible without the use of a calculator.

5

The correct answer is **D** because:

- Electrons are diffracted when they are scattered by a nucleus
- A circular diffraction pattern forms with a central bright spot (maxima) with dimmer concentric circles (minima) around it
- However, the first diffraction minima isn't found at zero intensity
  - The subsequent minima reduce in intensity until reaching zero
- This is graph **D**

A is incorrect as	the maxima in the diffraction become dimmer as angle θ increases. The maxima in this graph are all at the same intensity
B & **C** are incorrect as	the first few minima shouldn't go to zero intensity

6

The correct answer is **C** because:

- The decay constant *λ* is defined as the probability that an individual nucleus will decay per unit of time
- Since probability is dimensionless (it has no units) then the units of λ is per unit time
  - This is equal to s^{-1}

s^{-1} is the SI base unit of Bq (Becquerels), which is also the units for the activity, *A*

7

The correct answer is **D** because:

- The decay constant *λ* is the gradient of a **graph** of the number of undecayed nuclei *N* over time *t*
    - ***D*** has the shallowest gradient and therefore the smallest decay constant

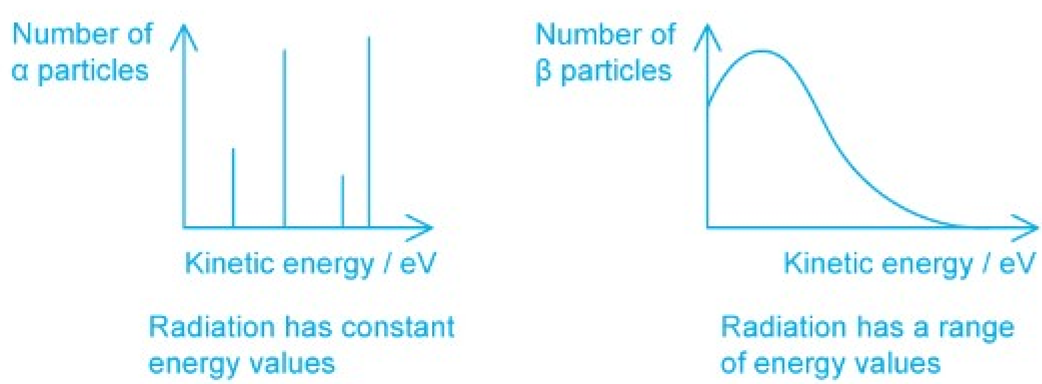
Remember that the gradient is defined by the 'steepness' of the slope of a graph. As the graph is more vertical, it is more steep and therefore has a larger gradient, and vice versa.

8

The correct answer is **C** because:

- When the number of β particles is plotted against kinetic energy, the graph shows a curve
    - This demonstrates that beta particles (electrons or positrons) have a continuous range of energies
- This implies that there is another particle is being released alongside the β particles, sharing the energy released in beta decay
    - This was one of the first clues of the neutrino's existence

The number of α particles against kinetic energy shows distinct kinetic energies. The number of β particles against kinetic energy shows a range of kinetic energies.



9

The correct answer is **A** because:

- Electrostatic force between the nuclei and alpha particles is given by
  - $F = k\frac{q_1 q_2}{r^2}$
- Therefore the force is proportional to the charge *q*
  - This means that the smaller the force *F*, the smaller the value of atomic number Z
- The alpha particles will approach much closer to a nucleus with a lower atomic number
- Greater scattering is observed with a closer approach as the strong nuclear force acts over a small distance
  - This eliminates answers **C** and **D**
- The speed of a particle is related to its kinetic energy by the equation
  - $E_k = \frac{1}{2}mv^2$
- Therefore, the greater the speed the more energy a particle will have
  - This allows the particle to overcome electrostatic repulsion and approach closer to the nucleus
- Greater scattering is observed with a closer approach as the strong nuclear force acts over a small distance
  - This eliminates answer **B**
- Therefore the correct answer is **A**

Remember that the atomic number *Z* is the number of **protons** in the nucleus. This is equal to the charge *q* of the nucleus, since neutrons have 0 charge.

10

The correct answer is **C** because:

- Since $N_t = N_0 e^{-\lambda t}$, when $t = 1$, the equation becomes
  - $N_1 = N_0 e^{-\lambda \times 1}$
- This simplifies to
  - $N_1 = N_0 e^{-\lambda}$
- This is answer **C**

A more complicated version of this question would be to ask for the number of nuclei which have decayed. In that case the number of nuclei decayed, $N_{decayed} = N_0 - N_1 = N_0 - N_0 e^{-\lambda} = N_0(1 - e^{-\lambda})$. N_0 is the initial number of nuclei and N_1 is the number of nuclei that is **left** after 1 second. Therefore, the number of nuclei decayed is $N_0 - N_1$.