

Nuclear-practice-1-MC [60 marks]

1. Which property of a nuclide does **not** change as a result of beta decay? [1 mark]

- A. Nucleon number
- B. Neutron number
- C. Proton number
- D. Charge

2. The rest mass of the helium isotope ${}^3_2\text{He}$ is m . [1 mark]

Which expression gives the binding energy per nucleon for ${}^3_2\text{He}$?

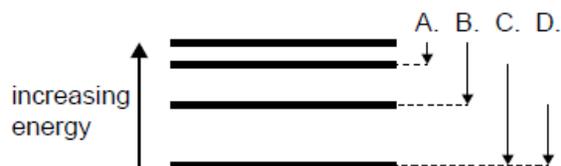
A. $\frac{(2m_p + m_n + m)c^2}{3}$

B. $\frac{(2m_p + m_n - m)c^2}{3}$

C. $(2m_p + m_n + m)c^2$

D. $(2m_p + m_n - m)c^2$

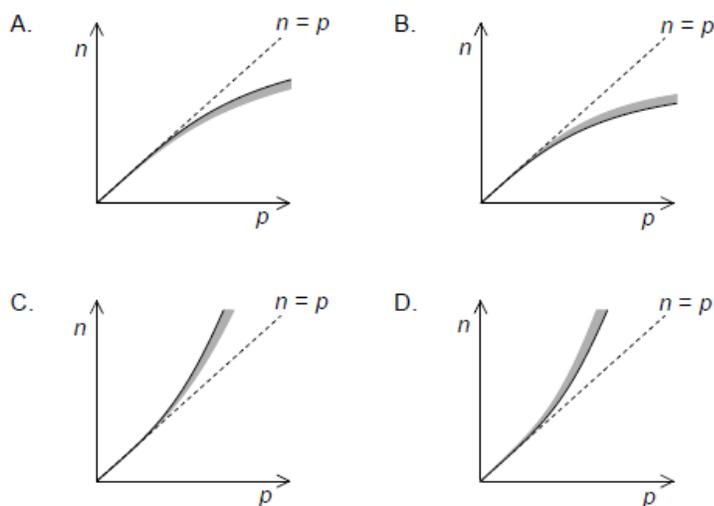
3. Which of the following atomic energy level transitions corresponds to photons of the shortest wavelength? [1 mark]



4. A radioactive nuclide with atomic number Z undergoes a process of beta-plus (β^+) decay. What is the atomic number for the nuclide produced and what is another particle emitted during the decay? [1 mark]

	Atomic number	Particle
A.	$Z - 1$	neutrino
B.	$Z + 1$	neutrino
C.	$Z - 1$	anti-neutrino
D.	$Z + 1$	anti-neutrino

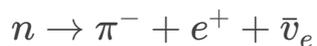
5. The positions of stable nuclei are plotted by neutron number n and proton number p . The graph indicates a dotted line for which $n = p$. Which graph shows the line of stable nuclides and the shaded region where unstable nuclei emit beta minus (β^-) particles? [1 mark]



6. Three conservation laws in nuclear reactions are [1 mark]

- I. conservation of charge
- II. conservation of baryon number
- III. conservation of lepton number.

The reaction

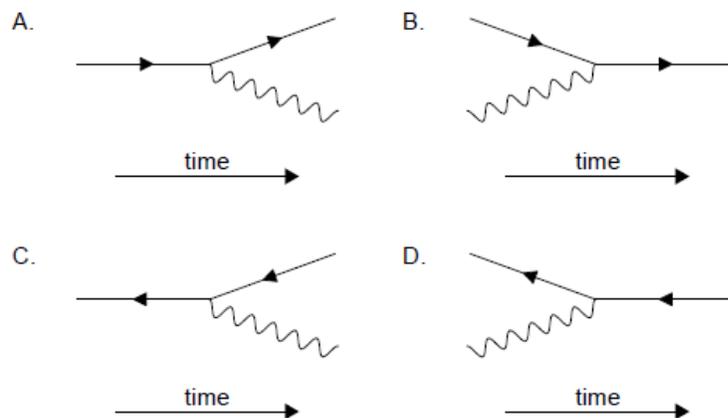


is proposed.

Which conservation laws are violated in the proposed reaction?

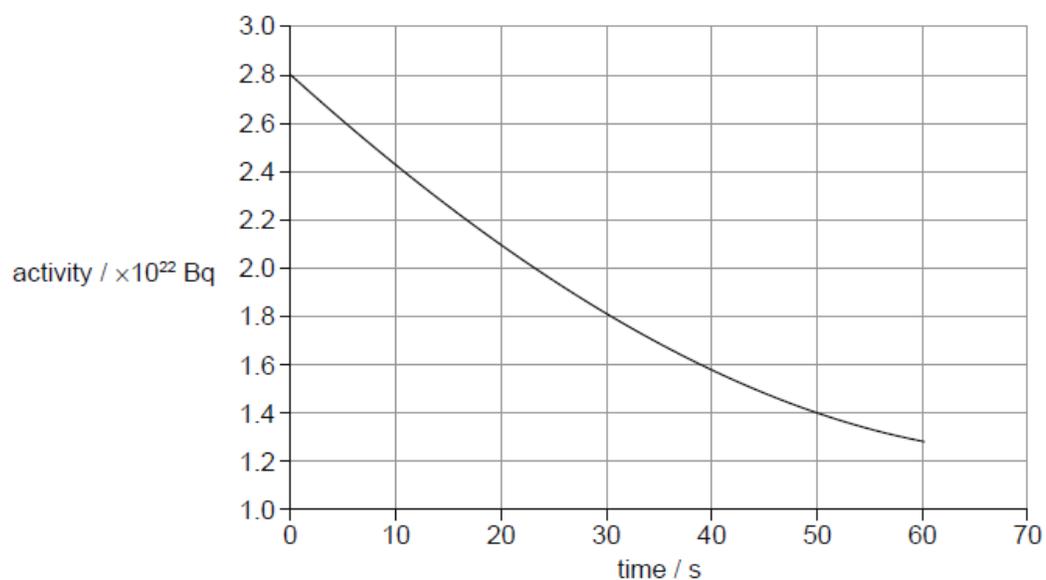
- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

7. Which Feynman diagram shows the emission of a photon by a charged antiparticle? [1 mark]



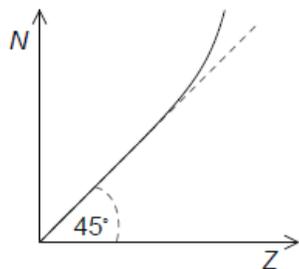
8. The graph shows the variation with time of the activity of a pure sample of a radioactive nuclide. [1 mark]

What percentage of the nuclide remains after 200 s?



- A. 3.1 %
- B. 6.3 %
- C. 13 %
- D. 25 %

9. The graph shows the variation of the number of neutrons N with the atomic number Z for stable nuclei. The same scale is used in the N and Z axes. [1 mark]



Which information can be inferred from the graph?

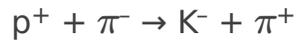
- I. For stable nuclei with high Z , N is larger than Z .
- II. For stable nuclei with small Z , $N = Z$.
- III. All stable nuclei have more neutrons than protons.

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

10. Copper (${}^{64}_{29}\text{Cu}$) decays to nickel (${}^{64}_{28}\text{Ni}$). What are the particles emitted and the particle that mediates the interaction? [1 mark]

	Particles emitted	Mediating particle
A.	β^- and neutrino	W^+
B.	β^+ and neutrino	W^-
C.	β^- and neutrino	W^-
D.	β^+ and neutrino	W^+

11. The following interaction is proposed between a proton and a pion. [1 mark]



The quark content of the π^- is $\bar{u}d$ and the quark content of the K^- is $\bar{u}s$.

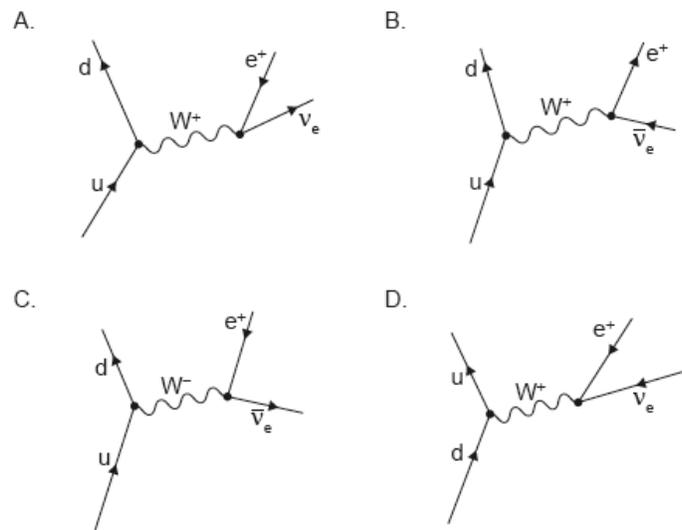
Three conservation rules are considered

- I. baryon number
- II. charge
- III. strangeness.

Which conservation rules are violated in this interaction?

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

12. Which Feynman diagram shows beta-plus (β^+) decay? [1 mark]



13. The average binding energy per nucleon of the $^{15}_8\text{O}$ nucleus is 7.5 MeV. [1 mark]

What is the total energy required to separate the nucleons of one nucleus of $^{15}_8\text{O}$?

- A. 53 MeV
- B. 60 MeV
- C. 113 MeV
- D. 173 MeV

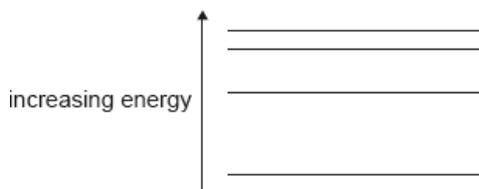
14. Two pure samples of radioactive nuclides X and Y have the same initial number of atoms. The half-life of X is $T_{\frac{1}{2}}$. [1 mark]

After a time equal to 4 half-lives of X the ratio $\frac{\text{number of atoms of X}}{\text{number of atoms of Y}}$ is $\frac{1}{8}$.

What is the half-life of Y?

- A. $0.25T_{\frac{1}{2}}$
- B. $0.5T_{\frac{1}{2}}$
- C. $3T_{\frac{1}{2}}$
- D. $4T_{\frac{1}{2}}$

15. The energy-level diagram for an atom that has four energy states is shown. [1 mark]



What is the number of different wavelengths in the emission spectrum of this atom?

- A. 1
 - B. 3
 - C. 6
 - D. 7
16. A detector, placed close to a radioactive source, detects an activity of 260 Bq. The average background activity at this location is 20 Bq. The radioactive nuclide has a half-life of 9 hours. [1 mark]

What activity is detected after 36 hours?

- A. 15 Bq
- B. 16 Bq
- C. 20 Bq
- D. 35 Bq

17. Element X decays through a series of alpha (α) and beta minus (β^-) emissions. Which series of emissions results in an isotope of X? [1 mark]
- A. 1α and $2\beta^-$
 - B. 1α and $4\beta^-$
 - C. 2α and $2\beta^-$
 - D. 2α and $3\beta^-$
-

18. A graph of the variation of average binding energy per nucleon with nucleon number has a maximum. What is indicated by the region around the maximum? [1 mark]
- A. The position below which radioactive decay cannot occur
 - B. The region in which fission is most likely to occur
 - C. The position where the most stable nuclides are found
 - D. The region in which fusion is most likely to occur
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19. Three of the fundamental forces between particles are [1 mark]
- I. strong nuclear
 - II. weak nuclear
 - III. electromagnetic.

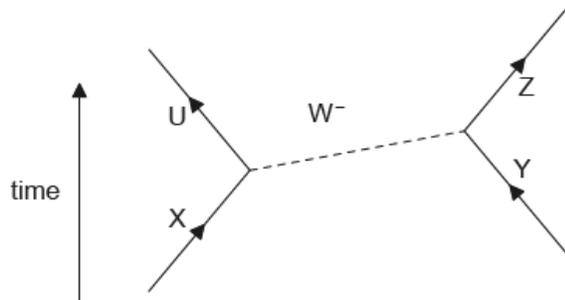
What forces are experienced by an electron?

- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III
-
20. Which statement about atomic spectra is **not** true? [1 mark]
- A. They provide evidence for discrete energy levels in atoms.
 - B. Emission and absorption lines of equal frequency correspond to transitions between the same two energy levels.
 - C. Absorption lines arise when electrons gain energy.
 - D. Emission lines always correspond to the visible part of the electromagnetic spectrum.
-

21. What gives the total change in nuclear mass and the change in nuclear binding energy as a result of a nuclear fusion reaction? [1 mark]

	Nuclear mass	Nuclear binding energy
A.	decreases	decreases
B.	decreases	increases
C.	increases	decreases
D.	increases	increases

22. The Feynman diagram shows a particle interaction involving a W^- boson. [1 mark]

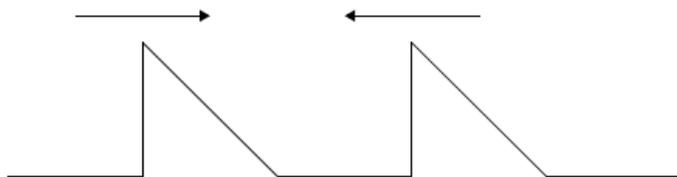


Which particles are interacting?

- A. U and Y
- B. W^- boson and Y
- C. X and Y
- D. U and X

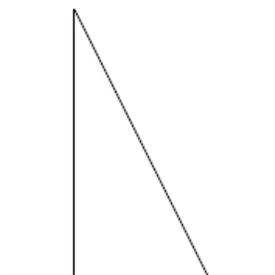
23. Two pulses are travelling towards each other.

[1 mark]

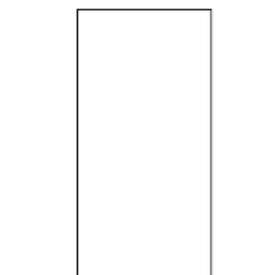


What is a possible pulse shape when the pulses overlap?

A.



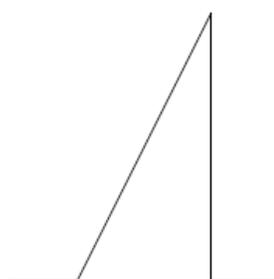
B.



C.



D.



24. A nucleus of phosphorus (P) decays to a nucleus of silicon (Si) with the emission of particle X and particle Y.

[1 mark]



What are X and Y?

	X	Y
A.	antineutrino	positron
B.	antineutrino	electron
C.	neutrino	electron
D.	neutrino	positron

25. What is the definition of the unified atomic mass unit?

[1 mark]

- A. $\frac{1}{12}$ the mass of a neutral atom of carbon-12
- B. The mass of a neutral atom of hydrogen-1
- C. $\frac{1}{12}$ the mass of a nucleus of carbon-12
- D. The mass of a nucleus of hydrogen-1

26. In nuclear fission, a nucleus of element X absorbs a neutron (n) to give a nucleus of element Y and a nucleus of element Z. [1 mark]



What is $\frac{\text{magnitude of the binding energy per nucleon of Y}}{\text{magnitude of the binding energy per nucleon of X}}$ and $\frac{\text{total binding energy of Y and Z}}{\text{total binding energy of X}}$?

	Magnitude of the binding energy per nucleon of Y Magnitude of the binding energy per nucleon of X	Total binding energy of Y and Z Total binding energy of X
A.	greater than 1	greater than 1
B.	less than 1	greater than 1
C.	greater than 1	less than 1
D.	less than 1	less than 1

27. What is the energy equivalent to the mass of one proton? [1 mark]

- A. $9.38 \times (3 \times 10^8)^2 \times 10^6 \text{ J}$
- B. $9.38 \times (3 \times 10^8)^2 \times 1.6 \times 10^{-19} \text{ J}$
- C. $\frac{9.38 \times 10^8}{1.6 \times 10^{-19}} \text{ J}$
- D. $9.38 \times 10^8 \times 1.6 \times 10^{-19} \text{ J}$

28. Atomic spectra are caused when a certain particle makes transitions between energy levels. [1 mark]
What is this particle?

- A. Electron
- B. Proton
- C. Neutron
- D. Alpha particle

29. The half-life of a radioactive element is 5.0 days. A freshly-prepared sample contains 128 g of this element. After how many days will there be 16 g of this element left behind in the sample? [1 mark]

- A. 5.0 days
- B. 10 days
- C. 15 days
- D. 20 days

30. The binding energy per nucleon of ${}^{11}_4\text{Be}$ is 6 MeV. What is the energy required to separate the nucleons of this nucleus? [1 mark]
- A. 24 MeV
 - B. 42 MeV
 - C. 66 MeV
 - D. 90 MeV

31. The reaction $p^+ + n^0 \rightarrow p^+ + \pi^0$ does not occur because it violates the conservation law of [1 mark]
- A. electric charge.
 - B. baryon number.
 - C. lepton number.
 - D. strangeness.

32. Photons of energy 2.3eV are incident on a low-pressure vapour. The energy levels of the atoms in the vapour are shown [1 mark]

0eV ———

-1.6eV ———

-2.5eV ———

-3.9eV ——— not to scale

What energy transition will occur when a photon is absorbed by the vapour?

- A. -3.9eV to -1.6eV
 - B. -1.6eV to 0eV
 - C. -1.6eV to -3.9eV
 - D. 0eV to -1.6eV
33. When an alpha particle collides with a nucleus of nitrogen-14 (${}^{14}_7\text{N}$), a nucleus X can be produced together with a proton. What is X? [1 mark]
- A. ${}^{18}_8\text{X}$
 - B. ${}^{17}_8\text{X}$
 - C. ${}^{18}_9\text{X}$
 - D. ${}^{17}_9\text{X}$

34. The mass defect for deuterium is 4×10^{-30} kg. What is the binding energy [1 mark] of deuterium?
- A. 4×10^{-7} eV
 - B. 8×10^{-2} eV
 - C. 2×10^6 eV
 - D. 2×10^{12} eV
-
35. As quarks separate from each other within a hadron, the interaction between them becomes larger. What is the nature of this interaction? [1 mark]
- A. Electrostatic
 - B. Gravitational
 - C. Strong nuclear
 - D. Weak nuclear
-
36. A simple model of an atom has five energy levels. What is the maximum number of different frequencies in the emission spectrum of that atom? [1 mark]
- A. 4
 - B. 6
 - C. 10
 - D. 25
-
37. Which of the following is the correct definition of the binding energy of a nucleus? [1 mark]
- A. The product of the binding energy per nucleon and the nucleon number
 - B. The minimum work required to completely separate the nucleons from each other
 - C. The energy that keeps the nucleus together
 - D. The energy released during the emission of an alpha particle
-
38. Which of the following lists three fundamental forces in increasing order of strength? [1 mark]
- A. electromagnetic, gravity, strong nuclear
 - B. weak nuclear, gravity, strong nuclear
 - C. gravity, weak nuclear, electromagnetic
 - D. electromagnetic, strong nuclear, gravity

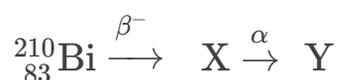
39. For which reason were quarks first introduced? [1 mark]

- A. To explain the existence of isotopes
- B. To describe nuclear emission and absorption spectra
- C. To account for patterns in properties of elementary particles
- D. To account for the missing energy and momentum in beta decay

40. A simple model of the hydrogen atom suggests that the electron orbits the proton. What is the force that keeps the electron in orbit? [1 mark]

- A. Electrostatic
- B. Gravitational
- C. Strong nuclear
- D. Centripetal

41. Bismuth-210 ($^{210}_{83}\text{Bi}$) is a radioactive isotope that decays as follows. [1 mark]



What are the mass number and proton number of Y?

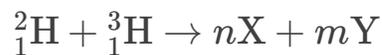
	Mass number	Proton number
A.	206	86
B.	206	82
C.	210	82
D.	214	83

42. Geiger and Marsden bombarded a thin gold foil with alpha particles. They [1 mark] observed that a small fraction of the alpha particles were deflected through angles greater than 90° . What does this observation suggest about the nucleus?

- A. It is at the centre of the atom.
- B. It is surrounded by orbiting electrons.
- C. It is made of protons and neutrons.
- D. It is a small region of the atom and is positively charged.

43. Nucleus P decays by a sequence of emissions to form nucleus Q. One α particle and two β^- particles are emitted during the sequence. Which statement is correct? [1 mark]
- A. Nucleus P has the same number of neutrons as nucleus Q.
 - B. Nucleus P is an isotope of nucleus Q.
 - C. Nucleus P has a greater charge than nucleus Q.
 - D. Nucleus P has fewer protons than nucleus Q.
-
44. In a nuclear fission reaction, nucleus X splits into nucleus Y and nucleus Z. Which of the following gives a possible order of the nuclei from lowest to highest binding energy per nucleon? [1 mark]
- A. $Z \rightarrow Y \rightarrow X$
 - B. $Z \rightarrow X \rightarrow Y$
 - C. $Y \rightarrow X \rightarrow Z$
 - D. $X \rightarrow Z \rightarrow Y$
-
45. What is the relationship between nucleon number A , proton number Z and neutron number N ? [1 mark]
- A. $A=Z=N$
 - B. $A+Z=N$
 - C. $A-Z=N$
 - D. $Z-A=N$
-
46. The initial number of atoms in a pure radioactive sample is N . The radioactive half-life of the sample is defined as the [1 mark]
- A. time taken for one atom to undergo decay.
 - B. probability for $\frac{N}{2}$ atoms to undergo decay.
 - C. time taken for $\frac{N}{2}$ atoms to undergo decay.
 - D. probability that one atom will decay per unit time.

47. A student suggests the following nuclear reaction between deuterium ${}^2_1\text{H}$ [1 mark] and tritium ${}^3_1\text{H}$



where n and m are integers. What are X and Y?

	X	Y
A.	electron	neutron
B.	electron	proton
C.	alpha particle	neutron
D.	alpha particle	proton

48. In a neutral atom there are n_e electrons, n_p protons and n_n neutrons. [1 mark]
What is the mass number of the nuclide?

- A. $n_p + n_e + n_n$
- B. $n_p + n_n$
- C. $n_n + n_p - n_e$
- D. $n_n - n_e$

49. The binding energy per nucleon of a ${}^3_1\text{H}$ nucleus is 3 MeV. What is the [1 mark]
minimum energy needed to
completely separate the nucleons of ${}^3_1\text{H}$?

- A. 12 MeV
- B. 9 MeV
- C. 6 MeV
- D. 3 MeV

50. The nuclear reaction ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n}$ would best be described as [1 mark]

- A. alpha decay.
- B. nuclear fission.
- C. nuclear fusion.
- D. neutron capture.

51. A radioactive sample has activity A_0 at $t=0$. What will be the activity of the sample after two half-lives? [1 mark]

- A. zero
- B. $\frac{A_0}{4}$
- C. less than $\frac{A_0}{4}$ if the sample is kept at high pressure
- D. greater than $\frac{A_0}{4}$ if the sample is kept at high temperature

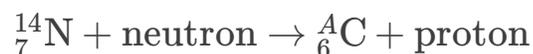
52. Which of the following provides evidence for the existence of atomic energy levels? [1 mark]

- A. Absorption spectra
- B. Nuclear fission
- C. The Geiger-Marsden experiment
- D. Radioactive decay

53. What is the definition of the unified atomic mass unit? [1 mark]

- A. The mass of one atom of hydrogen.
- B. $\frac{1}{12}$ of the mass of an atom of carbon-12.
- C. The mass of one atom of carbon-12.
- D. $\frac{1}{16}$ of the mass of an atom of oxygen-16.

54. Nuclei of the isotope nitrogen-14 are bombarded with neutrons and as a result nuclei of an isotope of carbon are produced. The nuclear reaction equation for this process may be written as [1 mark]



What is the nucleon number A of the isotope of carbon?

- A. 12
- B. 13
- C. 14
- D. 15

55. In a particular atom, the nucleon number is the total number of *[1 mark]*
- A. protons.
 - B. neutrons.
 - C. electrons.
 - D. protons and neutrons.
-
56. For which quantity can the unit MeVc^{-2} be used? *[1 mark]*
- A. Mass
 - B. Momentum
 - C. Kinetic energy
 - D. Binding energy
-
57. Which of the following would decrease the initial activity of a sample of plutonium? *[1 mark]*
- A. Placing the sample in a lead container
 - B. Placing the sample in a dark room
 - C. Decreasing the mass of the sample
 - D. Decreasing the temperature of the sample
-
58. A radioactive sample of initial activity 12 Bq has a half-life of 3 days. What is the activity after 6 days? *[1 mark]*
- A. 2 Bq
 - B. 3 Bq
 - C. 4 Bq
 - D. 6 Bq
-
59. Which particle is acted on by both the strong nuclear force and the Coulomb force? *[1 mark]*
- A. Antineutrino
 - B. Electron
 - C. Neutron
 - D. Proton
-

60. A nucleus of californium (Cf) contains 98 protons and 154 neutrons. Which [1 mark] of the following correctly identifies this nucleus of californium?

